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GOVERNMENT OF INDIA

स्वच्छ भारत

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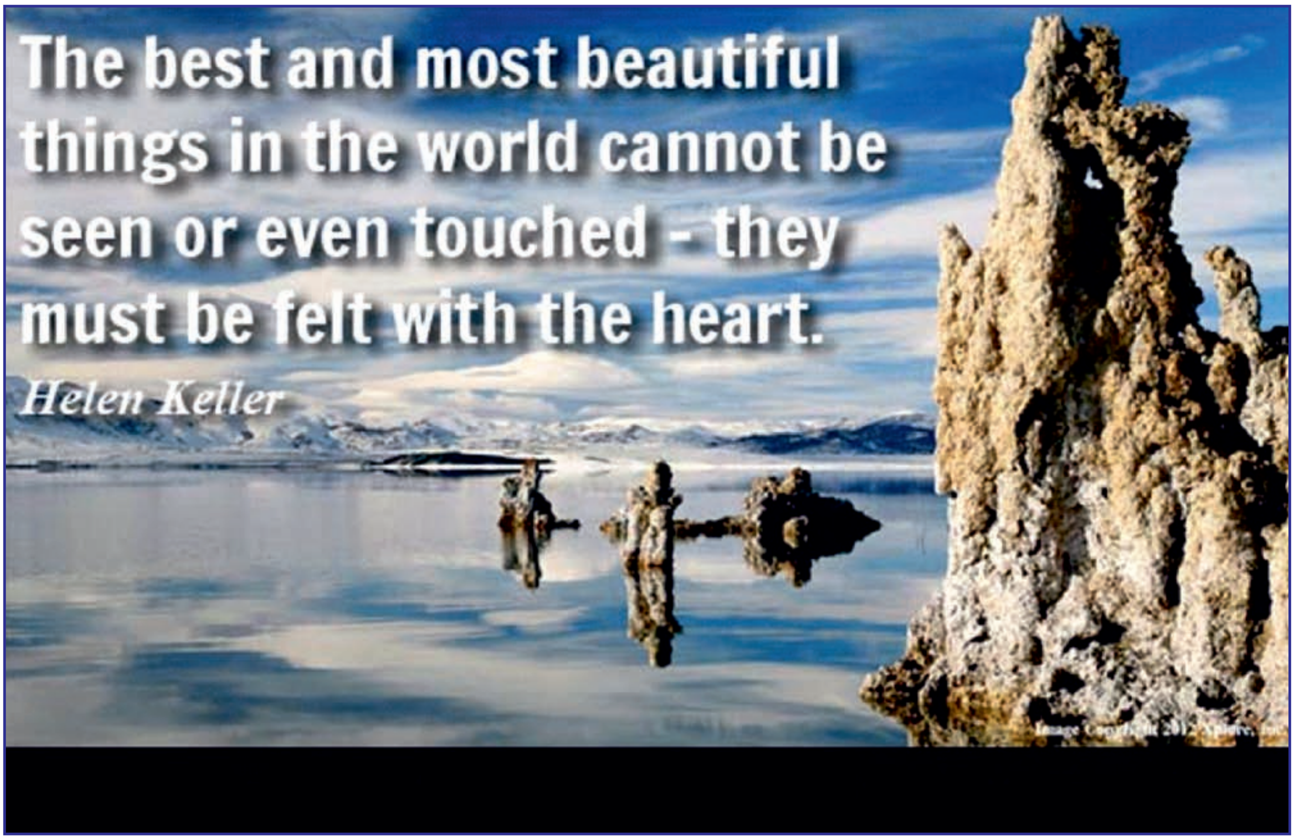
ANNUAL REPORT 2017-2018

BOARD OF RADIATION & ISOTOPE TECHNOLOGY (BRIT)

DEPARTMENT OF ATOMIC ENERGY


An investment in knowledge pays the best interest.
BENJAMIN FRANKLIN


The best and most beautiful things in the world cannot be seen or even touched - they must be felt with the heart.
Helen Keller

BOARD OF RADIATION & ISOTOPE TECHNOLOGY

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BRIT

ANNUAL REPORT 2017-2018

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CHAPTER 1


EXECUTIVE
SUMMARY


Think little goals and expect little achievements. Think big goals and win big success.
David Joseph Schwartz

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 mainstrea 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) Radio pharmaceuticals Production (RphP), Vashi

- ^{131}I as Na^{131}I is one of the most important isotope used for various thyroid disorders. More than 700 Ci of I-131 products (Na^{131}I and ^{131}I-mIBG) in ~26253 consignments have been supplied to various hospitals in the form of capsules and solution, for both, diagnostic and therapeutic purposes for thyroid disorders and treating thyroid cancer. I-131 radiolabelled mIBG is used for diagnosis and therapy of Neuro Endocrine Tumors (NET).

- New therapeutic product based on I-131 radiolabelling, ^{131}I-Lipiodol injection for the treatment of Liver [Hepatocellular Carcinoma] Cancer, was launched by BRIT in collaboration with RPhD, BARC.

- 37.2 Ci in 322 consignments of theraputic products, other than I-131 based radioactive products, such as ^{153}Sm-EDTMP, ^{177}Lu-EDTMP for bone pain palliation, ^{177}Lu-DOTA-TATE for PRRT for sstr positive Neuro Endocrine Tumours (NET) and ^{32}P [Samarium Phosphate Colloidal Injection] for radiation synovectomy, were supplied to nuclear medicine hospitals during the Financial Year 2017-2018.

- Regular production and supply of new therapeutic radiopharmaceutical, ^{177}Lu-DOTA-TATE injection for the treatment of (somatostatin receptor positive) neuroendocrine tumors, has been started for treating NET successfully, after its RPC clearance.

- Procedure for production and supply of 'Kit for the preparation of therapeutic ^{188}Re-HEDP injection', another alternative product for bone pain palliation, is optimized along with RphD, BARC.

- 3421 consignments containing approximately 600Ci of ^{99}Mo in the form of Sodium Molybdate solution for Coltech Generators, Geltech Generators and Solvent Extraction Generator for obtaining Technetium-99m at hospital end, have been supplied to various hospitals in India during 2017-2018.

- More than 19000 consignments of Technetium-99m cold kits (19 Products; BRIT Code: TCK) for imaging various organs have been supplied to nuclear medicine centres in India. Production and regular supply of new product, ^{99m}Tc-cold kit for the preparation of ^{99m}Tc-Macro Aggregated Albumin (MAA) injection, useful for lung perfusion imaging, has been started. Production and regular supply of another new product, ^{99m}Tc-Ubiquicidine (Tc-UBI), used for infection imaging, is also started during the reported time.

- Radiopharmaceutical Committee (RPC) approval is also obtained for extension of shelf-life (expiry date) of Technetium-99m cold kits, namely, DTPA and Phytate injections, from existing one year to two years.

- Production of 'Kit for the preparation of ^{99m}Tc-HYNIC-TATE injection', useful for imaging neuroendocrine tumors, started as a part of technology transfer from RPhD, BARC.

- A total of 2100 Radioimmunoassay (RIA) and Immunoradiometric Assay (IRMA) kits are produced and supplied to various pathology laboratories and nuclear medicine centres throughout the country for *in-vitro* diagnosis of thyroid disorders.

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

- Around 437 batches of radiopharmaceutical samples and 50 batches of ^{99}Mo-^{99m}Tc COLTECH Generators were routinely analysed and certified by QC during this period upto March 2018.

- Validation for the procedure for in-house Bacterial Endotoxin Test (BET) of TCK products (cold kits) was successfully completed. Also, Quality Control analyses methods for new products were standardized. The method is implemented in regular Quality Control tests of new kits. HPLC method for the analysis of ^{99m}Tc-MIBI is standardized and would be put up for RPC approval. Animal use for the quality control analysis of this product will be stopped, once it is approved by RPC.

- Batch Manufacturing Production Records (BMPR) for TCK cold kits (19 Products) were modified and improvised as per GMP guidelines. QC records and certificates of analysis (COA) for TCK cold kits (Seven products) were modified as per the requirement of IP 2014 by Quality Control Section.

(c) Medical Cyclotron Facility (MCF)

- The Medical Cyclotron Facility (MCF) of BRIT continued the synthesis and supply of Positron Emitting Tomography (PET) radiotracers, the maximum being [F-18]-FDG. Other PET radiopharmaceuticals include [F-18]-NaF, [18F]-FLT, and newly launched [F-18]-FET, which are produced in smaller scales.

- Renewal of Operation Licence was renewed until December 2021. New users were added to the existing list of hospitals. They are Breach Candy Hospital, HCG Apex and MPCT Hospital.

- 320 Ci of [F-18] FDG in 817 consignments have been supplied to various hospitals in Mumbai for PET imaging upto March 2018. More than 15000 patients are benefitted with PET investigations in the reported year 2017-18.

(d) Labelled Compounds (LC)

- This Section of BRIT continued the synthesis and supply of a variety of ^{14}C, ^{3}H and ^{35}S-labelled products and various types of Tritium-filled self luminous sources (TFS). It is also involved in the production and supply of C-14 Urea Capsules. The 'Urea Breath Test' using these capsules is useful in the diagnosis of the infections caused by microorganisms named, Helicobacter pylori, a spiral bacterium, which may be responsible for gastritis, gastric ulcer, and peptic ulcer disease.

- Since April 2017, more than 26000 TFS sources of various sizes, shapes and tritium content were supplied to defence establishments which are used for illumination of various types of gadgets and instruments.

- Based on MoU between BRIT and Heavy Water Board, deuterated NMR solvents were dispensed and supplied to various customers. All the solvents supplied had >99.8% Deuterium abundance.

II. Engineering Products

(a) Sealed Radiation Sources

- Twenty Four Teletherapy sources of ^{60}Co (CTS) containing activity in the range of 154 and 232 RMM were supplied to different cancer hospitals in India and abroad upto March 2018.
- Co-60 with activities of 808 Ci in eleven pencils and 83,711 Ci in 128 pencils were loaded in one unit of Blood Irradiator (based on Co-60 BI 2000) and seven units of Gamma Chamber 5000 respectively. Cs-137 is planned to be loaded in Blood Irradiator 2000, the availability of which is being awaited from WMD, BARC.
- Irradiator sources of industrial grade in eleven consignments with total activity of 16, 25, 178 Ci (1625 kCi) were supplied to twelve radiation processing plants within the country and abroad upto March 2018.
- Co-60 teletherapy source of 180 RMM was exported to Kenyatta National Hospital, Kenya. One Co-60 Irradiator source of 125 RMM was exported to Srilanka Atomic Energy Board for source replenishment in Multipurpose Gamma Irradiator at Biyagama.
- A total of 721 consignments of ^{192}Ir & ^{60}Co Radiography sources containing 32,152 Ci of activity were supplied to NDT users during the reported period.
- Seven hundred and five consignments of Co-60 Custom Made Reference (CMR) sources with total activity of 2.08 Ci were supplied to its user's upto March 2018.
- Integrated Facility for Radiation Technology (IFRT) continued the fabrication & loading of radioactivity (sealed sources) in Gamma Chambers and Blood Irradiators which are supplied from Vashi Complex

(b) Radiation Equipments

- 53 Radiography Cameras, ROLI-2 model, were supplied to various NDT users within India and services were provided for 658 numbers of BRIT and imported radiography cameras.
- Seven Blood Irradiators – 2000 (BI-2000) units with Cs-137 source were supplied to hospitals in India in the reported time period.
- Seven Gamma Chamber – 5000 units have been supplied to various Universities/Institutions for research purposes upto March 2018.

B. Services Provided by BRIT

I. Consultancy and MoU for Radiation Processing Plant

- BRIT signed two MoU's for setting up Gamma Radiation Processing Plants for disinfestations, shelf-life extension of food products and sterilization applications of healthcare products. One with M/s Jamnadas Industries, Dahod, Gujarat, to set up Gamma Radiation Processing Plant at Indore, Madhya Pradesh and the other MoU was signed with M/s. Andhra Pradesh Med Tech Zone Ltd., Vishakhapatnam, Andhra Pradesh.

II. Gamma Radiation Processing Services (GRPS)

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

- 4871 Cubic meters of medical supplies have been sterilized using gamma radiation processing at ISOMED, BRIT upto March 2018.

(b) Radiation Processing Plant (RPP), Vashi

- About 4748 Tons of spices and allied products were processed during the reported time period.
- Surveillance Audits for ISO – 22000:2005 (Food Safety Management Systems) and ISO 9001:2008 were carried out by certifying agency and found the Radiation Processing Plant at Vashi, in full compliance with Standard's requirement.
- Dose rate certification was provided to two blood irradiators and three gamma chambers which were supplied to various cancer hospitals and research universities respectively.
- Production & supply of ~1.9 Lakhs Ceric-Cerous Sulphate Dosimeters were done for various gamma irradiators in the country and abroad, for the measurement of absorbed dose.
- More than 2000 biological indicators, Bacillus Pumilus (a product of Microbiology Section, RPP, Vashi), for monitoring radiation sterilization process was manufactured and supplied to the different irradiators & manufacturers of medical devices & pharmaceutical products.
- NABL accreditation was renewed for the Calibration Dosimetry Laboratory which will be valid upto 2019.

III. Radiation Physics Services

- ❖ Shielding calculations were carried out for handling Adjustor rods up to 10 MCi of ^{60}Co for the proposed new water pool of RAPPCOF facility, Kota.
- ❖ Theoretical dose evaluations were carried out for 2 new Radiation Processing Plants 1). M/s. Pinnacle Therapeutics Ltd. & 2). Dry sludge irradiator AMC, Ahmedabad.
- ❖ Source loading patterns designed for replenishment of ^{60}Co activity in 10 Gamma Irradiators.
- ❖ Shielding of ROTEX-1, radiography camera was analyzed after design modification for approval from AERB.
- ❖ Radiological Surveillance provided to the following facilities of BRIT, Vashi:
  - ➢ Radiation Processing Plant (RPP)
  - ➢ Decayed Source Removal Facility (DSRF)

IV. Calibration Services for Portable Radiation Monitoring Instruments

- ❖ BRIT has provided calibration services for portable gamma radiation survey instruments during the reported period. A total of 555 numbers of survey meters, dosimeters and portable area monitors are calibrated upto March 2018.

V. Isotope Application Services (IAS)

- Isotope Application Services was provided for Gamma Column Scanning for seven different petroleum industries. Gamma scanning of Process columns and Identification of leaky heat exchangers using radiotracer techniques to trouble shoot different kinds of problems at various industries such as HPCL, both, Mumbai and Vishakhapatnam, IOCL, Mathura, BORL etc. thereby saving crores of rupees for the country.

- Radiometry tests for efficiency of of Spent Fuel Canisters and Discs for Larson & Tubro Ltd. Ranauli, near Vadodra, Gujarat was tested. More than 50 such radiometry tests have been carried out during 2017-18.

VI. Radioanalytical Laboratory (RAL) Services:

- Radioanalytical Laboratory carried out more than 3200 tests on export/domestic commodities for gross alpha, gross beta, ^{226}Ra, ^{228}Ra and total uranium content and 940 tests on water samples. RAL has carried out around 5478 tests on export/domestic commodities and 700 tests on water samples (gross alpha, beta ^{228}Ra & ^{226}Ra)

- Radioanalytical Laboratory has started surveying and certifying surface radiation dose of steel consignments at factory premises and warehouses.

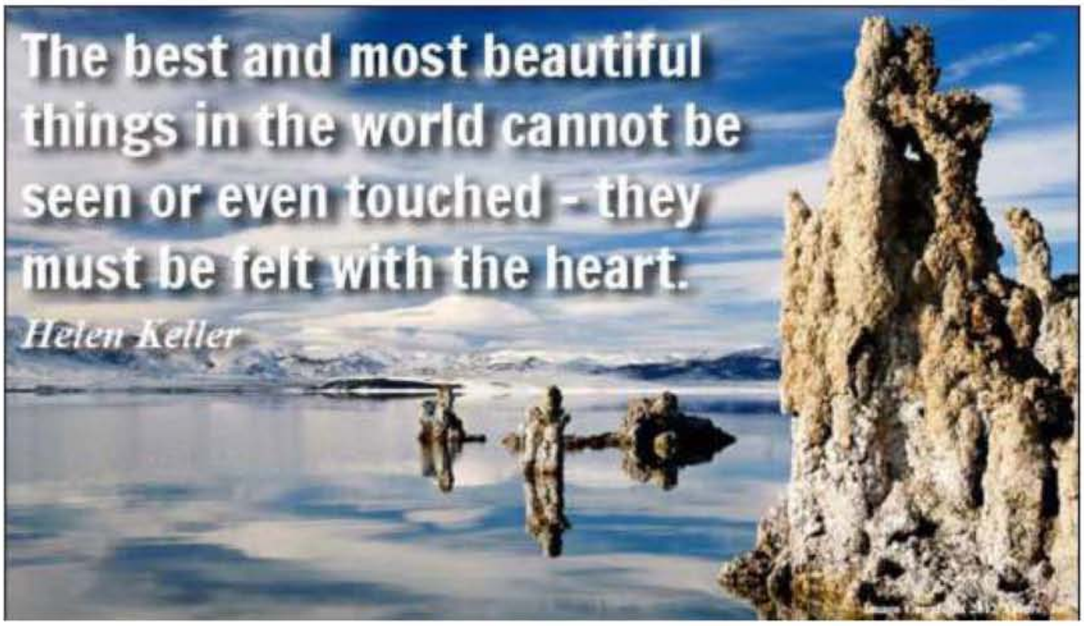
C. Customer Support:

- As the nodal agency for sales and supply, marketing and customer relations, co-ordination & logistics support cell continued to provide regular and uninterrupted supply of radioisotopes & allied products, radiation technology equipments to about 2000 user institutions in the healthcare, industrial, research and agricultural sectors.

CHAPTER 2

DESCRIPTIVE PART

BRIT has reached to higher ever revenue of Rs. 105 Crores in Financial Year 2017-18



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 (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

BRIT continued the supply of healthcare products and its services useful for *in-vivo* and *in-vitro* investigations, apart from the products from labelled compounds and radiochemicals for varied research purposes, tritium filled sources (TFS) for defence establishments, providing quality control testing of all the radiopharmaceuticals supplied by BRIT. The sale of Radiopharmaceuticals & Labelled Compounds Products during the Financial Year 2017-2018 amounted to Rs. 41.55 Crores.

(a) Radiopharmaceuticals Production (RPhP)

Radiopharmaceuticals are meant for *in-vivo* use, mainly for diagnostic and therapeutic purposes. Since they are meant for *in-vivo* use as pharmaceutical grade products, compliance to good manufacturing practices (GMP) is mandatory. *In-vitro* Radioimmunoassay (RIA) and Immunoradiometric Assay (IRMA) Kits and C-14 Urea capsules are used mainly for diagnostic use. Positron Emitting Tomography (PET) is a powerful imaging agent through which quantitative information on the distribution of positron-emitter labeled radiopharmaceuticals (PET radiopharmaceuticals) in the body can be realized. ^{18}F-FDG is currently the most widely used PET radiopharmaceutical in clinical oncology in addition to its clinical applications in cardiology and neurology. The application of PET in clinical oncology is increasing since many molecular targets relevant to cancer can be labeled with positron emitter radionuclides.

- Regular, uninterrupted, production and supply of radiopharmaceuticals, all over India, was continued. However, efforts were made towards expanding the production capacity by introducing some new products based on ^{99m}Tc, ^{68}Ga and ^{188}Re radiopharmaceuticals.

- ^{131}I as Na^{131}I is one of the important isotopes used for various thyroid disorders. Approximately 700 Ci of Na^{131}I and over 26250 consignments were processed, formulated and supplied to various nuclear medicine hospitals all over India in the form of solution and capsules. This also includes I-131 labelled mIBG which is supplied as sterile injections and is used for the diagnosis and treatment of Neuro Endocrine Tumors (NET).

- Currently, I-131 labelled therapeutic product, I-131-Lipiodol, which is used for the treatment of Hepatocellular Carcinima, the most common type of Liver Cancer (single patient dose is 75mCi of I-131), was produced by RPhD, BARC and is supplied through BRIT in the reported period.
- Amongst the other therapeutic products supplied by BRIT includes Sm-153-EDTMP & Lu-177-EDTMP

Production facility of I-131 Lipiodol at RPhP, Vashi Complex

for bone pain palliation, new product, Lu-177-DOTA-TATE for treatment of metastatic [somatostatin receptor (sstr) positive] neuroendocrine tumors (NET) which is launched by BRIT during the reported year and ^{32}P [Samarium Phosphate Colloidal Injection] for radiation synovectomy, were supplied to nuclear medicine hospitals. ~37.2 Ci in 322 consignments were supplied to nuclear medicine centres all over India during 2017-18.

- Another new alternative therapeutic radiopharmaceutical for bone palliation, Re-188-HEDP injection

Despatch particulars for ^{131}I-Lipiodol Injection

(as a part of technology transfer from RPhD, BARC) is expected to be launched by BRIT in collaboration with RPhD, BARC. This would be another alternative for bone pain palliation agent.

- Factory acceptance test was performed for 2" thick, GMP compliant, lead shielded facility for the production of I-131 mIBG and other therapeutic radiopharmaceuticals. Some improvements in the in-cell gadget setup were completed by March 2018.

- During the year 2017-18, more than 80000 cold kits for formulation of ^{99m}Tc radiopharmaceuticals (19 products; BRIT Code-TCK) in nearly 19000 consignments were formulated, lyophilized, QC tested and supplied to various nuclear medicine hospitals all over India.
- Radiopharmaceutical Committee (RPC) approval is also obtained for the extension of shelf-life (expiry

date) of Technetium-99m cold kits, namely, DTPA and Phytate injections, from the existing one year to two years.

- Production of 'Kit for the preparation of ^{99m}Tc-HYNIC-TATE injection', useful for imaging neuroendocrine tumors (NET), especially carcinoid tumors, started as a part of technology transfer from RPhD, BARC.

- Nearly 600 Ci of ^{99}Mo, in 3421 generators in the form of Sodium Molybdate solution, for solvent extraction generator, Coltech generators and Geltech generators is supplied during 2017-18.

- More than 2,50,000 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 ^{99}Mo-^{99m}Tc generator systems and around 17000 therapeutic applications are estimated to have carried out during the reported year using BRIT therapeutic radiopharmaceuticals including Na^{131}I for treating hyperthyropidism and thyroid cancer therapy.

- A total number of about 2200 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits to

^{188}Re-HEDP Cold Kit and ^{177}Lu-EDTMP Injection for Bone pain palliation

serve about 1,22,450 *in-vitro* investigations, were supplied to various hospitals, research centres and immunoassay laboratories throughout India.

(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 2017-18, following are the QC reports:

➢ Routine sample analyses: Around 437 batches of various radiopharmaceutical samples and 50 batches of ^{99}Mo-^{99m}Tc COLTECH Generators were routinely analysed and certified by QC during this year, 2017-18. These samples were tested for their performance in physico-chemical analyses, sterility, tests, bacterial endotoxin tests and animal biodistribution studies. Additionally, several Tc-99m based cold kits were evaluated for stability beyond the assigned shelf life.

- Development & Implementation of Alternate Methods for Biodistribution QC Analysis: New chemical method was developed for the estimation of Tin content from the ^{99m}Tc-cold kit (Stannous Pyrophosphate) in lieu of animal experiments and is approved by RPC. Similarly, in the QC analysis of ^{99m}Tc Cold Kit (Mebrofenin), use of HPLC instead of less sensitive analytical method, TLC and the animal biodistribution study for one batch in every five batches, was cleared by RPC. These developments reduce the animal use for Quality Control checks and are in adherence to animal ethics practices for routine testing applications.

- Standardization of Quality Control Analysis methods for new radiopharmaceuticals for products under development: Various target specific new radiopharmaceutical products are being developed

by RPhD, BARC as well as by BRIT with the aim to their translation for routine clinical applications. Quality Control Programme has been involved in rendering analytical support for developing analysis methods for these products and validates the radiopharmaceuticals kits for the ones which pass through RPC.

- Method Development/Modifications: a) Validation for in-house BET of TCK products (Cold kits) was successfully completed. The method thus validated is implemented in regular Quality Control tests of TCK Kits. b) HPLC method for the analysis of ^{99m}Tc-MIBI is standardized. The method thus developed and validated would be put up for RPC approval. This method would reduce the animal biodistribution testing of the cold kit of TCK, ^{99m}Tc-MIBI. c) Bio-evaluation of a novel drug delivery system using radiotracer technique is being carried out. d) Standardization of Tin estimation in Technetium cold kits supplied by BRIT using advanced instrumentation technique such as X-ray Fluorescence (XRF) is underway in collaboration with PMD, BARC.
- GMP Certification: Quality Control Laboratory was audited by the third party auditor for GMP

Installed SS top kitchen cabinets with shelf and SS Fume Hoods (14 Nos.) for QC laboratory, RPL

Compliance. Based on the audit of TCK production and Quality Control, GMP Certification was renewed for TCK production facility.

- Refurbishment of Quality Control Laboratory under XII Plan: New fume hoods and SS top kitchen cabinets have been procured and installed. Validation of air-flow meters on fume hoods also is completed. Two radio-TLC scanners purchased under plan budget have been delivered and installed. Procurement of new HPLC is in advanced stage.

New Radio-TLC Scanner installed in Quality Control Laboratory

Quality Assurance (QA): Production and Quality Control Testing processes are routinely monitored and documented by QA Section and appropriate QA certification for a total of 337 batches of radiopharmaceuticals were released from April 2017 to March 2018. Batch Manufacturing Production Records (BMPR) for TCK cold kits (19 products) were modified and improvised as per the GMP guidelines. Calibration and certification of instruments, electronic balances and pipettes used in Production and Quality Control Sections are all a part of Quality Assurance Group.

(c) The Medical Cyclotron Facility (MCF)

The Medical Cyclotron Facility (MCF), Parel continues the production and supply of Positron Emission Tomography (PET) radiopharmaceuticals, mainly ^{18}F-FDG and ^{18}F-Sodium Fluoride and to a lesser extent ^{18}F-Flurothymidine (FLT) and newly launched [F-18]-Fluro Ethyl–L-Tyrosine (FET).

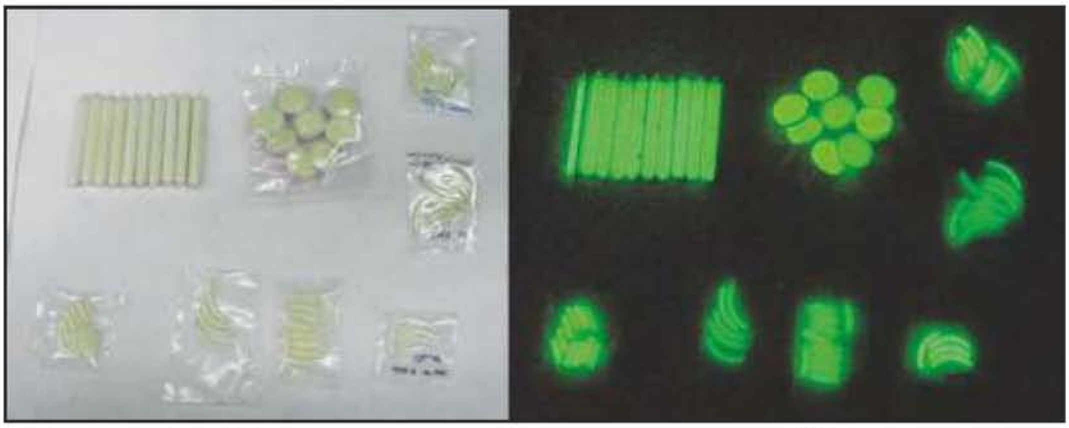
- Regular and uninterrupted supply of about 817 consignments of PET radiopharmaceuticals such as ^{18}F- FDG, ^{18}F-NaF, ^{18}F-FLT, and ^{18}F- FET to various hospitals in and around Mumbai accounting for nearly 320 Ci of radioactivity during the year 2017-18. More than 15000 patients benefitted with PET investigations in the reported year.

- Renewal of operation license for operating the medical cyclotron was obtained upto December 31, 2021. PET radiopharmaceuticals are now supplied to new users such as Breach Candy Hospital, HCG Apex, MPCT Hospital etc along with the users of PET radiopharmaceuticals already procuring from BRIT.

- Installation of ACU gen II: Accelerator control Unit (ACU) generation II was installed during the reported period. The purpose of the ACU is to monitor and control the accelerator and peripherals. The ACU is connected to the Master System via an Ethernet local area network. The ACU is a part of the Accelerator Control System (ACS) which also consists of the Vacuum Control Unit (VCU) and the Control Interface Unit (CIU).

(d) Labelled Compounds (LC)

Labelled Compounds Programme of BRIT is involved in the synthesis & supply of a variety of ^{14}C, ^{3}H and ^{35}S-labelled products and various types of Tritium-Filled Self-Luminous sources. The radiolabelled compounds are used extensively as tracer in biological field. Labelled Compounds offers number of regular (catalogue) products & also customized products based on the requirement by the researcher with high specific radioactivity & radiochemical purity. Tritium Filled Self-luminous (TFS) sources of various sizes and shapes are supplied to defence establishments and used for illumination of various types of gadgets and instruments.



(a) (b)

Tritium Filled Light Source supplied by BRIT: (a) view under normal light (b) view inside a dark-room

During the year, the work related to design and testing of three Type-A packages were carried for obtaining AERB approval. These packages are for the transportation of (i) C-14 and H-3 labelled compounds, (ii) Tritium gas as uranium tritide and (iii) Tritium filled light sources.

Custom synthesis of variety of labelled compounds along with ^{35}S-labelled amino acids, having very high specific radioactivity and radiochemical purity, are also supplied. Labelled Compounds Laboratory is also engaged in the production and supply of ^{14}C-Urea Capsules which is used for diagnosis of Helicobacter Pylori infection which causes stomach ulcers.

Based on the MoU signed between BRIT and Heavy Water Board, deuterated NMR solvents were dispensed and supplied to various customers. All the solvents that were supplied had >98% Deuterium abundance.

Highlights

- Supply of 23860 numbers of tritium filled light sources to defence establishments.
- Standardization of preparation of ^{14}C-tetrahydrofuran with potassium [^{14}C]-cyanide as the starting material.
- Procedure standardization for the preparation of deuterated pyridine is in progress.

II. Engineering Products

The various engineering products offered by BRIT included the supply of more than 2011 kCi of radioactivity in various forms and for varied uses. The total revenue collected from the supply of Engineering Products in the Financial Year 2017-18 amounted to a total of Rs. 47.58 Crores.

(a) Sealed Radiation Sources:

- Co-60 Teletherapy Sources (CTS) for Cancer Hospitals: Twenty four numbers of ^{60}Co teletherapy sources with total activity of about 257 kCi in the range of 154 and 232 RMM were supplied to various cancer hospitals in India. Out of these CTS sources, two sources are exported to Kenya and Kyrgyzstan. Six sources with higher activity are planned to fabricate. Seventeen 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.

- Industrial Irradiator Sources: Sixty six irradiator sources with total activity of around 1625.18 kCi were supplied in eleven consignments to various processing plants within the country. The irradiators to which these sources are supplied are namely, (a) AVPP, Ambernath – 199081 Ci; (b) AIIPL, Vasai – 155 kCi; (c) SARC, Delhi – 125 kCi (d) NIPRO, Pune – 200 kCi; (e) Sri Lanka – 125 kCi; (f) OGFL, Kolkata – 100 kCi; (g) KRUSHAK, Lasalgaon – 97688 Ci, (h) Vietnam – 100 kCi, (i) UML, Vadodra – 200 kCi; (j) Aligned Industries, Bhiwandi – 125 kCi; (k) MICROTOL, Bengaluru – 200 kCi and (l) SARC, Delhi – 125 kCi .

- ^{192}Ir and ^{60}Co Radiography sources: Seven hundred and twenty one numbers of ^{192}Ir radiography sources with total activity 332 kCi were supplied upto March 2018. Fourteen Co-60 radiography sources with 762 Ci activity were supplied upto March 2018.

- Custom Made Sources (CMR) and Reference Sources: Seventeen numbers of Custom Made Sources (CMR) of Co-60 in 705 consignments, with total activity of 2.1 Ci, were supplied upto March 2018.

- A contract is to be signed with LANL, USA for provision of technical support on repatriation of decayed radioactive sources in India back to USA. The sources from five institutes are to be collected, removed from the devices and repatriated to USA. The contract is already forwarded to DAE for their approval.

- At RAPPKOFF, Kota, total activity of Co-60 which was processed during the year was about 63.52 PBq (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.

- ^{60}Co 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 RAM CTS using indigenous ^{60}Co 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.

(b) Radiography and other Radiation Equipment Devices

- Radiography Camera: Supply of 61 new indigenous radiography camera model ROLI-2 and servicing and inspection of 499 numbers of BRIT manufactured as well as imported ROLI cameras were the highlights during the reported period.

- Gamma Chamber 5000: Seven units of GC-5000 was loaded with 88996 Ci of ^{60}Co and transported to different institutions in India upto March 2018.

- Blood Irradiator: Seven Blood Irradiators-2000 units with Cs-137 source (7011 Ci) have been supplied to hospitals in India during April 2017-March 2018.

B. Services

Apart from Production & Supply of Radioactive Products related to Radiopharmaceuticals (from Vashi Complex and Medical Cyclotron Facility), Labelled Compounds (from Vashi Complex as well as RCR, Hyderabad, Jonaki) and Engineering Products and Equipments & Devices, BRIT offers Services in various fields such as Isotope Application Services, Radiography Camera Services, Industrial Services, Neutron Irradiation Services, ISOMED Services, Radiation Processing Services, Radioanalytical Services (both, at Vashi Complex and RCR, Bengaluru), KRUSHAK Services, Radiopharmaceutical Services provided by various Regional Centres of BRIT, etc. The total revenue collected by providing these Services during the Year 2017-2018 amounted to a total of Rs. 17.10 Crores.

I. Consultancy and MoU for Radiation Processing Plants

- BRIT signed two MoU's for setting up Gamma Radiation Processing Plants for disinfestations, shelf-life extension of food products and sterilization applications of healthcare products. One with M/s Jamnadas Industries, Dahod, Gujarat, to set up Gamma Radiation Processing Plant at Indore, Madhya Pradesh and the other MoU was signed with M/s. Andhra Pradesh Med Tech Zone Ltd., Vishakhapatnam, Andhra Pradesh.

II. Gamma Radiation Processing Services (GRPS)

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

- During the year 2017-18 ISOMED facility, which is engaged in contract gamma radiation processing services for terminal sterilization of the medical products, has processed 4748 Cubic mtrs of products.

(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 285 customers from all over the country. Source strength of the plant was increased up to 700 kCi so as to increase the throughput of the plant. Eight new customers for Spice, Ayurvedic raw material and pet feed were registered with the facility during last nine months. New products such as coconut water powder, liver extract powder, watermelon powder and tobacco were also successfully irradiated to achieve microbial decontamination.

- During the current financial year 2017-18, 4748.56 Tons of spices and other products were processed.

- Survellience audits for ISO-22000:2005 (Food Safety Management Systems) and ISO 9001:2008 were carried out at RPP, Vashi Complex, by certifying agency and was found to be in full compliance with the standard requirement.

- Additional revenue obtained from GRPS related products and services were towards the production & supply of 1.9 Lakh Ceric-Cerous Sulphate dosimeters to the various gamma irradiators in the country for absorbed dose measurements.

- More than 2000 biological indicators, Bacillus pumilus (a product of Microbiology Section, RPP, Vashi), for monitoring radiation sterilization process was manufactured and supplied to the different irradiators& manufacturers of medical devices & pharmaceutical products.

- International order for supply & installation of 125 kCi Co-60 sources was received from Sri Lanka Atomic Energy Board. Work was successfully completed.

- As a support for R&D activities, following materials/equipments were irradiated at various doses to study the effect of radiation so as to develop radiation resistant materials:

1. Gamma irradiation of motorised and pneumatic operated valves from M/s. INDAAI Technologies Pvt. Ltd. was carried out to develop radiation resistant valves and actuators.

2. Gamma irradiation of annealed tinned copper conducer, EPR insulated instrumentation cables and fire survival cables from M/s. KEI Industries Ltd. at 150 kGy were carried out for radiation test qualification.

3. Gamma irradiation of virgin PTFE dumbbells, buttons and rings from M/s. L&T Valves were carried out to test radiation resistance.

Spices for gamma irradiation

Activities at Dosimetry Group of RPP include the following:

- Export of 2500 Nos. of Ceric-Cerous Sulphate dosimeters to Atomic Energy Regulatory Board, Sri Lanka Atomic Energy Regulatory Board, Sri Lanka. Also, 2000 dosimeters were exported to AERE, Bangladesh for their gamma irradiators for absorbed dose measurement in radiation processed medical and food products.

- Radiation Processing Plant recommissioning dosimetry was carried out for six plants in the country for low, medium and high dose application, including M/s. Shriram Applied Radiation Centre, New Delhi and M/s Innova Agri Bio Park, Bengaluru. Dosimetry for mango irradiation was carried out at M/s Irradiation Facility Centre, Vashi, for approval of the facility by USFDA – APHIS for quarantine purpose.

- Plant recommissioning dosimetry was carried out for the sterilization of medical products and for microbial decontamination of spices at Sri Lanka Gamma Centre, Sri Lanka.

- Dose rate certification of two Blood Irradiators supplied to various cancer hospitals and three gamma chambers supplied to research universities was carried out.

- NABL accreditation for calibration of dosimetry laboratory was renewed till 2019.

- Dosimetry studies of the radiation processing plant at Dry Sludge Irradiation Plant at Ahmedabad, Gujarat, and at SARC, Innova Plant at Delhi was carried out by March 2018.

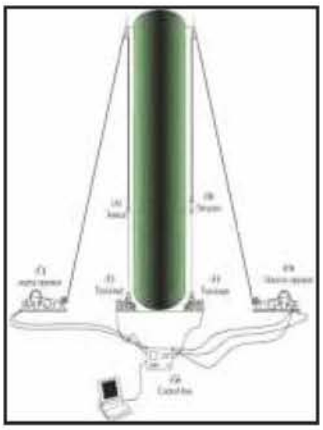
III. Isotope Application Services

Isotope Application Services (IAS) Section of Marketing & Services (M&S) Division of BRIT offered its valuable, timely and elegant services and solutions to various industries across the nation.

Sri Lanka Gamma Chamber for Radiation Processing, Sri Lanka

(a) Gamma Scanning of Process Columns

In the refinery of ESSAR Oil Ltd., Jamnagar, Gujarat, it was observed that the kerosene production was getting reduced to more than 40%, causing huge loss to the refinery. Gamma Scanning of crude distillation tower was carried out. These occur at various zones for different products from this tower such as light naphtha, heavy naphtha, light kerosene, LGO, HGO etc. To identify the cause, Gamma Scanning was done with the help of auto column scanner. Collimated 120 mCi of Co-60 source was placed on one side of the column and collimated BGO detector was placed on the other side of the tower and they were simultaneously manoeuvred to obtain 6 scan lines. Heavy flooding was observed in the light kerosene section which could be due to dislodgement of tray and thus blocking the flow in down-comer.



Gamma Column Scanning Process

During the reported period, seven such, Gamma Column Scanning was carried out in different refineries.

(b) Gamma Scanning and Flow Rate Measurement in PTA5 plant of RIL, Dahej, Gujarat

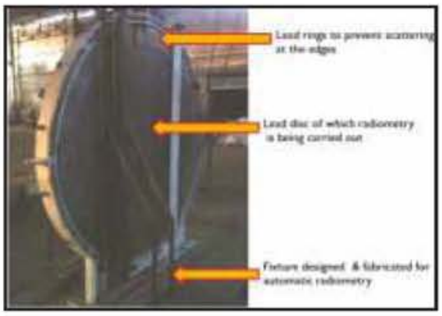
Per-Terphthallic-Acid (PTA) is produced in oxidation reactor. Reactor overhead condensate is cooled using series of heat exchangers. The cooled condensate is fed back to the reactor. It was suspected that flow dynamics in the legs of heat exchangers is improper which the cause of reduced production. The legs of all the five heat exchangers in series were scanned successfully using collimated 100mCi of Cs-137 sealed source coupled to collimated scintillation detector is connected to a rate meter which resulted in bringing the production to normalcy. Flow rate estimation was also carried out using transit time method.

(c) Leak detection study from Heat Exchangers for Pollution Control

Due to stringent pollution control norms, diesel produced in petroleum refineries should have sulphur less than 10 ppm. DHDS and DHDT plants are used to achieve this. To utilize the energy in efficient manner, the feed having high sulphur is heated in series of heat exchangers with the effluent from the reactor in which the sulphur is reduced to less than 10 ppm. If any minute leak from the high pressure side (feed) takes place then that result in to low pressure (effluent) and finally quantity of sulphur increases to unacceptable values. Radiotracer is injected in high pressure side and its ingression into low pressure side is monitored using collimated radiation detectors placed on outlet pipes of each of the heat exchangers. Appearance of radiotracer in any of such detector is indicative of that heat exchangers are leaking. This type of study was carried out in HPCL, Mumbai, HPCL, Vishakhapatnam, BORL, Bina, IOCL, Mathura refineries.

(d) Radiometry of Spent Fuel Canisters and Discs for L&T

M/s. Larson & Tubro Limited at Ranauli, near Vadodra, Gujarat are fabricating canisters for spent fuel, their top shielding plates and bottom shielding plates for AREVA and Trans Nuclear, USA. Canister is a lead shielded cylinder with thickness of about 80mm lead and its bottom and top plates of about 1.2 meter diameter 108 mm thick lead were scanned for their shielding automatic scanning machine. 80 mCi collimated source of Co-60 and collimated BGO detector was used for this purpose. More than Fifty such radiometry tests have been carried out during 2017-18.



IV. Radiation Physics Services Group

- To meet with the increasing demand of ^{60}Co usage for various applications, production of ^{60}Co is done in 700 MWe PHWRs also in addition to the production in 220 MWe PHWRs. The Adjustor Rods (ARs) in which the raw material is incorporated and irradiated for ^{60}Co production are transported from reactors to BRITs RAPPCOF (Rajasthan Atomic Power Project Cobalt Facility) at Kota. The ARs are unloaded and the sub-assemblies are separated in water pool of RAPPCOF. It is planned to construct an additional water pool adjacent to the existing facility for handling ARs up to 10 MCi. Evaluations were done to find the adequate shielding required for handling Adjuster Rods (ARs) of maximum 10 MCi ^{60}Co in the proposed water pool.

- For the commissioning of the newly set up gamma plants M/s. Pinnacle Therapeutics Ltd. & Dry sludge irradiator for Ahmedabad Municipal Corporation, theoretical dose evaluations were carried out in the product material before the first source loading.

- Source Loading patterns were designed for the following 10 gamma irradiators for ^{60}Co source enhancement:

1. SARC, Delhi
2. OGFL, Kolkata
3. MGIF, SriLanka
4. AIIPL, Vasai
5. Krushak, Lasalgaon
6. Microtrol, Bengaluru
7. Alligned Industries, Gurgaon
8. GAMPPL, Hyderabad
9. Pinnacle Therapeutics Ltd.
10. Dry sludge irradiator for AMC, Ahmedabad

- ❖ Shielding of ROTEX-1, radiography camera was analyzed after design modification for approval from AERB.
- ❖ Radiological Surveillance provided to the following facilities of BRIT, Vashi:

- ➢ Radiation Processing Plant (RPP): Regular inspection of safety systems, area monitoring and personnel monitoring, Safety Status Reports prepared and forwarded to AERB, Convened Local Safety Committee meetings quarterly.
- ➢ Decayed Source Removal Facility (DSRF): Radiation monitoring and Personnel monitoring, Safety Status Reports forwarded to AERB quarterly.

V. Calibration Services for Portable Radiation Monitoring Instruments

- ➢ BRIT is providing calibration services for gamma radiation survey instruments. So far 555 Portable Radiation Monitoring Instruments such as survey meters, portable area monitors etc. have been calibrated till March 2018.

VI. Radioanalytical Laboratory Services

Radioanalytical Laboratory is engaged in the measurement and certification of radionuclide content in commodities. Depending on the nature of sample and test request, testing of either man-made radionuclide content or naturally occurring radionuclides is carried out. Generally, ^{137}Cs content is measured for certification of man-made radioactivity level various types of food items meant for human or animal consumption. In addition to man-made radionuclide assay, Radioanalytical Laboratory carries out the measurement & certification of residual radioactivity content in water samples, uranium content in water samples, naturally Occurring Radioactive Materials (NORMs) in environmental samples such as coal, fly ash, soil, rock phosphate & gypsum, soil etc. Large number of environmental samples such as soil, coal, fly ash etc. were analysed during the year for the presence of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K content. Another activity taken up by Radioanalytical laboratory is the survey & certification of surface radiation dose of steel consignments at factory premises and warehouses.

Radioanalytical Laboratory is accredited by NABL in the field of Radiological Testing.

During 2017-18 RAL, Vashi Complex alone has carried out more than 4800 tests on export/domestic commodities and 836 tests on water samples (gross alpha, gross beta ^{228}Ra & ^{228}Ra) whereas Radioanalytical Laboratory Services both, at Vashi Complex and RCR, Bengaluru, together performed approximately 5570 analyses of food and 850 water samples for the presence of radioactivity.

VII. Radiopharmaceuticals Services by RCR's, BRIT and QC, Vashi

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 2264 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.

RCR, Kolkata & Dibrugarh:

- ➢ Sale of cold kits for radiopharmaceuticals from the retail outlet at RC, Kolkata: 296 Nos. of Technetium cold kits for formulation of ^{99m}Tc-radiopharmaceuticals were sold this year to nuclear medicine centres 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.

RCR, Bengaluru:

- Regional Centre, BRIT, Bengaluru supplied ~75 Ci of ready-to-use ^{99m}Tc-pertechnatate to nuclear medicine hospitals and 851 TCK cold kits were sold through retail outlet and door delivery for the preparation of ^{99m}Tc-radiopharmaceuticals to nearby nuclear medicine centres.

- Gamma irradiation services were provided for 617 blood bags to Kidwai hospital. 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.

- Radioanalytical Laboratory analyzed and certified 110 samples for the measurement of residual radioactivity in various commodities such as food items for human & animal consumption, medicine etc

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. During the period, Regional Centre, Delhi has been involved in production & supply of ~34 Ci of clinical grade, ready-to-use Tc-99m radiopharmaceuticals injections after QC analyses.

- RCR, Delhi is involved in supply of TCK Cold kits from retail outlet to different private and Government hospitals in Delhi, NCR and northern region of India.

- The Radiation Protection Procedure Manual [RPC-Rc(Delhi)] for operation and handling of ^{68}Ge/ ^{68}Ga generator at Regional Centre, Dehi, has been applied to AERB for its clearance.

RCR, Hyderabad (Jonaki):

- During the period, Regional Centre of BRIT, Hyderabad (Jonaki) shall start supplying ready-to-use $^{99m}TcO_4$- (Pertechnatate) and ^{99m}Tc-Radiopharmaceuticals through their retail outlet to the nuclear medicine centres of Andhra Pradesh. Also, it continued to synthesize and supply ^{32}P labelled nucleotides and a few molecular biology kits such as Taq DNA Polymerase, PCR master mix and enzymes, for research in frontier areas of Molecular Biology, Biotechnology, Biomedical and Drug Discovery research of the country. It markets ^{35}S-labelled amino acids products produced at BRIT, Vashi Complex.

- Under XII Plan Project, RCR, Hyderabad, BRIT, was successful in patenting Fluorescence Resonance Energy Transfer (FRET) primer-primer method based on Real Time PCR Technology. In an attempt towards the commercialization of the patented method, its performance was validated for a) target detection of M.tuberculosis (microorganism responsible for causing Tuberculosis) & b) mutation detection in Epidermal Growth Factor Receptor (EGFR) which is overexpressed in cancer tissues, thus helping in their early in-vitro diagnosis.

Quality Control Analysis Services from Vashi Complex for Outside Agencies

- Testing Services: a) Drug Control General (India) (DCGI) entrusted the responsibility of quality testing of ^{99}Mo-^{99m}Tc Generators imported in India by various vendors. a) Quality Control analyses were performed for imported ^{99}Mo-^{99m}Tc Generators from different manufacturers world over, which were intended to be used in India. Compliance certificates were provided to the vendors after evaluating all the QC parameters. b) One batch of Tc cold kit for the preparation of Tc-99m-labelled Myoview was analyzed for outside agency (GE Healthcare), whereby certificates of analyses were provided to them after evaluating the performance for all the QC parameters.

C. Customer Support

As the nodal agency for sales and supply, marketing and customer relations, co-ordination & logistics support cell continued to provide regular and uninterrupted supply of radioisotopes & allied products, radiation technology equipments to about 2000 user institutions in the healthcare, industrial, research and agricultural sectors.

Eighteen new customers were registered for supply of radio pharmaceuticals during the year. 100 No. of A1 forms are processed every week for ordering radio pharmaceuticals and till date 125 standing order forms have been registered for supply of Radio pharmaceuticals.

BRIT participated, presented and demonstrated BRIT activities at 'Science & Technology Exhibition' held during 28/07/2017 to 14/08/2017 at Parliament of India, New Delhi.

BRIT also participated in the second DAE-Journalist meet at Kalpakam during March 25, 2018 to March 31, 2018 and briefed about the activities of BRIT.

Domestic requirement of Irradiator source and Teletherapy source were also met as per the order received. Applications for various permissions and approvals are also being processed through eLORA portal to meet the regulatory compliance.

BRIT participation at Parliament, New Delhi

BRIT participation at DAE-Journalist meet at Kalpakam

Export orders of two teletherapy sources, one low dose Irradiator, one Irradiator source consignment, two dosimeter consignments and radiopharmaceutical cold kits were also processed and supplied bringing foreign exchange revenue.

With implementation of GST necessary steps have been undertaken to comply with GST requirement in order to ensure smoother transactions. BRIT also introduced new price list for all radio pharmaceuticals, on 01/01/2018. Further, BRIT products got registered under excise duty on 30/06/2017 valid till 19/01/2018. For Radio pharmaceuticals, excise duty at 10 % has been loaded to base price.

In an effort to improvise on sales support, feedback was collected during various conferences and seminars which have been consolidated and analyzed.

D. HRD and Activities related to Official Language Implementation at BRIT

- HRD and Research & Development 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. These are detailed in the next Chapters.

- Activities related to the Official Language Implementation at BRIT: BRIT, along with its scientific activities, has continuously encouraged the use of Official Language in its official correspondence by complying with the directions issued by Department of Official Language.

❖ The quarterly meetings of Official Language Implementation Committee (OLIC) are organized regularly, in which the OLIC members discuss the various activities with regard to monitor the progress of each quarter.

❖ Apart from the routine work, BRIT has organized four Hindi Workshops and Hindi Competitions under the auspices of Joint Official Language Implementation Committee and also conferred the prizes to the winners of the competitions on the eve of Hindi Diwas in Joint Ceremony.

❖ The officers/employees have been nominated in the workshops organized under the aegis of Joint Official Language Implementation Committee.

❖ BRIT officers/employees have also been nominated for attending technical/scientific seminars organized by Heavy Water Board and Atomic Energy Regulatory Board.

❖ BRIT organized additional competitions, such as Quiz, Dictation & Essay writing and Noting/Drafting and Extempore Speech, under the auspices of Official Language Implementation Committee in Vashi Complex premises during the period 2017-2018.

❖ Initiative is being taken to propagate Rajbhasa through Electronic devices by flashing an appealing description of the purchased Hindi literary books, some motivational quotes, proverbs, sayings along with the Noting Drafting phrases in Official Language on the display screen situated at the Administrative Building/REPF in BRIT . Along with it, in order to ease the hesitance of the BRIT Customers, and at the same time propagate Rajbhasha through its customer services, a Desk Plate displaying "You can speak to me in Hindi", at the Customer's Desk would be displayed.

The Glimpses of the regular activities held during 2017-18 are as follows:

Hindi Day Celebrations (September 2017)

Message of Chairman, AEC being read by Smt. Priya Gunjal, Assistant Director (OL), BRIT

Shri. V.K. Kulkarni, Deputy Director (OL) HWB welcoming the guest

Saraswati Puja & lighting of lamp by Shri A. C Dey and Shri A. C Dey addressing the gatherin

Audience enjoying the Programme

Release of Hindi House Magazine

Hindi Competitions (October & November 2017)

Dictation, Essay Writing, Noting/Drafting Competitions were organized on the eve of Hindi Day under the auspices of Official Language Implementation Committee, BRIT.

BRIT officials participating in Essay writing & Noting/Drafting Hindi Competitions

Vishwa Hindi Diwas (January 2018)

Vishwa Hindi Diwas program was organized on 10th January, 2018 under the auspices of Joint Rajbhasha Coordination Committee. Chief Guest Dr. Damodar Khadse, Senior Literary and Reviewer presented a talk on "Hindi Language on the World Forum". Also, Dr. Shweta Sharma, Medical Division, BARC Hospital, Mumbai presented 'Health Care' Talk.

Banner of Vishwa Hindi Diwas - 2018

Dr. Damodar Khadse presenting his talk

Dr. Shweta Sharma from BARC Hospital, being welcomed by Smt. Priya Gunjal

Dr. Khadse giving away the momento for best recited poetry

Lucky draw being drawn during Vishwa Hindi Diwas

Haasya Kavi Sammhelan followed by Prize Distribution to the winners of various Competitions (Februarary 2018)

OLIC arranged a hassya kavi samhelan at BRIT premises on 14th February, 2018 which was followed by prize distribution for the winners of various competitions. The chief guests for kavi samhelan were Kavi Dr. Rajnikant Mishra and Kavi Shri. V.V. Kulkarni.

Kavi Dr. Rajnikant Mishra being welcomed by Dr. Yojana Singh

Kavi Shri V.V. Kulkarni being welcomed by Shri. J.P. Bhalshanka

Audience enjoying the Hassya Kavi Samhelan at BRIT

Hindi Competition Prize Distribution

Chief Executive, BRIT, Shri. G. Ganesh, giving away the prizes to the winners of Hindi Competitions


Chairman, OLIC, BRIT, Shri. Piyush Srivastava, giving away the prizes to the winners of Hindi Competitions


Chief Administrative Officer, BRIT, Shri. P. Ramakrishnan giving away the prizes to the winners of Hindi Competitions

Hindi Workshop in BRIT (14th - 16th March 2018)

OLIC, BRIT conducted Hindi Workshop in BRIT premises from 14-16th March, 2018. This was followed by distribution of participation certificates. An initiative was taken by OLIC, BRIT, to brief the workshop participants about the BRIT activities and thus a lecture on 'An Overview of Activities of BRIT' in Hindi was delivered by Dr. Vivek N. Yelgaonkar.


Evaluation session of the Workshop in presence of OLIC, Chairman and Members, BRIT

Lecture on BRIT activites being delivered in Hindi during the Workshop by Dr. V.N.Yelgoankar

Distribution of Participation Certificate in Workshop by OLIC Chairman and members

Plan Projects

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

Progress: Towards the installation of hot cells at the radiopharmaceutical facility, fresh indent for hot cells work was put up after getting the consent and budgetary quotation from the suppliers, quotations have been received and identification of the suitable party is already under consideration. Identified the vendors for installation of I-123 production system from Xe-124 gas route in the 3rd beam line of the 30 MeV cyclotron. Budgetary estimate for Xenon-Iodine gas target assembly and enriched ^{124}Xe gas have been taken up from the vendors. Procurement of eleven fume hoods has been procured at Medical Cyclotron Project site.

(b) Project: Indigenous HDR Brachytherapy Equipment (IHDR)

Progress: Cold trial for HDR equipment is completed and the equipment has been tested with radioactive source as well. IEC compliance tests for HDR brachytherapy equipment; 'KARKNIDON' has been successfully completed. Certificates for the compliance of the equipment, IEC-60601-1-1, IEC 60601-1-2, have been received. Treatment planning software, exclusively for 'KARKNIDON' has also been received and the testing for the same is in progress by TMH, Parel and RPAD, BARC during the reported time. Approval for new design of miniature source housing Ir-192 has been obtained from AERB. Approval for 'KARKNIDON' from AERB will be put up in January 2018.

IEC compliance test of HDR in progress

TPS being evaluated at RPAD/BARC & TMH, Mumbai

(c) Setting up of Fission based ^{99}Mo Production Facility.

Progress: Civil construction of building is 90% completed & occupied. Civil modification to be incorporated so as to accommodate M/s. INVAP design layout of the processing equipment.

Design documentation: Critical Design Review (CDR) has been completed & inputs have been implemented in design.

Processing: Equipments are arriving at project site, 16 Shipping authorizations are given. Nine consignments containing SS hot cell boxes, H2 cell, overhead crane, special tubes & cables, MSM etc already been received.

(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 ^{90}Y, ^{177}Lu, ^{89}Sr, ^{131}I, ^{32}P,

^{153}Sm. etc . Also the present production capacity of radiopharmaceuticals and services from RPL, Navi Mumbai and Jonaki Hyderabad would be enhanced under this project. New Pharmaceuticals Services Facility area is commissioned and is in operation during the reported period. Old facility area is decommissioned. Hot cells in the Main Production Laboratory is refurbished and refitted with the new hot cells for production of new Ready-to-use Radiopharmaceutical product, ^{177}Lu-DOTATATE injection.

External view of Fission Molybdenum Project FMP) building

Internal view of Fission Molybdenum Project FMP) building

Progress: A) Facilities set-up/developed and put to use: Industrial grade storage shed installed, CCTV camera network, two portal monitors for RPL, augmentation of QC facility using fourteen SS fume hoods, automatic gamma area monitoring system for QC, suspended type remotely operated flexible crimping/unsealing machines, PLC controlled remotely operated liquid transfer machine, rearrangement of supply and exhaust duct of AC & ventilation system in RPL.

Installed CCTV Camera System at RPL

Installed portal monitor for RPL

B) Partially completed facilities/equipment's/machines/gadgets: a) Factory Acceptance Test performed for 2" thick GMP compliant lead shielded facility for production of I-131 mIBG therapeutic doses suggested improvements in the incell gadget setup, facility likely to be dispatched from Germany to Mumbai in January 2018. b) Fabrication of the H-3 recovery system for TFS production facility at LCL is in progress, accessories such as special valves and bellows pump received. Set-up is likely to be installed in the month of January 2018. c) Lathe machine for RPL workshop received. d) Type-A package for: I) Transport of 1080Ci of H-3 adsorbed on natural uranium and ii) C-14 and Tritiated water in sealed glass ampoules designed, fabricated and tested as per AERB guidelines. Preparation of application for registration of the above packages is in process.

Two probe automatic gamma area monitoring systems and New SS fume hoods for processing new RPh

C) Initiation of procurement/PO stage through DPS/limited tender: Procurement of equipments/machines/facility such as 2T capacity fork lift, on-line H-3 monitoring system(PO released), thyroid uptake counting system (PO released), TLC scanner, ^{68}Ge-^{68}Ga generator, 2" thick lead shielded facility for production of the I-131 capsules, 4" thick 5 cell lead shielded facility for handling I-131/Mo-99, freeze drying unit, PVC floor tile, etc (initiated through DPS) cleared through various committees.

Major Works: Following are the high-lights: Civil works: First floor over RPL extension building is complete in all respects (brick wall partition, flooring, false ceiling, roof, staircase and lift shaft, emergency exit, etc); Electrical works: this job is divided into following three parts, major electrical works which includes total electrification of the first floor, fire alarm system, etc is 95% completed. Testing is in progress. Lift (1T capacity, goods) installation: installation done, testing is in progress. Minor electrical works: this job includes installation of lightening arrester with earth pits, wall mounted fans, exhaust fans, telephone cable work (from EPABX to TTB at first floor), etc. installation is in progress. c) Mechanical works: AC and ventilation duct work complete in all respect.

Industrial grade shed over RPL building

Entrance lobby of the first floor over RPL extension building

(a)

(b)

Repeater panel for addressable fire alarm system for first floor over RPL extension building

(a) Corridor of the first floor over RPL extension building
(b) Installed 1Ton capacity goods lift: Testing in progress

(e) **Project :** Technology Development for Radiation Technology Equipment

Manufacturing facility for Iodine-125 Seeds as brachytherapy sources are useful for management of Prostate Cancer. The civil construction for the I-125 seeds plant facility is in advanced stage of completion at BRIT Vashi Complex and so far civil and electrical work has been completed. Tender with enhanced scope of work has been raised for the supply of I-125 seeds manufacturing plant which is on 'Turn-key' basis.

Process has also been started to set up a hospital facility for the treatment using I-125 Seeds at TMC/RMC, Parel.

External View of I-125 Seeds Plant

Internal view of I-125 Seeds Plant

BRIT Website

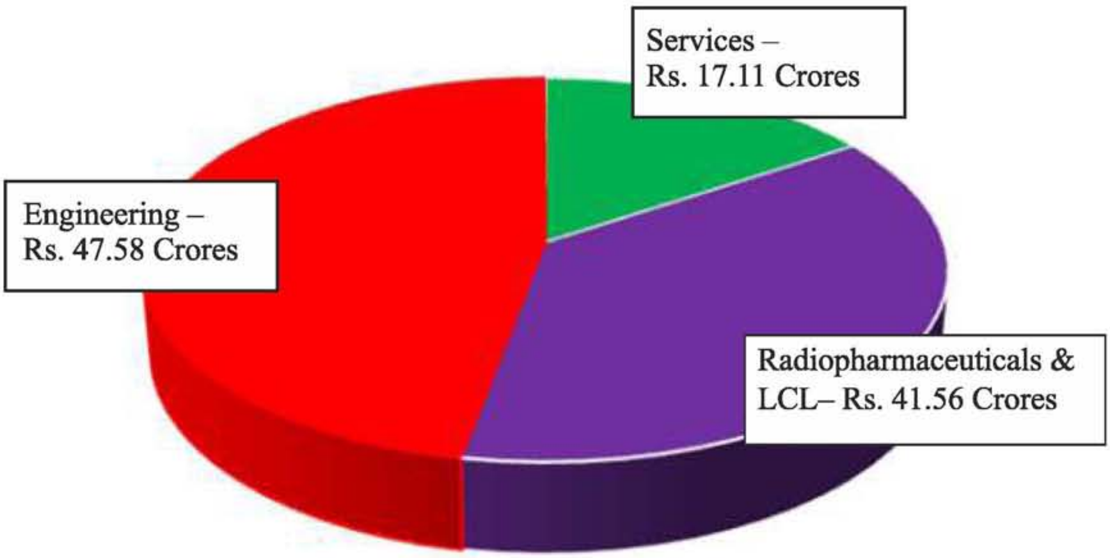
BRIT website provided regular updates on various programs and activities related to developments in BRIT. Customer oriented reports were uploaded on website almost on daily basis enhancing co-ordination and communication with the customers.

Also, Marketing & Services programme of BRIT has undertaken project to revamp its current website located at < www.britatom.gov.in > along with building an online sales management system (SMS); online quality management system (QMS) and an online radioisotope inventory management system (RIMS). The modules are proposed to be implemented in phase-wise manner.

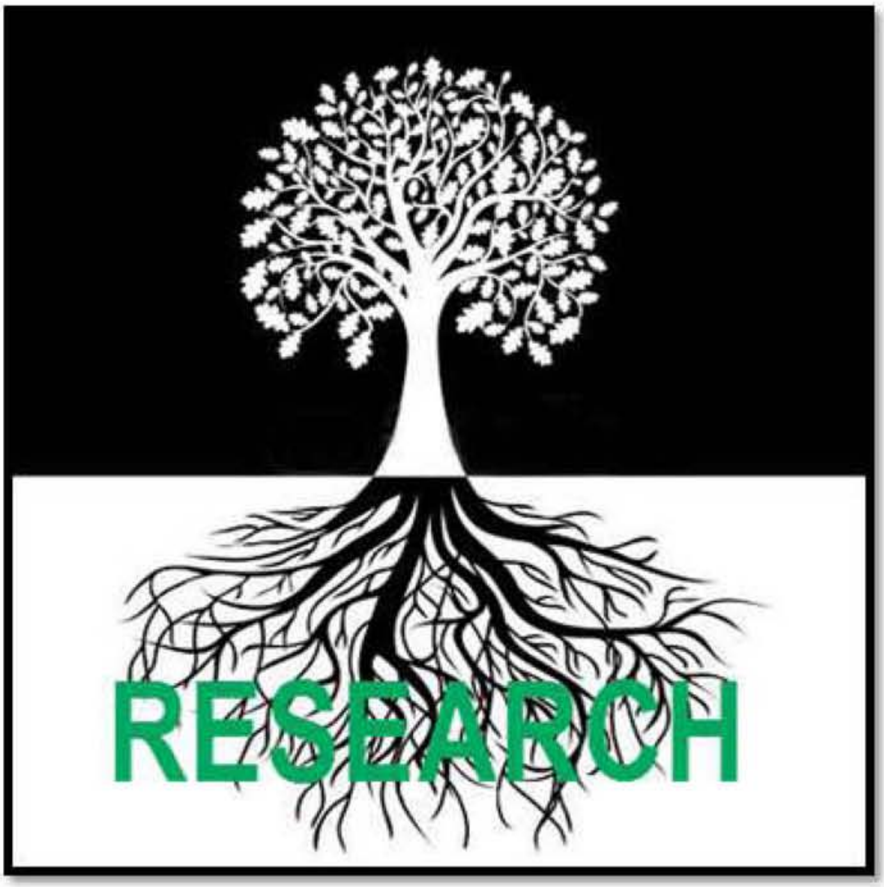
Sales Turnover in 2017-18

Appropriate Services and Sales of Radioisotopes & Allied Products Supplied by BRIT during 2017-18

S.No.	Item	Sales turnover from April 2016-March 2017
1.	Consignments	84, 172
2.	Activity	~ 2020 kCi
3.	Total Sale/Target Sale	Rs. 105.31 Crores/ Rs. 100 Crores

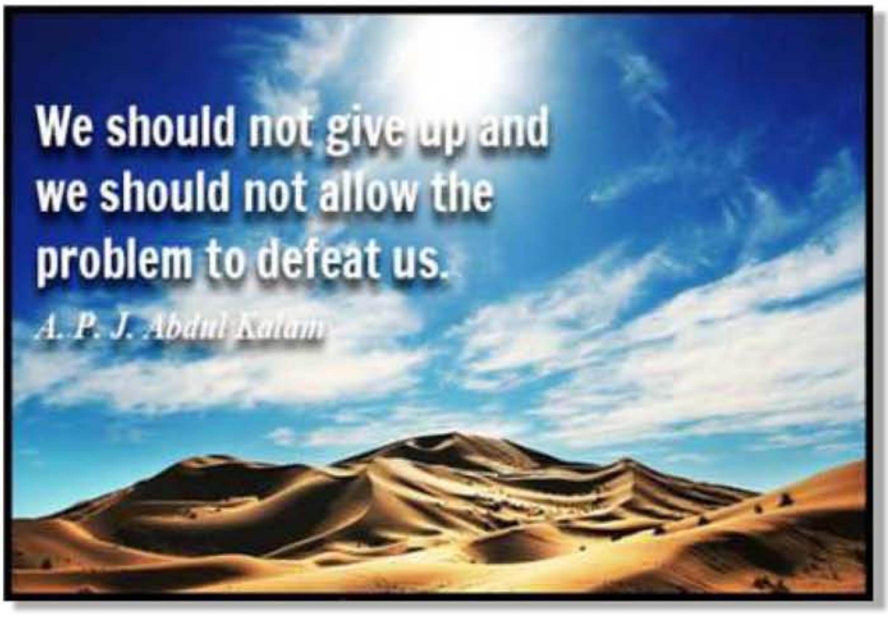


CHAPTER 3



Research & Development Activities at BRIT


SCIENTIFIC
RESEARCH
SKILLS
© BY DALAL2009


We should not give up and
we should not allow the
problem to defeat us.
A. P. J. Abdul Kalam

A. Development Work by Design & Development Section of Engineering Division:

(i) Qualifying COCAM-120 as an radiography equipment

Cobalt-60 based radiography exposure device (COCAM-120) has been designed for source strength of 120 Ci of Co-60 that will be used for non-destructive testing in industry. The device can be used to find defects in weld in the thickness range from 40 mm to 200 mm in steel. The device is made primarily of a combination of shielding material such as lead, tungsten and depleted uranium to make it compact and light in weight. Zircaloy-2 tube in form of S shaped has been used for smooth movement of pigtail and to avoid any radiation streaming. The COCAM-120 package wassubjected to 9m drop test, 1m punch test, 800 oCthermal test and has been approvedas a Type B(U) package from Atomic Energy Regulatory Board (AERB).

Fig.1: COCAM-120 under Shock Resistance Test

Fig. 2: COCAM-120 under Endurance test

Fig.3: COCAM-120 under Endurance test and Lock-breaking test

The package was subsequently subjected to number of tests such as vibration test, shock-resistance test, endurance test, lock-breaking test, projection-resistance test etc. to qualify it as a radiography device as per ISO 3999. In vibration test, the package was subjected to 1g acceleration for duration of 30 minutes at each identified natural frequencies in three orthogonal directions placed over an electro-dynamic shaker at RED,BARC facility. Vibration test was followed by shock test in which device moving at speed of 1m/s was dropped freely down a step height of 15 cm. The shock test was carried out 100 times. In lock-breaking test a force of 400 N was applied to the most vulnerable part of the interlocking mechanism of COCAM-120. In endurance test 50,000 complete exposure cycles were carried out with COCAM-120 device. Figures 1, 2 and 3 show the shock test, endurance test and lock breaking tests carried out on the exposure device respectively.

(ii) Remotely Operated Tungsten Shielded Exposure Device (ROTEX-I)

Remotely Operated Tungsten based Exposure device (ROTEX-I) has been designed for 65 Ci of Ir-192 radio-isotope. The tungsten is used as shielding material. The S–shaped bend path has been provided in the tungsten block so that additional tube is not required. The tungsten block is put inside a stainless steel shell of diameter 148 mm and fixed with gussets. The empty space in between is filled with polyurethane foam (PUF) to act as a shock absorber under impact loading. The device is mounted in a High Density Polyethylene (HDPE) structure. It is a compact, portable radiography device with weighing approx. 26 kg. A working prototype of ROTEX-I exposure device (without shielding block) along with the newly designed compact interlocking mechanism was also fabricated in-house. Fig.4 below shows the prototype of ROTEX-I device (without tungsten and PUF).

Fig. 4: Prototype of ROTEX-I exposure device

- **Development of Tungsten shielding block of ROTEX-I**

Development work for the fabrication of tungsten shielding block of ROTEX-I have been carried out in the continuous supervision. With limited facilities in India for tungsten sintering it was a challenge to develop the prototype. The complex shape of the job and the machining the stepped s-bent made the fabrication more challenging. The tungsten shielding block was fabricated using cold iso-static pressing of tungsten heavy alloy powder to get the green compact, followed by pre-sintering & sintering at around 900°C and 1535°C respectively in hydrogen environment. The technology of 3D printing were used for the first time to develop plastic moulds in near exact geometry, which in turn, were used to form the rubber bags to hold the large amount of powder. The cold iso-static pressing operation of such a large size also was a challenge. The Shrinkage allowance were determined and well taken care off while pressing and sintering. The pre sintering and sintering cycles were precisely designed carefully controlled for the large green compact in a batch-furnace. The sintered tungsten block was further machined to achieve the final shape in exact geometry of tungsten shielding block.

The Figures 5 and 6 below show the tungsten green compact in sintering furnace and the machined tungsten shielding block.

Fig. 5: Tungsten green compact block in furnace

Fig.6: Machined Tungsten Shielding Block

- **Numerical Simulation of ROTEX-I under 9 m drop test and 1 m punch test**

The device was been designed to meet the requirement of Type B(U) package. The performance of the device under 9m drop test and 1m punch test was carried by numerical simulation using explicit finite element solver PAM Crash for different orientations such as vertical drop, lock-side drop, side drop, corner drop, inverted corner drop and inverted vertical drop. The stress intensity of the outer shell & critical component i.e. tungsten is found to be within the safe limit and meet the ASME criteria. It was found that the device maintains its structural and shielding integrity under 9meter drop test and 1 m punch test. Figures 7 and 8 shows the FEM model of the Rotex and final deformation of the package under 9m vertical drop (lock side) respectively.

Fig. 7: Finite Element Model of ROTEX-I device

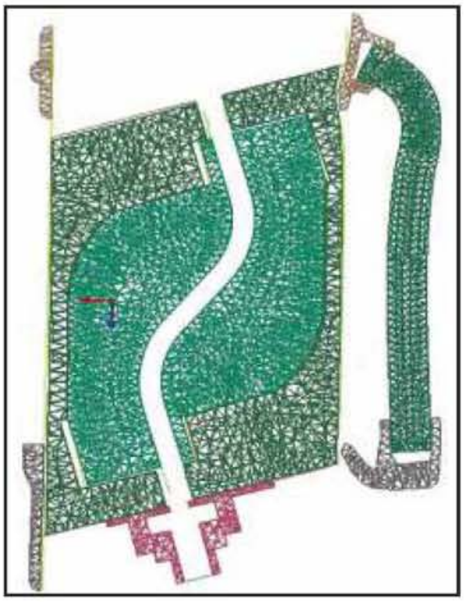


Fig. 8: Final deformation of ROTEX-I under 9m drop test in vertical orientation (lock side)

The final deformation under 1 m punch test is shown in Fig. 9

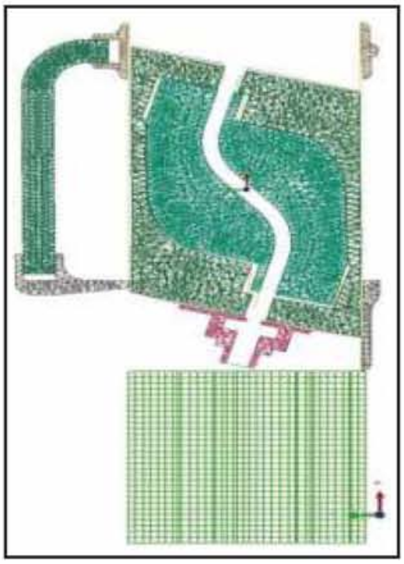


Fig. 9: Final Deformation of ROTEX-I under 1 m punch test

(iii) Design of Remotely Operated Depleted Uranium Shielded Exposure Device (RODEX-I)

Imported radiography devices are available in market with 120 Ci of Ir-192 radioisotopes and are also expensive. BRIT currently does not have any 120 Ci Ir-192 exposure devices. The existing lead shielded radiography devices weight around 38 Kg with 65 Ci of Ir-192 source. Hence, there was a need to develop high source strength capacity radiography devices which are also light in weight and compact. Fig. 10 shows the model of RODEX-I. The device has been designed for source strength of 120 Ci of Ir-192. It uses depleted uranium as shielding material. Zircaloy tube in form of S shape is used for smooth movement of pigtail and to avoid radiation streaming. The depleted uranium (DU) shielding is put inside a stainless steel shell of diameter 140 mm and fixed with gussets. The empty space in between is filled with polyurethane foam (PUF) to act as a shock absorber under impact loading. The device is mounted in a high density polyethylene (HDPE) structure. The RODEX-I device is 140 mm in diameter & 230 mm in height and weighs less than 25 Kg. The first piece casting of DU has been successfully carried out in AFD, BARC and is shown in Fig.11.

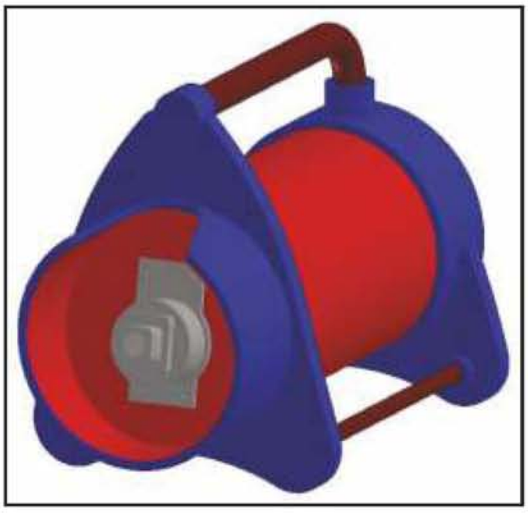


Fig. 10: Model of RODEX-I Radiography Exposure Device

Fig. 11: Casting of depleted uranium of RODEX-I radiography exposure device

The thermal analysis has been carried out to evaluate temperature transients during exposure of IGRED to a flame temperature of 800°C for 30 minutes. The normal condition temperature profile of camera (cross section) is shown in Fig.12. The maximum accessible temperature of the device is 38.42°C.The temperature history at various nodes during fire test is shown in Fig. 13. As PUF is neglected during fire test analysis the results of fire test are expected to be highly conservative since PUF acts as insulating protective medium against fire.

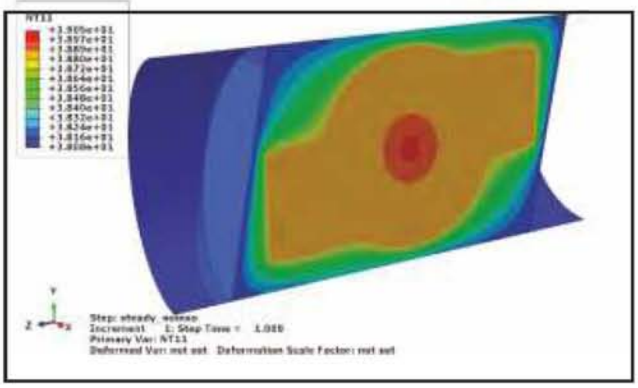


Fig.12: Normal condition temperature profile of RODEX-I

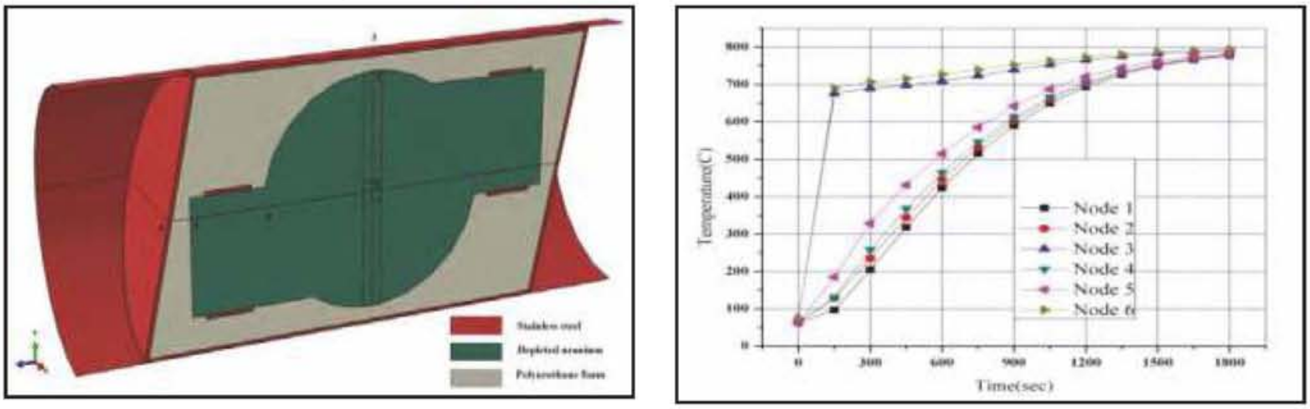


Fig.13: Temperature history of various nodes of RODEX-I during fire test analysis

(iv) Impact analysis of Low Dose Irradiator (LDI-1000) (Cs)

LDI-1000(Cs) has been design for low dose irradiation application. It can be utilized to irradiate blood and its component to prevent graft versus host disease (GvHD). The irradiator is designed for source strength of 3200Ci of Cesium-137. The package is design to meet the requirement of a Type B(U) package. A suitable outer enclosure has been designed to be used for transportation of the cask. The sectional views of the package are shown in the Fig.-14 and Fig.-15.The outer enclosure was designed

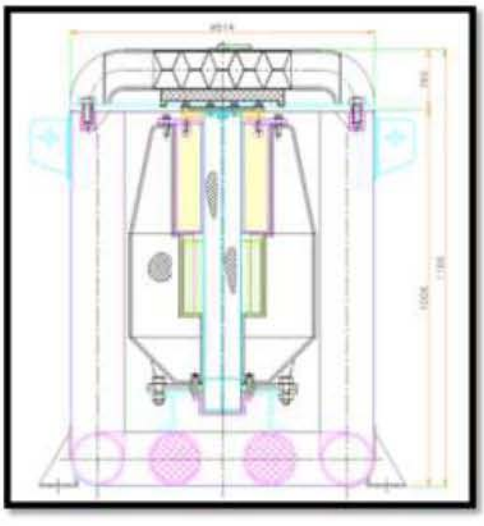


Fig-14 Sectional View of LDI-1000 (Cs) Package (Elevation)

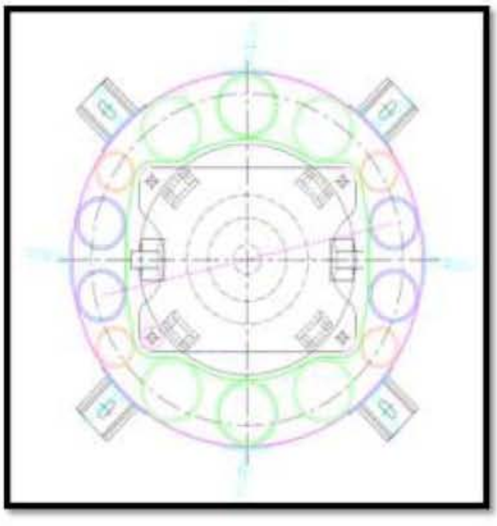


Fig-15 Sectional View of LDI-1000 (Cs) Package (Plan) in such a way that it restricts the internal movement of the cask. In order to enhance the performance of package under9m drop test, pipe cage structure has been provided all around. In addition, frustum shaped shells and lead filled pipes are provided at the top and bottom respectively. The package was simulated for 9m drop and 1m punch test using finite element method. Fig.-16 shows the solid model of the transportation package. Four drop orientations such as end, corner, inverted end and side drop were selected for analysis.Fig.-17 shows the final deformation of package after 9m end drop.

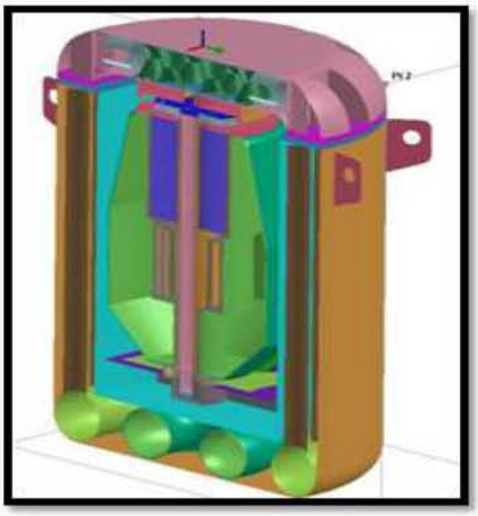


Fig-16 Solid Model of LDI-1000 (Cs)

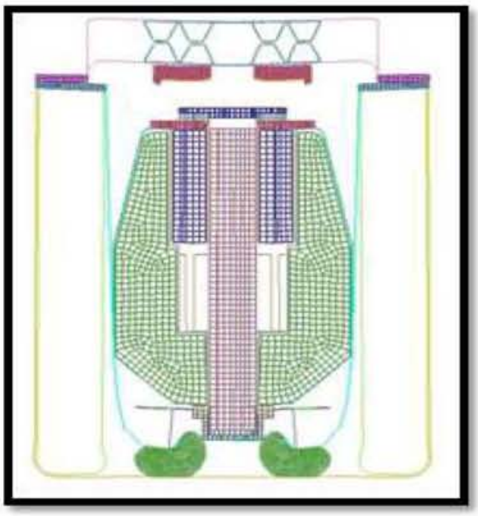


Fig-17 Final Deformation under 9m End Drop

(v) Design of Research Irradiator for Medical Science (RIMS)

A research irradiator has been designed for medical application. It will be used in laboratory for study of irradiation effect on sterile insect and stem cells etc. The irradiator has been designed to carry 3200Ci of Cs-137 and can deliver a dose rate of 13 Gy/min. The schematic sketch of irradiator is shown in the Fig.-18.The overall dimension of the irradiator is 1560 mm x678 mm x1340 mm having an overall weight of 1.4 Ton. Lead and tungsten are used as shielding material and encased in 6 mm thick stainless steel. Source cage has been designed with provision of accommodating 8 numbers of Cs-137 pencils in horizontal orientation. The motion of product box is also in horizontal direction and drive by the help of a driving mechanism which consist of one power screw shaft, gear and a motor. Two numbers of guiding shafts are also provided for precise linear motion; all these driving components are assembled on a single plate.

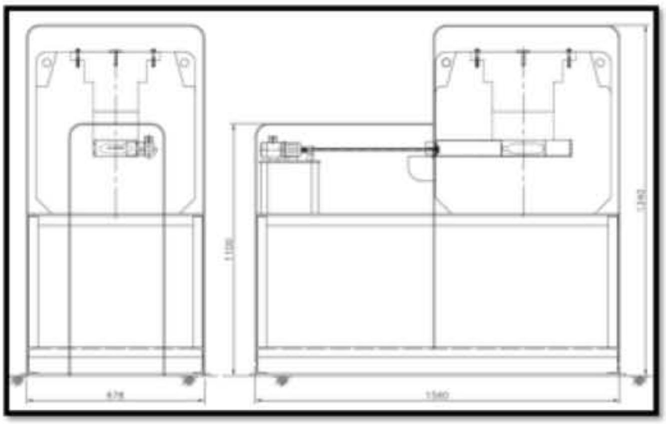


Fig-18 Schematic of Research Irradiator for Medical Science

For ease in installation the assembly has been divided in three parts i.e. cask, driving subassembly and table with operating panel. The driving sub assembly will be tightened to table with the help of bolts and locating pins. Table has been divided into two parts for convenience. One part will be used for placing the cask and other will be used for installing driving sub assembly. The two part of the table will be connected precisely with help of locating pin.

(vi) Thermal analysis of Molybdenum-99 package:

The Mo-99 container is type B (U) package having source capacity of 55.5TBq (1500 Ci) of Molybdenum-99. The shielding material used in the package is tungsten. According to AERB and IAEA guidelines the container has to demonstrate its conformance under 800oC fire test for 30 minutes to qualify as a Type B (U) package. The cask employs tungsten as shielding material hence no damage to cask shielding during postulated 30 min fire test is envisioned however to evaluate the maximum temperatures attained during fire test, a FE simulation is performed. The normal condition temperature profile of package is shown in Fig. 19. It seen that the maximum accessible temperature of package is 42.18oC. The temperature history at various nodes during fire test is shown in fig 20. As polyurethane foam has been neglected during fire test the results of fire test are expected to be highly conservative.

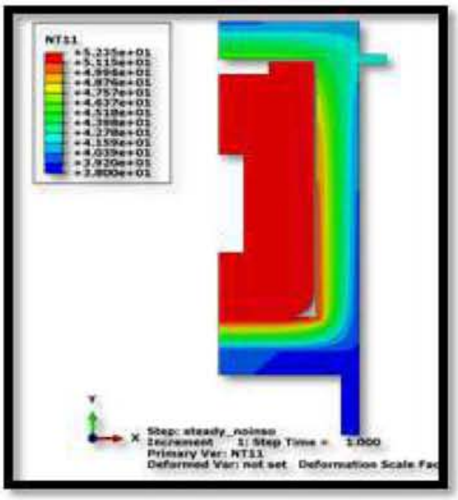


Fig.19: Normal condition temperature profile of package (axi-symmetric view)

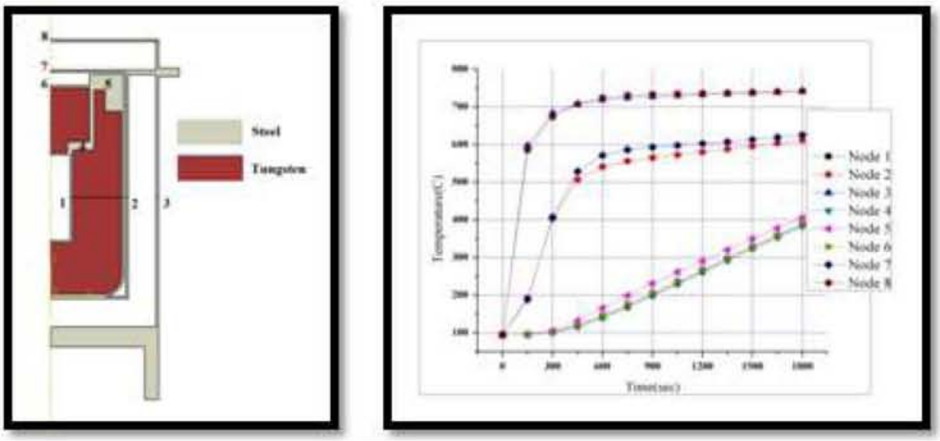


Fig.20: Temperature history of various nodes in Moly-99 package during fire test analysis

(vii) Syringe shield:

A tungsten syringe shield with lead glass was designed and fabricated (Fig. 21). It shall be used to reduce the hand exposure of clinicians during preparation and administration of radiopharmaceuticals. The syringe shield shall be used with standard 2ml syringes. A dose reduction of 99.7% has been seen for Tc-99m.

Fig. 21: Syringe shield

(viii) Load testing platform:

A 30 tonne capacity platform for load testing of overhead cranes was designed and successfully implemented. The platform is fabricated using ISMB 300 beams. The weight of platform is one tonne. The Fig.22 shows load testing being done at IFRT high-bay area.

Fig. 22: Load testing of IFRT high-bay crane

(ix) BLC-200 temperature profile:

An experiment to determine the normal condition temperature profile of BLC-200 with 200kCi Co 60 was conducted at RAPPCOF, Kota (Fig. 23). The experiment was done to verify the accessible temperature requirements of the cask. Subsequently a FE simulation of normal condition was performed and fairly good agreement between experiment and simulation was observed.

Fig. 23: BLC-200 being handled at RAPPCOF, Kota

The maximum observed accessible temperature of BLC-200 at an ambient of 31°C is 64.3°C (Fig. 24) at top centre of outer enclosure whereas the corresponding maximum accessible temperature from simulation is 61.6°C. The observed error in maximum temperature is -4.2%.

Fig. 24: Maximum accessible temperature of BLC-200

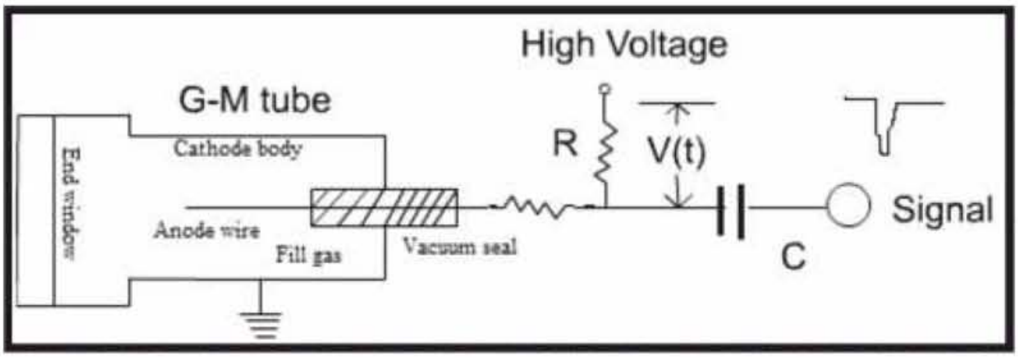
B. Development work by MIG Section of Enggineering Division

(i) Development of prototype Zone Radiation Monitor for Industries (ZRM-1)

An instrument is being developed in BRIT, The Zone Radiation Monitor, which is an instrument for measuring dose rate in the vicinity. It denotes Radiation dose rate in terms of either mR/hr or µSv/hr. The instrument uses a very rugged and well known Geiger-Muller tube (GM Tube). Apart from that High Voltage DC source for biasing the GM tube. Pulse shaper and counter circuit. Microcontroller based readout and alarm generation. Optional modules such as RS-485 serial communication and 4-20mA industrial current loop are available. We know that GM tube is gaseous ionization detector used to detect nuclear radiation by using Townsend Avalanche effect. The tube contains a gas mixture at low pressure of about 0.1 atm. The chamber contains two electrodes as shown in Figure 1.

The walls of the tube are either metal or have their inside surface coated with a conductor to form the cathode, while the anode is a wire in the center of the chamber.

When ionizing radiation strikes the tube, some molecules of the gas are ionized, either directly by the incident radiation or indirectly by means of secondary electrons produced in the walls of the tube. This creates positively charged ions and electrons, known as ion pairs, in the fill gas. The strong electric field created by the tube's electrodes accelerates the positive ions towards the cathode and the electrons



towards the anode. Close to the anode in the "avalanche region" the electrons gain sufficient energy to ionize additional gas molecules and create a large number of electron avalanches which spread along the anode and effectively throughout the avalanche region. This is the "gas multiplication" effect which gives the tube its key characteristic of being able to produce a significant output pulse from a single ionizing event. This short, intense pulse of current can be measured as a count event in the form of a voltage pulse developed across an external electrical resistor. This can be in the order of volts, thus making further electronic processing simple.

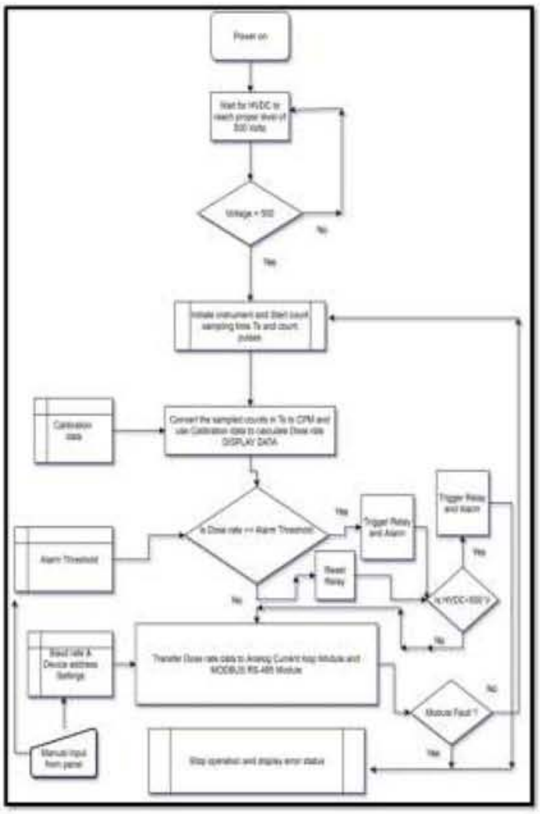


Fig. 2: Operation Flow Chart of the unit under fabrication

The GM Tube used is LND7121 that works from a range of 450V to 600V HVDC. The HVDC circuit has been constructed using a boost converter that converts 9V DC to 500V DC and is a clean DC Voltage. When radiation is incident on GM tube and inside the pulse output can be seen in Figure 3. The pulses are processed and converted into Logic level compatible pulses using pulse shaper circuit as in Figure 4, so that it can be read by Microcontroller based Counter assembly as CPM or CPS, as well as dead time compensation for GM tube is done. The Microcontroller contains calibration data that converts the respective counts in terms of mR/hr or µSv/hr. There is user set alarm radiation threshold in the system, and if the incident radiation crosses this limit the Logic relay is activated for safety interlocking as well as the Alarm LED starts to blink and Alarm buzzer starts to sound. The entire data can be seen on Instrument local display that consists of a very high contrast OLED display screen as seen in Figure 7. A very reliable 4-20mA current loop module has been implemented for the instrument which is very useful for gathering instrument parameter value to a centralized PLC based system with Analog Input modules which would help to gather all the Plant Radiation data on to a single system and display on SCADA. The instrument also includes RS-485 based serial communication module that is essential for Industrial digital serial communication. However these modules are optional and maybe implemented as per user's choice. Operations flowchart has been depicted in Figure 2.

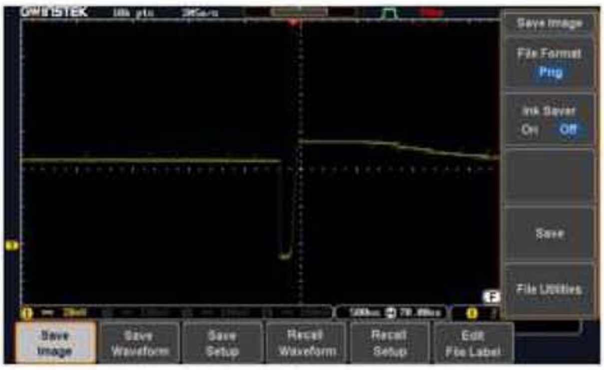


Fig. 3: The oscilloscope readout of GM tube pulses

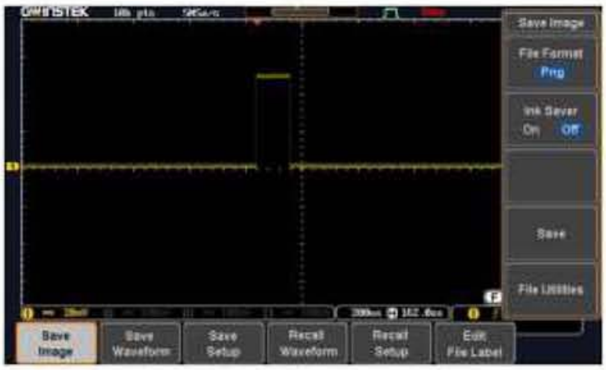


Fig. 4: The output of Signal shaper

A complete Instrument Block diagram has been shown in Figure 6.

The Printed circuit board is shown in Figure 5. It has been completely assembled now and the prototype has been calibrated Many iterations in design has been done to make HVDC power supply efficient for very high dose rate, proper component placement modifications has been done in order to reduce interference noise of DC to DC boost module, proper component selection for reliable data communication and alarm.

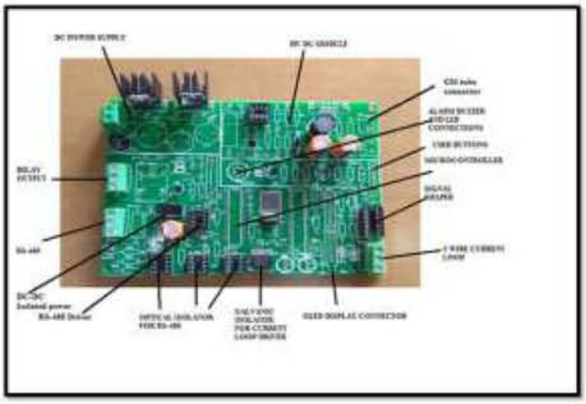


Fig. 5: Prototype Printed circuit board

Use of OLED display in place LCD display has been done in order to provide very high contrast display for easy readability from all angles and at a given minimum distance.

The Calibration graph has been plotted between CPS and Dose rate as per Figure 8 is found to be almost linear for a range of 0-100mR/hr.

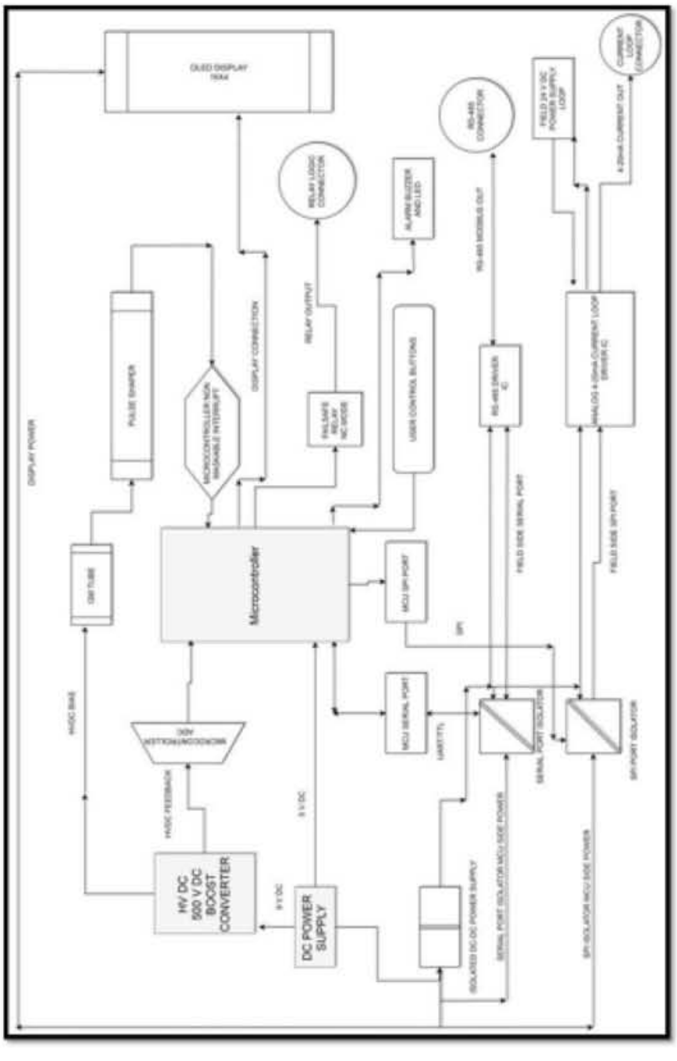


Fig. 6: Instrument Block Diagram

Fig. 7 Instrument readout screen

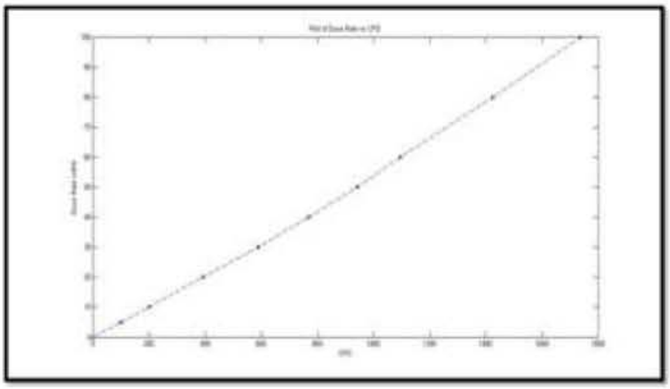


Fig. 8 The plot of Dose rate vs. CPS (Calibration performed in BRIT Calibration lab)

The Calibration was done for a range of 0mR/hr to 100mR/hr and after that instrument prototype was found to be accurate within 10% of Actual reading which is acceptable.

Conclusion:

1. It can be seen that our first prototype has been successful and is providing basic functionality of an Zone Radiation Monitor for Radiation Industry Safety.

2. Apart from Potential free relay logic output, we also have features for optional Industrial 4-20mA and RS-485 MODBUS communication.

3. Instrument has been in house fabricated and calibrated at BRIT, Vashi Complex.

4. Instrument has been mounted for testing at BRIT Vashi Complex Gate portal.

Future Work:

A civilian version ZRM (Mark-2) with highly sensitive GM Tube and Ethernet connectivity is already under development and is expected to be completed and tested soon.

C. Development work done by Radiation Physics Group Section

(i) Conceptual Development of an Irradiator for Cross-linking of Cables using ^{60}Co 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 cross-linking are thermal/chemical/e-beam from accelerators. E-beam cross-linking is the latest and improves properties like fire

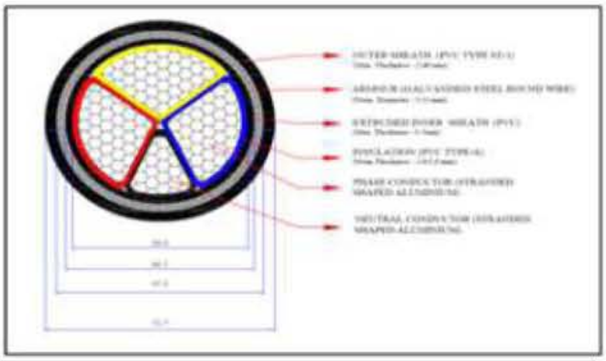


Fig. 1: Cross-Section of a mult core cable of 72.7mm

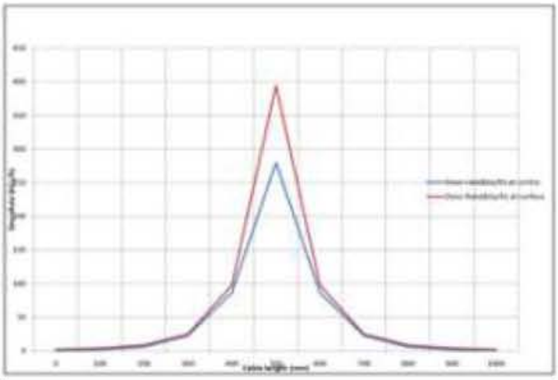


Fig. 2: Dose profile of cable in a GIC

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 (Fig.1).

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 ^{60}Co 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 (DUR) with the specified target dose of 100 kGy & to arrive at no. of irradiation cells required for a suitable through-put.

Table 1: DUR and throughput of multi-core cable Irradiation

Cable dia.	Cable core details	DUR	Throughput
72 mm	3.5x400/185	1.99	84.8 cm/min.
65 mm	3.5x300/150	1.64	71.2 cm/min
58mm	3.5x240/120	1.47	64.6 cm/min
52 mm	3.5x185/95	1.34	60.0 cm/min
47 mm	3.5x150/70	1.25	58.0 cm/min
42 mm	3.5x120/70	1.21	56.4 cm/min

(ii) A Study on the Feasibility of using Waste Canisters for Sewage Processing

Radiation processing of sewage sludge has been attempted at Sludge Hygeinisation Research Irradiator (SHRI), Vadodara, by taking a stream of the sludge from the sewage plant and passing it through an irradiator for making it pathogen free with gamma rays emanating from fabricated ^{60}Co sealed radioactive sources made by neutron irradiation of ^{59}Co in nuclear reactors.

In DAE there exists a large no. of canisters containing reprocessed waste from reactors in vitrified form. This nuclear waste contains a range of isotopes predominantly ^{137}Cs which is a gamma emitter. A study was carried out for evaluating the feasibility of using processed nuclear waste from nuclear reactors stored in waste canisters for in-situ sewage processing in sewage treatment plants. For this purpose the dose profile was determined in sewage for a tentative arrangement of canisters.

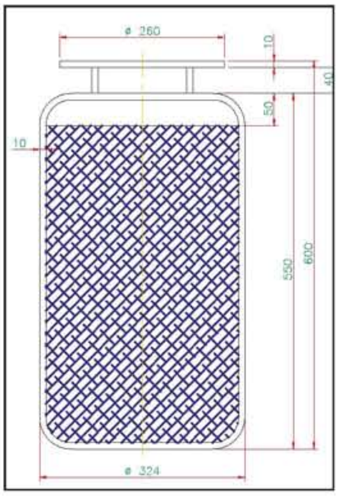


Fig.1: Waste Canister

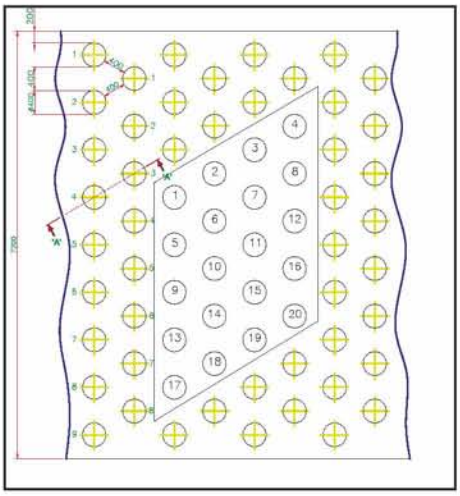


Fig. 2: Tentative arrangement of canisters in sewage

The dimensions of the canisters are given in Fig.1. Empty canister weighs about 50 kg and can accommodate about 90 kg of vitrified radioactive waste. As per the data obtained from WIP, BARC, the volume of waste filled per canister is 1000 litre with a specific activity of 60 Ci per litre. This means that the activity per canister is 60 kCi. Cesium-137 loading can be adjusted to be 100% per canister. The tentative arrangement of canisters in sewage is shown in Fig 2. Depth of sewage column=220 cm (Fig. 3). Density of sewage is 1.2g/cc.

A representative sample /a lot of 60 canisters were chosen for dose evaluation. They are arranged in 20 positions, having 3 tiers as marked in the Fig. 2 & Fig. 3. Their positions are numbered as 1, 2, 3, 4 ----, 20 as in Fig. 2. An MCNP model was developed for dose evaluations (Fig. 4). The dose rates were

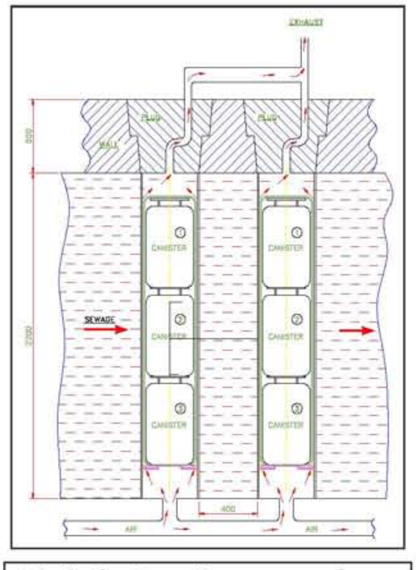


Fig.3: Canisters in sewage column

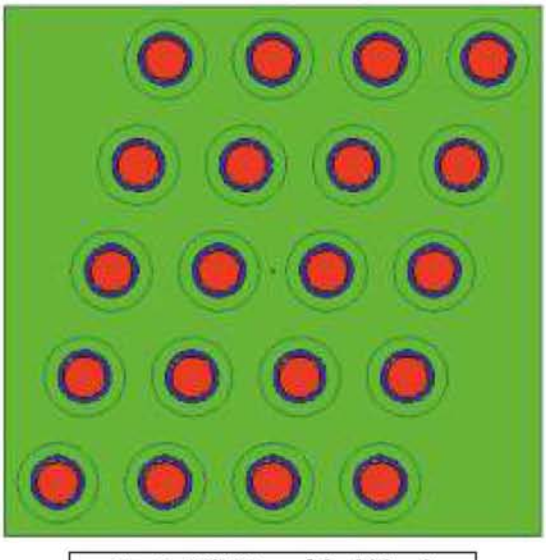


Fig.4: MCNP model of 20 x 3 canisters

calculated at points 20 cm and 40cm from the centre line of each canister positions, in sewage. This is done for the entire depth (220 cm) of sewage column. At 20 cm from the canisters the average dose rate is 581.6 Gy/h in sewage and at 40cm it is 115.8 Gy/h. This means that the overall average dose rate in sewage is 348.7 Gy/h.

The evaluated dose profile from 60 canisters indicates that the residence time of sewage should be 8.6 h for receiving a maximum dose of 3 kGy in $7m^3$ sludge. This study shows that waste canisters can be thought of being utilized for sewage treatment which otherwise are discarded as waste.

(iii) Feasibility of using ^{137}Cs in Gamma Irradiators for Food Processing

A study was carried out on using ^{137}Cs as source for panoramic gamma irradiators. At present all gamma irradiators of Category II & IV (Radiation Processing Plants) in India are using ^{60}Co as the radiation source. If ^{60}Co is to be replaced by ^{137}Cs, to maintain the same throughput from a radiation processing plant, the activity requirement is 4 times that of ^{60}Co because of the characteristics of ^{60}Co and ^{137}Cs which are shown in Table1.

Table 1: Characteristics of ^{60}Co & ^{137}Cs

Characteristics	Cobalt-60	Cesium-137
Half life	5.27 years	30 years
Energy	1.17 MeV and 1.33 MeV	0.662MeV
Dose rate at 1m from 1 Ci	1.32 R/h	0.34 R/h
Specific Activity	Up to 300 Ci/g	Up to 25 Ci/g
Physical form	Metal	Glass matrix/powder

Such large activity can be accommodated in two ways. 1) By using ^{137}Cs pencils of very high specific activity, maintaining the no. of pencils. 2) By using more no. of ^{137}Cs pencils with low specific activity. As a typical example for Radiation Processing Plant (RPP) of BRIT at Vashi, there are 100 pencils for the accommodation of 1MCi of ^{60}Co. To accommodate 4MCi of ^{137}Cs in 100 pencils the specific activity required is 120 Ci/g (approx.). For a specific activity of 2.5 Ci/g (present availability in DAE), the source frame size becomes about 70 m x 1.5 m for RPP. [For ^{60}Co it is 2.5 m x 1.5 m only]. Accordingly the size of irradiation room, source storage pool etc. is to be very large.

Feasibility of utilization of available ^{137}Cs in the Department of Atomic Energy (DAE), India without many changes in the existing irradiator designs is also considered in this study. For this, designs of two existing radiation processing plants are taken 1) RPP, BRIT for medium/ high dose products and 2) KRUSHAK, Lasalgaon for low dose products.

Radiation Processing Plant (RPP) at Vashi, BRIT is designed for 1MCi ^{60}Co. The source frame has 2 tiers and can accommodate 100 source pencils (W-91 type). The product boxes are of dimensions 60 cm x 45 cm x 110 cm. Two such boxes can be kept in the 2 shelves of a carrier which moves around the source in a 2+2 pass system. The box changes its shelf position in the carrier for the second passage in the irradiation cell.

KRUSHAK plant is designed for 300 kCi ^{60}Co. The source frame has 3 tiers and can accommodate 102 source pencils (W-91 type). The product boxes are of dimensions 85 cm x 57 cm x 135 cm. A carrier loaded with one such tote box move around the source in a 2+2 pass system.

W-91 type ^{60}Co source pencils used in the above said plants are of dimensions: outer diameter 27.2 mm and total length 463 mm. The optimized dimensions of ^{137}Cs pencils by the study carried out in 2006 for laboratory irradiators (Blood irradiators and Gamma Chambers) was 21.4 mm diameter and 194 mm length for inner pencil. Two such pencils can be used for making one source pencil for panoramic irradiators. ie. Activity filling dimensions of pencil are 21.4 mm (dia.) and 398 mm (length).

For the optimized dimensions of ^{137}Cs pencil, the effective activity was evaluated to be 790 Ci /pencil. This value was arrived at by considering the self absorption losses and for a specific activity 2.5 Ci/g.

Throughput of the plants is estimated for ^{137}Cs pencils and a comparison is done with ^{60}Co source pencils which are shown in Tables 2&3.

Estimated throughputs for the medium dose and low dose Panoramic irradiators are comparatively less for ^{137}Cs sources of 2.5 Ci/g specific activity. If the specific activity is increased, the throughput increases proportionally and use of ^{137}Cs can be taken up for low dose panoramic food irradiators.

Table 2: Throughput of RPP-BRIT for 10 kGy target dose in 0.5 g/cc material

Source	^{137}Cs	^{60}Co
Maximum activity	79 kCi in 100 pencils	1000 kCi in 100 pencils
Average dose rate	0.09 kGy/h	5 kGy/h
Throughput	0.64 tons/day	30 tons/day

Table 3: Throughput of KRUSHAK-Lasalgaon for 500Gy target dose in 0.38 g/cc material

Source	^{137}Cs	^{60}Co
Maximum activity	80.58 kCi in 102 pencils	300 kCi in 102 pencils
Average dose rate	0.08 kGy /h	1.24 kGy/h
Throughput	12.4 tons/ day	200 tons/day

D. Development work done by Microbiology Section of Radiation Processing Plant (RPP), Vashi Complex

(I) Investigation of radiation resistant bacteria from irradiation cell pool water of type IV gamma irradiator

Radiation processing plant, Vashi, Navi Mumbai, India, is one of the Type IV, wet storage type irradiator with maximum design capacity of 1 MCi ^{60}Co source activity. An attempt was made to isolate & study radiation resistant bacteria from irradiation cell pool water of the facility. Number of water samples were collected from the irradiation cell pool water and investigated for the resistant organisms. An average of 550 CFU of microorganisms per liter of the pool water sample was observed. Few experiments were carried out by precipitating the pool water organisms on 0.45μ cellulose nitrate membrane by filtration technique and exposing these membranes on soybean casein digest agar to gamma radiation dose of 3, 4 & 5 kGy in gamma chamber GC-4000. The membranes were incubated at 30-35^{0}C for 2-3 days and it is observed that 3.3% and 0.58% of the organisms showed survival at radiation doses of 3 & 4 kGy respectively with no survival at 5 kGy radiation dose. More than 25 such bacterial isolates were studied in detail. The microscopic observation reveals that most of the isolated organisms were gram positive rods some of them arranged in long chains resembling Actinobacteria. The radiation sensitivity studies showed that two 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 which is 50 times more than that of E. coli, a common gut bacterium. All the bacterial isolate studied showed variations in the biochemical test indicating diverse group of organisms. Being highly radiation resistant, these bacteria may be exploited for bioremediation of nuclear and radioactive waste.

(ii) Microbiological assessment and establishment of radiation sterilisation dose for Copper-T

Copper IUDs is one of the well known & widely accepted birth control contraceptives. It primarily works by disrupting sperm motility and damaging sperm so that they are prevented from joining with an egg. The IUD's should be sterile so as to avoid cross infection and related post-surgical complications. The present work is an attempt to establish radiation sterilization dose for the IUDs, Copper-T based on the methods given in standard ISO11137-2 .The product Copper-T from one of the leading manufacturer in India was studied to establish the radiation sterilization dose. Three different batches of Copper-T were evaluated for its bio-burden. The overall average bio-burden was found to be 59.5 cfu/unit product. Considering the antimicrobial properties of copper an additional correction factor due to antimicrobial property was applied while calculating an overall average bio-burden. Since the overall average bio-burden of the said product was found to be less than 1000 cfu/unit product, the method I given in standard ISO-11137-2 was applied to establish radiation sterilization dose. The method followed for bio-burden determination was membrane filtration technique as per standard ISO-11737-1 and SIP taken was 1 as whole product was tested for determination of bio-burden. The overall average bio-burden 59.5 cfu/unit product was not listed in the Table 5 of the standard , hence next closest bio-burden of 60 is considered for verification dose calculation. The verification dose (VDmax for SAL 10-2) for the tabulated bio-burden of 60 was found to be 7.3 kGy. Total 100 unit products from one of the production batch were exposed to the verification dose, VDmax 7.3 kGy at Radiation Processing Plant BRIT Vashi, Navi Mumbai. The maximum radiation dose delivered to the product was found to be 7.03 kGy (i.e. < 7.73, not more than 10% of VDmax dose). The radiation exposed samples were individually tested for sterility test and no positive test of sterility was observed out of 100 test sample hence verification was accepted to establish the sterilization dose of 20.4 kGy as given in Table 5 of the standard ISO-11137-2 so as to achieve SAL 10-6. Thus said batches of product Copper-T can be sterilized to the radiation sterilization dose of 20.4 kGy. Few microorganisms were isolated from the product and studied in detail. Most of the organisms were found to be gram positive cocci arranged in clusters. The carbohydrate utilization test results showed that most of the organisms utilize dextrose, sucrose, fructose with acid production. Most of the organisms were found to be catalase & mannitol positive, few organisms were also found to be oxidase, and citrate positive. One of the bacterial isolate showed lecithinase activity when tested of Baird Parker's agar and confirmed to be Staphylococcus aureus. None of the organisms were found to be positive for xylose fermentation. The radiation sensitivity studies of the isolated organisms were found to be in range of 0.3 – 1.0 kGy in terms of their D_{10} value.

(iii) Microbiological assessment and establishment of radiation sterilisation dose for Tubal Ring

Tubal ring is an intrauterine device (IUD) used as a permanent female birth control contraceptive. Tubal ligation or tubectomy (also known as having one's "tubes tied") is a surgical procedure for sterilization in which a woman's fallopian tubes are clamped and blocked or severed and sealed, either of which prevents eggs from reaching the uterus for implantation. The IUCD's should be sterile so as to avoid cross infection and related post-surgical complications. The present work is an attempt to establish radiation sterilization dose for the said product tubal ring .The product tubal ring from one of the leading manufacturer in India was studied to establish the radiation sterilization dose. Three different batches of tubal ring were evaluated for its bio-burden. The overall average bio-burden was found to be 12.63 cfu/unit products. Since the overall average bio-burden of the said product is less than 1000 cfu/unit product, the method I given in standard ISO-11137 part-2 was applied to establish radiation sterilization dose. The method followed for bio-burden determination was membrane filtration technique as per standard ISO-11737-1 and SIP taken was 1 as whole product was tested for determination of bio-burden. The overall average bio-burden 12.63cfu/unit product was not listed in the table 5 of the standard, hence next closest bio-burden of 13 is considered for verification dose calculation. The verification dose (VDmax for SAL 10^{-2}) for the tabulated bio-burden of 13 was found to be 5.5 kGy. Total 100 unit products from one of the production batch were exposed to the verification dose, VDmax 5.5 kGy at Radiation Processing Plant BRIT Vashi, Navi Mumbai. The maximum radiation dose delivered to the product was found to be 5.6 kGy which was ≤ 6.05 (i.e not more than 10% of VDmax). The radiation exposed samples were individually tested for sterility test and no positive test of sterility was observed out of 100 test sample hence the dose verification was accepted to establish the sterilization dose of 18kGy as given in table 5 of the standard ISO-11137-2 so as to achieve SAL 10-6. Thus said batches of product tubal ring can be sterilized to the radiation sterilization dose of 18kGy. Few microorganisms isolated from the product were studied in detail. Most of the organisms were found to be gram positive cocci arranged in clusters, few of the organisms were found to be yeast species. The carbohydrate utilization test results showed that most of the organisms utilize dextrose, sucrose, fructose with acid production. Most of the organism were found to be catalase positive, few organism were also found to be oxidase, mannitol and citrate positive. None of the organism showed lecithinase activity when tested of Baird Parker's agar. The radiation sensitivity studies of the isolated organisms were found to be in range of 0.16 - 0.64 kGy in terms of their D_{10} value.

E. Development work by Radiopharmaceuticals Production Programme (RPhP), Vashi Complex

(i) Labeling of Antagonist peptide with ^{177}Lu and their evaluation for neuroendocrine tumor therapy

DOTA-BASS is an antagonist peptide known to express high affinity towards somatostatin receptor (sstr) expressed on neuroendocrine tumors. The labeling of this peptide with ^{177}Lu was standardized and demonstrated for its affinity towards sstr receptors expressed on AR42J cell lines. Further experiments are underway to evaluate the efficacy of ^{177}Lu-DOTA-BASS in comparison to agonist peptide agent ^{177}Lu-DOTA-TATE in clinical use.

(ii) Synthesis of ^{125}I-Methotrexate for establishing the diffusion mechanism through a skin patch

The above work was carried as a part of BRNS project in collaboration with Bombay College of Pharmacy. Methotrexate is an anti-cancer drug and is an established drug for the treatment of rheumatoid arthritis. Oral intake of drug for rheumatic disease treatment leads to undue side-effects to the suffering patients. Delivery of drug through liposomal incorporation via a skin permeation gel over extended periods in suffering patients is a novel methodology explored worldwide to regulate the release of drug inside the human body minimizing the toxic effects of drug. In this preview, methotrexate was directly labeled with ^{125}I and obtained in reasonable yields post HPLC purification. This was then used as a tracer to establish the above mechanism in rats where the radiolabeled drug incorporated in liposome was applied in a skin gel patch and permeation through skin followed by withdrawing the blood samples and measuring the activity. The above technique could successfully help in quantifying the percentage of drug uptake, its kinetics of uptake with time and establishing the identity too.

(iii) Synthesis and bio-distribution studies of ^{8}C, ^{11}C and ^{15}C- $^{99m}Tc(CO)_3^-$fatty acid derivatives via click chemistry route for metabolic cardiac imaging

^{123}I-Iodophenylpentadecanoic acid (IPPA) is a clinical agent used for detecting metabolic cardiac abnormalities. Due to restricted availability of ^{123}I, there is a continued effort worldwide to develop a ^{99m}Tc substitute of this agent. Present work employs use of a well-known 'click chemistry labeling' approach for incorporating ^{99m}Tc to different fatty acids of variable chain lengths (8, 11 and 15 carbons) and evaluating them for cardiac imaging. ω-Bromo fatty acids (^{8}C/^{11}C/^{15}C) were synthetically modified at ω terminal to introduce a triazole ring bearing glycine moiety in a five step procedure. These were subsequently radiolabeled with preformed $[^{99m}Tc(CO)_3]^+$ synthon to yield the desired complexes. Biodistribution studies in Swiss mice showed myocardial uptake of ~6-9 % ID/g nearly similar to*I-IPPA (~9% ID/g) for all the tracers at 2 min post injection with significant retention up to 30 min (~1-2% ID/g). Activation study of ^{15}C fatty acid derivative with acyl-CoA synthetase (determined by HPLC) showed recognition of this complex by the enzyme. Significant uptake in myocardium and *in vitro* activation study shows that this 'click' approach of ^{99m}Tc incorporation holds potential for myocardial metabolic imaging.

(iv) Another Neutral ^{99m}Tc analogue of *I-mIBG prepared via $^{99m}Tc(CO)_3$ synthon for potential imaging of Neuroendocrine tumors

$^{123/131}$I-mIBG (meta-Iodobenzylguanidine) is a clinical agent used for imaging neuroendocrine tumors of neural origin, where the uptake in the tumor is via active transport pathway through nor-epinephrine transporters (NET). Our group in past have evaluated two ^{99m}Tc analogues based on ^{99m}Tc-4+1 and $^{99m}Tc(CO)_3$ designs. The present work attempts to synthesize and evaluate a new neutral derivative based on $^{99m}Tc(CO)_3$ approach with an aim to improve uptake and specificity towards NET. Precursor 1,3-bis(chloromethyl)benzene was synthetically modified in a five step procedure to produce benzylguanidine derivative bearing aminoethylglycine tridentate chelate. This ligand was labeled with ^{99m}Tc via freshly prepared $^{99m}Tc(CO)_3$ synthon to yield the desired neutral radioactive complex. The complex was then evaluated in SK-N-SH neuroblastoma cells. Specificity towards NET was ascertained by pre-incubating the cells with DMI (desmethylimipramine), a known blocker for NET. Cell uptake of the radiolabeled complex in SK-N-SH cells was low and specificity too was significantly affected in comparison to standard nca-^{125}I mIBG for different concentrations of the complex studied. The synthesized complex in comparison to previous ^{99m}Tc-4+1 design loses its uptake characteristics via NET and lacked suitability for NET imaging in neuroendocrine tumors.

(v) Development of indigenous synthesis module for preparation of ^{131}I-Lipiodol for hepatocellular carcinoma (HCC) therapy

The above radiopharmaceutical was launched by BRIT in collaboration with BARC in Nov. 2017. The radiolabeling of lipiodol is a challenging procedure where complete radiolabeling needs to be carried under inert nitrogen atmosphere conditions. All the transfers and dispensing of the starting and finished material needs inert environment to maintain the integrity of the final radiolabeled preparation. Nature of lipiodol in the form of an organic oil further adds to the miscibility issues with hydrophilic radioiodine activity affecting the labeling yield and generation of significant volatile radioiodine activity. All the above issues have been sorted out by developing an indigenous synthesis module. The module has three different work stations for transfer of raw material activity for labeling, dilution and sterilization of the labeled product and dispensing of consignment under inert environment conditions. Cold trials of the above module have been successfully completed. Work is underway for its installation inside the shielded hot cell facility for initiation of bulk produce and supply of this therapeutic radiopharmaceutical .

F. Development work by Quality Control & Quality Assuarance Section of Radiopharmaceuticals Production Programme (RPhP), Vashi Complex

(i) Standardization of Bacterial Endotoxin Tests (BET) and Sterility Tests (ST) for TCK cold kits, Tc-99m Collection vials, empty autoclaved vials and eluent (saline) used in Tc-99m COLTECH generator

Biological Quality Control tests such as Sterility testing and Pyrogen testing (in rabbits), an alternative for testing bacterial endotoxins, for TCK cold kits, Tc-99m Collection vials and empty autoclaved vials were outsourced to FDA approved Laboratory till date, whereby BRIT needed to spend a lot of corpus.

Bacterial Endotoxin Tests (BET)

Endotoxin represents the pyrogens (fever-inducing agents) of gram-negative bacteria. Bacterial endotoxin is the lipopolysaccharide (LPS) component of the cell wall of Gram-negative bacteria. It is pyrogenic, and it is a risk to patients who are administered intravenous and intramuscular preparations. Therefore, testing for endotoxins is very important for all the injectables radiopharmaceuticals.

BET by gel clot method had been restandardized for twelve TCK- kits based on the method approved by Radiopharmaceuticals Committee last year and is being implemented regularly at Quality Control Laboratory of Radiopharmaceuticals Programme, BRIT. BET method was also standardized for Tc-99m Collection vials (these vials are prepared by cleaning them thoroughly, making the vials pyrogen-free, evacuating and sterilizing them by gamma irradiation) and empty autoclaved vials (these are prepared by heating and sealing the empty glass vials in steam under pressure for 15 psi and 121°C temperature for 20 minutes) and eluent (saline) used in Tc-99m COLTECH generator. As a result we have stopped sending the testing of TCK- kits, Tc-collection vials and sterile autoclaved vials to FDA approved Laboratory. In addition, we have developed a gel-clot technique for testing endotoxins for newly developed TCK cold kits such as Macro Aggregated Albumin (MAA), HYNIC-TOC, and HSA Nano colloid.

Following are the results of the experiments undertaken towards standardization of BET of all the above mentioned TCK cold kits, TCK collection vials and empty autoclaved vials. The MVD (Maximum Valid Dilution) was standardized at 200 for all the TCK cold kits, where the endotoxin limit was not more than 25 EU/ml. Standardization of BET for Tc-99m collection vials and empty autoclaved vials, the endotoxin limit is 0.25 EU/mL whereas and for eluent (saline) used in Tc-99m COLTECH generator, the endotoxin limit is 0.5 EU/ml. BET for MAA and HSA nanocolloid was performed by enhanced BET.

The reconstituted cold kits were filtered through 0.22µm pre-sterilized PES (Polyethersulfone) membrane filter and the filtered solution was analysed for BET study.

Studies for other new TCK cold kits, TRODAT and Ubiquicidine (UBI) are in progress. By using gel clot method, we can avoid the use of animals for pyrogen testing.

Standardization of Sterility Test (ST)

We have standardized the sterility test (both, bacterial and fungal) for all the TCK- cold kits supplied by BRIT as per the procedures mentioned in the Indian Pharmacopeia (IP). We have also standardized ST for Tc-99m collection vials, empty autoclaved vials and eluent (Saline) for ^{99m}Tc–COLTECH Generator (TCM-1) as per IP. Further work is planned for implementation in -house.

(ii) Standardization of Sterility (ST) and Bacterial Endotoxin Testing (BET) of the new radioactive injectables, such as, ^{177}Lu-DOTMP and ^{177}Lu-DTPA Trastuzumab injections sent by RPhD, BARC, which are under development

^{177}Lu-DOTMP injection is a bone seeking radiopharmaceutical which plays a role in the management of malignant disease localized in the bone or bone marrow. ^{177}Lu-DTPA Trastuzumab is a Lutetium labelled monoclonal antibody used for the treatment of breast cancer.

Six batches of each of these products were tested for sterility testing (bacterial as well as fungal) and Bacterial Endotoxin Tests (absence of bacterial endotoxins).

Standard gel-clot BET method for ^{177}Lu-DOTMP injection revealed interference due to the chelating agent, DOTMP. This problem was circumvented by the addition of 60 mM of CaCl2 solution and this optimized protocol will contribute towards RPC clearance of this radiopharmaceutical. Similarly, the gel-clot method of testing the absence or presence of BET in ^{177}Lu-DTPA Trastuzumab injection showed interference due to the presence of high acetate ion concentration in the radioactive samples. This problem was circumvented by using PBS buffer for dilution of the lyophilized samples and these results would be submitted to RPC for the clearance of the BET method for this radiopharmaceutical product.

(iii) HPLC used as a Quality Control method for analysis of Tc-99m MIBI

Worldwide, instrument based analysis is preferred over manual analysis for its reproducibility and accuracy. As a part of continuous improvement and pharmacopeial compliance, HPLC method for analysis of ^{99m}Tc-MIBI has been standardized. The method involves HPLC and Reverse phase TLC to determine percentage of ^{99m}Tc-MIBI and impurities such as ^{99m}Tc-colloids. Many batches have been analysed so far and this method will be implemented as a regular Quality Control method of analysis, after approval from Radiopharmaceuticals Committee.

(iv) Post expiry analysis of Mo-99/Tc-99m Generators to check the integrity of filters

Generators received from different manufactures were analyzed post-expiry to check the integrity of the filters. These sterile filters are attached in the Mo-99/Tc-99m Generators to make sure that the eluent (Tc-99m) is sterile. These filters were analyzed for change in pH, Sterility Testing (ST) and Bacterial Endotoxin Testing (BET) to confirm the biological integrity post expiry of the generators.

The results obtained showed that the filters in all 25 generators retained their integrity and the pH was maintained throughout. This indicates the suitability of these generators for use up to three months post-expiry, on fulfilment of all other Quality Control criteria.

(v) Comparative studies of sterilization and apyrogenecity using Electron Beam and Autoclave

Plastic consumable items (microbial spreaders and tips) and water samples were sterilized by both Electron Beam (EB) and autoclave methods.

The results showed that there was no change in physical appearance of the samples by both methods. The ST and BET results indicated that EB, being a high through put and rapid method, is a good alternative to the autoclave method.

G. Development Work by Regional Centre for Radiopharmaceuticals (RCR, BRIT), Kolkata

(I) Production of ^{111}In after irradiation of ^{nat}Ag target in VECC, suitable chemical separation and preparation of radiopharmaceuticals

- ^{nat}Ag foil target (200µm, 250mg) externally irradiated with 32 Mev, average 400 nA alpha beam for 48hrs.
- The irradiated Ag target was cooled sufficiently to decay the short lived In isotopes before doing chemistry.
- Inactive Ag foil of 850 mg added to irradiated ^{nat}Ag foil target intentionally to get actual target amount for internal irradiation for production of around 200 mCi ^{111}In at the end of bombardment.
- Radiochemical separation of ^{111}In from irradiated Ag has been carried out by two methods-

a. Precipitation method (as shown in the figure)

The separation yield was 83%.

The separation time was 60 min.

The radiochemical purity of ^{111}In was >99% (as determined by TLC).

The co-produced radionuclidic impurities were ^{109}In, ^{110}In are short lived, thus were below detectable limit in the purified ^{111}In fraction. The radionuclidic purity of In-111 was >99.9%. Radiolabelling of ^{111}In with DTPA, Oxine and DTPA-octreotide was performed with RC purities of the labeled compounds more than 98% in each case as determined by TLC.

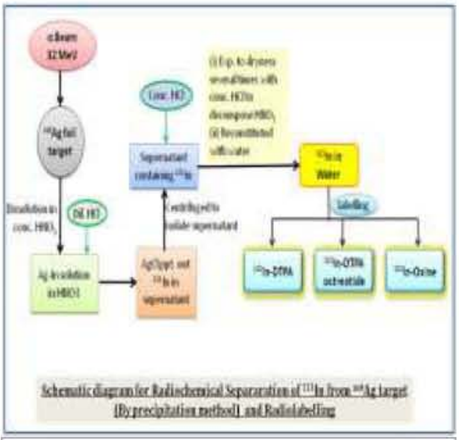


Figure 1: Schematic diagram of radiochemical separation of ^{111}In from ^{nat}Ag target and radiolabeling (precipitation method)

b. Small Sephadex Column method (as shown in the figure)

The separation yield was >90%

In-111 elution was done in 1,5ml dilute HCl (Elution profile is shown below).

The separation time was 25 min.

The radiochemical purity of ^{111}In was >99% (as determined by TLC).

The co-produced radionuclidic impurities were same as the previous method. The radionuclidic purity of In-111 was >99.9%.

Here also, radiolabelling of ^{111}In with DTPA, Oxine and DTPA-octreotide were carried out and RC purities of the labeled compounds were found more than 98% as determined by TLC.

The beauty of the method is that the tiny sephadex column can produce ^{111}In in high radioactive concentration in a very short time avoiding any evaporation step.

The separation of ^{111}In from irradiated Ag target using sephadex, an indigenous, novel method is reported for the first time as far our knowledge.

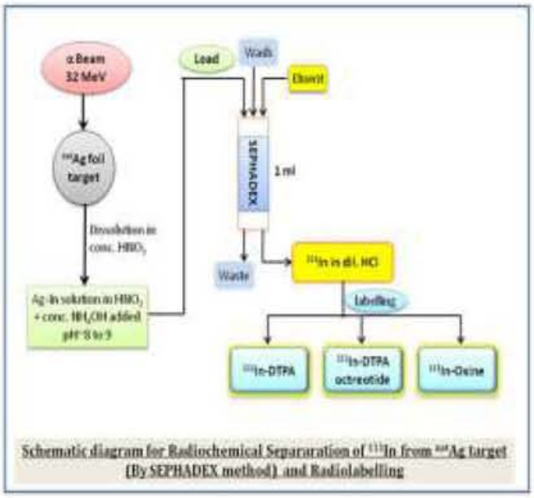


Figure 2 : Schematic diagram of radiochemical separation of ^{111}In from natAg target and radiolabeling (Sephadex method)

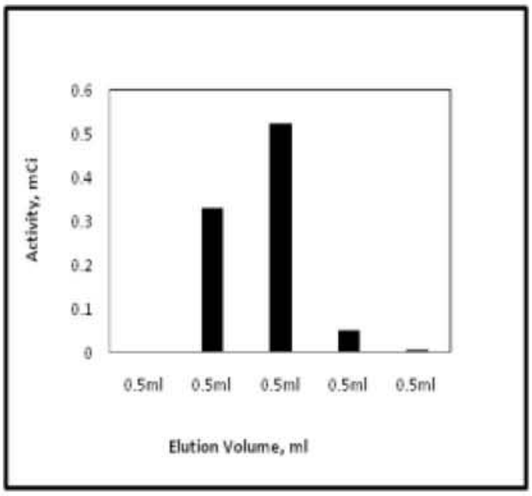


Figure 3: Elution Profile of pure ^{111}In-Chloride from Sephadex column

(ii) Irradiation of $^{nat}CaCO_3$ target for production of ^{43}Sc and a new indigenously chemical separation and labelling of ^{43}Sc (Method is shown in figure)

- Two irradiations have been carried out.
- $^{nat}CaCO_3$ pellet target (150mg each) externally irradiated with 26Mev, 400-800nA alpha beam for 16-19hrs.
- Dissolution of irradiated $^{nat}CaCO_3$ target: dilute Hcl
- Radiochemical separation of ^{43}Sc from irradiated $CaCO_3$ target has been carried out by sephadex method.
- ^{43}Sc was eluted in 0.25M ammonium acetate solution which was directly used for radiolabelling with DOTA-TATE and PSMA-617.
- The separation yield of ^{43}Sc was 83%.
- The separation time was 25 min.
- The radiochemical purity of ^{43}Sc was >95% (as determined by TLC).
- The no co-produced radionuclidic impurities were determined by HPGe. The radionuclidic purity of ^{43}Sc was >99.9%.
- The ^{43}Sc was labeled with DOTA-TATE and PSMA-617 successfully with labelling yield 70%. We have to optimize labelling condition to get higher yield.

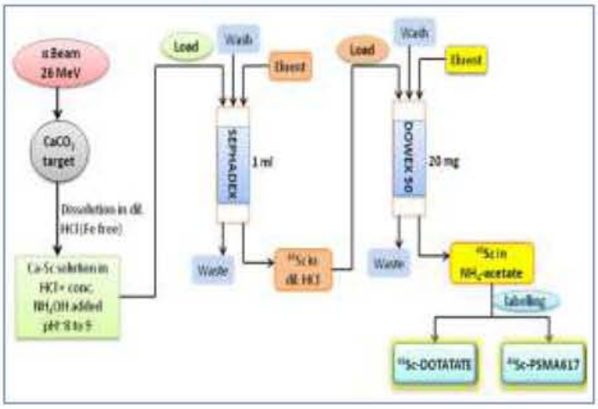


Figure 1: Schematic diagram of radiochemical separation of ^{43}Sc from $^{nat}CaCO_3$ target and radiolabeling (Sephadex method)

(iii) Targetry for Internal Irradiation VECC cyclotron for Production of Medically Important Radioisotopes

Development of targetry for production of different medically important isotopes by internal irradiation at VECC Room Temperature Cyclotron (RTC):

(i) Target for ^{111}In production :

Recently two kinds of silver targets on Cu base have been developed for ^{111}In production. In case of electroplated Ag target, during post irradiation dissolution the base material copper and its co-produced isotopes gets dissolved and chemistry becomes complicated. To prevent this the following targets have been thought off and fabricated the targets.

(a) **Removable type 1 mm. thick Ag target :** 1 mm thick silver cone has been mechanically pressed on the Cu based to make the target.

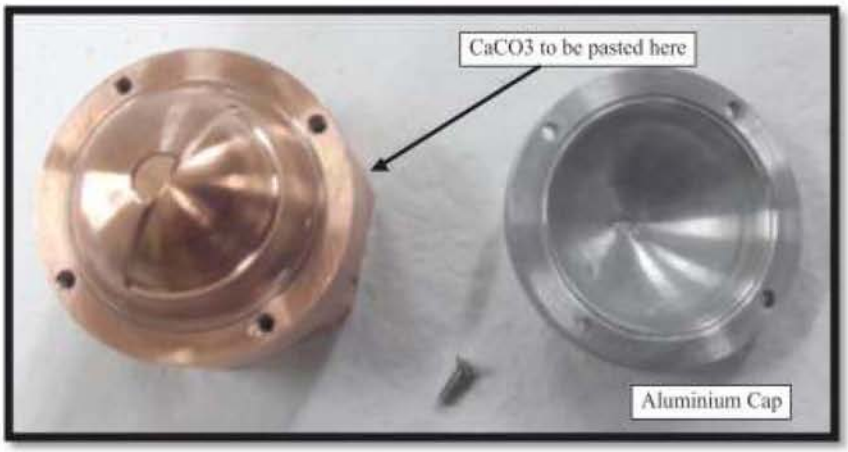


(b) **Solid Ag target fixed on Cu base:** Solid Ag target has been fixed on flat Cu base by brazing



(ii) Target for ^{43}Sc production :

^{43}Sc (Scandium-43), a medically important PET isotope has been produced from ^{nat}Ca (Calcium carbonate) target via ^{40}Ca(α,p) and ^{40}Ca(α,n) channels, first time in India, by external irradiation at lower beam current in VEC cyclotron. Around 4 mCi of ^{43}SC was produced by irradiating $^{nat}CaCO_3$ target with 30 MeV α- beam of about 0.8 μA current for 2.75 h. For internal irradiation at higher beam current $CaCO_3$ targetry has been indigenously designed and fabricated.



(iv) Development of a new and indigenous (n,γ)^{99}Mo/^{99m}Tc generator system: A new, portable solvent extraction based ^{99}Mo/ ^{99m}Tc generator utilizing (n,γ) ^{99}Mo IN SODIUM CHLORIDE SOLUTION for hospital radiopharmacy

Technetium-99m [$t_{½}$= 6.02h; 140.51 keV (89%)] is the most important and useful radioisotope in diagnostic nuclear medicine, thanks to its optimal characteristics - short half life, low-energy γ emission, versatile chemistry, and relatively low cost. The MEK based solvent extraction technique is a well known method for the separation of ^{99m}Tc from low specific activity ^{99}Mo obtained either through ^{98}Mo(n, γ) ^{99}Mo or ^{100}Mo(γ ,n) ^{99}Mo and ^{99m}Tc produced directly through ^{100}Mo(p, 2n) ^{99m}Tc nuclear reaction. Here we report a new, portable solvent extraction based ^{99}Mo/^{99m}Tc generator in tandem with alumina column utilizing (n, γ) ^{99}Mo to produce highly purified, concentrated, clinical grade ^{99m}Tc.

The new ^{99}Mo/^{99m}Tc generator system utilized (n,γ) ^{99}Mo and was MEK based solvent extraction in absence of NaOH & in presence of saturated NaCl. An aqueous solution of (n, γ) ^{99}Mo (200-500mCi) in dilute NaOH solution (6-15 ml) obtained from BARC/BRIT, Mumbai was taken in an extraction tube (50ml) kept in a lead shielding arrangement. The pH of the solution was adjusted to 7 and saturated with solid NaCl. The pertechnetate ($^{99m}TcO4^{-}$) was selectively extracted in MEK from aqueous sodium chloride saturated ^{99}Mo solution and passed through two small alumina column (neutral alumina to remove traces of ^{99}Mo and acidic alumina to hold ^{99m}Tc selectively from MEK) in tandem with the extraction tube. Finally, highly pure ^{99m}Tc was recovered from acidic alumina column with 3-5 ml saline in high concentration. The performance of this new ^{99}Mo/^{99m}Tc generator based on MEK solvent extraction in absence of NaOH was evaluated by studying the recovery yield of ^{99m}Tc, physico-chemical tests and radiolabelling with the standard radiopharmaceutical kits like MDP, DTPA & MIBI.

Some hospitals are still using the conventional manual solvent extraction method to extract radiopharmaceutical grade ^{99m}Tc from large volume of alkaline ^{99}Mo-molybdate solution in 5N or 6N NaOH, resulting generation of large radioactive waste. An extraction strict to 5N/6N NaOH condition increases the probability of induced aldol condensed impurities in the final product during evaporation of MEK. In view to utilise low specific activity (n,γ) ^{99}Mo produced in our BARC reactor more effectively in hospital radiopharmacy, we need to have a mobile, portable, compact and ready to use conventional ^{99}Mo-^{99m}Tc alumina column like generator utilizing solvent extraction technique. For this, we may need some logistic changes in few parameters of the solvent extraction principle and usage. The size and shape of the newly developed generator of 500mCi was similar to a commercial alumina column generator.

Different batches of ^{99}Mo-Moly (Batch size: 200mCi or 500mCi) were processed to recover pharmaceutical grade ^{99m}Tc using this new MEK based solvent extraction in absence of NaOH & in presence of saturated NaCl. The average yield of separation of ^{99m}Tc was above 90% and ^{99}Mo breakthrough in ^{99m}Tc pertechnetate was <0.0002% (n=10). The pertechnetate obtained as above was checked for clarity, pH, radiochemical purity (RCP) and chemical purity. The final $^{99m}TcO_4^-$ fraction has the Mo and Al content <10ppm and MEK content <0.1 % v/v, with RC Purity >99% and RN Purity >99.9%. The efficacy of labeling specific compounds was assessed using standard radiopharmaceutical kits, such as ^{99m}Tc-MDP, ^{99m}Tc–DTPA and ^{99m}Tc-MIBI and RC Purity was above 95% (n=6).

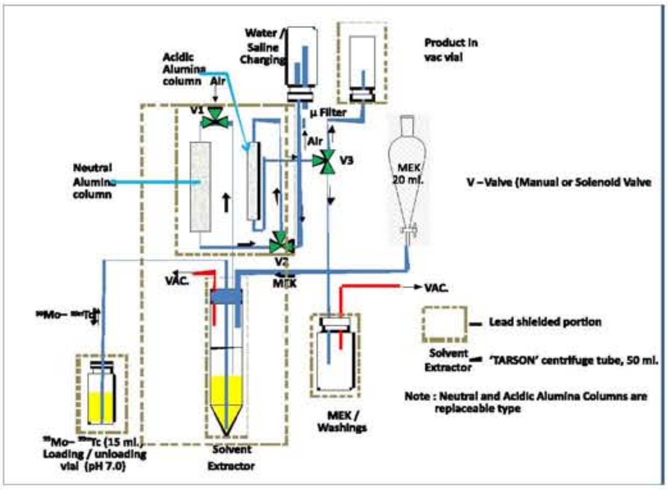


Figure 1: Flowchart for ^{99}Mo(n,γ)^{99m}Tc Separation (500mCi batch) at pH-7.0

The newly developed portable ^{99}Mo/^{99m}Tc generator based on MEK solvent extraction in absence of NaOH can provide the highly concentrated and purified ^{99m}Tc-pertechnetate using indigenously produced ^{99}Mo from our research reactor and finds its application for hospital radiopharmacy.

(v) Production of ^{111}In for usage in RMC, BARC/BRIT:

^{111}In (100 mCi at EOB) has been produced in VECC Cyclotron from indigeneously developed hemispherical Ag target on Cu base by internal irradiation with ~ 32 MeV alpha of 10 µA beam current for 2.5 days. After irradiation the target was cooled and radiochemical separation of ^{111}In from target matrix has been achieved by following indigenously developed small Sephadex column (0.5 ml) method with high radioactive concentration.

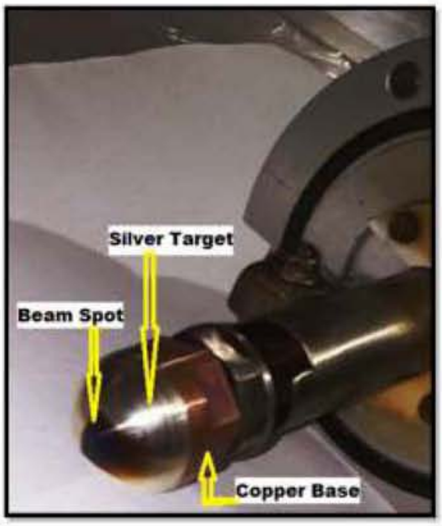


Figure1. Irradiated Hemisherical Silver Target on Copper based for In-^{111} production

The radiochemical purity of ^{111}In was >99% (as determined by TLC) and the radionuclidic purity of In-111 was >99.99% (determined by HPGe). The co-produced radionuclidic impurities ^{109,110}In were short lived, and were present below detectable limit in the purified ^{111}In fraction. Radiolabelling of ^{111}In with DTPA-octreotide, a somatostatin receptor related tumour imaging radiopharmaceutical was carried out and Radiochemical purities of labeled compound was found to be more than 98% as determined by TLC. ^{111}In activity (55 mCi/1.5ml dil HCl ^{111}In activity at the calibration time) has been used at RMC, BARC/BRIT for the preparation of ^{111}In-DTPA-octreotide for its physicochemical and biological evaluation.

H. Development work carried out at Labelled Compounds, BRIT, Vashi Complex

(i) Standardization for the preparation of Labelled Compounds for chemical/biological reseach

Standardization of the preparation of the following were completed (i) ^{14}C-Tetrahydrofuran with potassium, where [^{14}C]-Cyanide was taken as the starting material, (ii) methyl-^{14}C-labelled Sodium acetate (Sodium acetate-2-^{14}C) and (iii) deuterated pyridine (pyridine-d5) by the catalytic exchange with deuterium oxide under hydrogen atmosphere.

All these products are extensively used as tracers in the field of chemical/biological research.

I. Development work carried out at Medical Cyclotron Facility (MCF), BRIT

(i) Development of solid target irradiation system:

The Medical Cyclotron Facility has only liquid and gas target irradiation systems. Solid target irradiation facility in medical cyclotron has gained importance due to production of medically useful radioisotopes viz. ^{64}Cu, ^{111}In, ^{89}Zr etc. An indigenous solid target irradiation system was developed and tested. Fig 1 shows the assembled solid target. After obtaining permission from ULSC-PA, trial irradiation at 2 μA for 30 minutes was carried out. Among the several challenges faced in the development of Solid target assembly, the issue of safe transfer of the target after irradiation with minimum radiation exposure and contamination to the individual was a challenging requirement. To meet this need, a target removal assembly has been designed and tested. Fig 2 shows the irradiated target removal system .

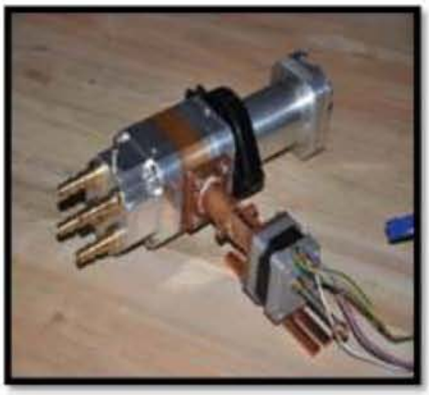


Fig 1: Assembled solid target

Fig 2: Irradiated target removal system

(ii) Development of a high-yield [^{18}O] water target of Niobium, for routine F-18 production in a Medical Cyclotron

The PETtrace Cyclotron is operated 3 - 4 times daily to produce ~ 5 Ci of ^{18}F radioisotope and converted to ^{18}F Fluro-deoxyglucose (FDG) for supply to various nuclear medicine centres.

Target cavities used over the years in medical cyclotrons for producing F-18 from O-18 have changed over the years based on cost, availability, demand, ease of maintenance, advances of technology.

Medical Cyclotron Facility in collaboration with CDM, BARC has indigenously fabricated Niobium cavity for liquid target to replace existing Silver cavity liquid target in the medical cyclotron target. The level of maintenance required in a water target is very much a function of the target body material. Silver targets are notorious for needing regular maintenance, while Niobium water targets often go for years with no maintenance at all. The level of maintenance also differs depending on the particular cyclotron beam energy, beam current and frequency of production. Advantages of Niobium target cavity over silver target cavity are

- Worldwide there has been a gradual replacement of Silver with Niobium, due to its chemical inertness, reduced maintenance and induced activity.
- Higher beam current i.e. with Niobium 70-µA beam target current can be typically used whereas for silver target typically 55 µA. Hence more activity can be produced in lesser time
- The maintenance schedule for niobium is much less stringent than silver. It is not uncommon for the target to go on for years without maintenance. The Niobium Target System can be used for 10000-µA-hour, whereas for Silver 4000 µA-hour before scheduled maintenance of target is recommended, hence maintenance cost is reduced.
- The induced activation in the Niobium Target is quite less compared to Ag target and hence can be maintained as early as one week after allowing for decay.

(a) (b) (c)

Fig (a and b) shows the beam strike area and the cooling fins and Fig (c) exploded view of the target irradiation system respectively.

(iii) Development of successful Gel Clot BET Assay method for Technetium cold kits (TCK) after resolving the interferences:

Highlights: These two particular assay methods have been approved by Radiopharmaceuticals Committee, DAE. It has been implemented at RPL QC laboratory for routine BET assay (Quality Control test) for all the TCK cold kits produced from RPL, BRIT Vashi.

a) Limulus Amebocyte Lysate Testing – Adapting it for Determination of Bacterial Endotoxin in ^{99m}Tc-labeled Radiopharmaceuticals at Hospital Radiopharmacy

Rationale: Bacterial endotoxin test (BET) is required to detect or quantify bacterial endotoxin that may be present in radiopharmaceutical preparations. It uses Limulus Amoebocyte Lysate, which in the presence of bacterial endotoxin and divalent calcium ions causes the formation of a coagulin gel. ^{99m}Tc-labeled radiopharmaceuticals have chelating ligands such as, DTPA, EC, ECD, Mebrofenin, DMSA(III), DMSA(V) and several others which form a coordination complex with $Na^{99m}TcO_4$ in the presence of reducing agents. During BET by gel-clot method, the free sulfhdryl (–SH) and carboxyl (–COOH) in some of the chelating agents in the final ^{99m}Tc-labeled radiopharmaceuticals decrease the free divalent calcium ions concentration, which in turn inhibits coagulin gel formation. This study was designed using the premise that addition of calcium chloride solution to the reaction mixture would nullify this effect. Methods: We present here the data obtained from BET assay analysis of ^{99m}Tc-labeled radiopharmaceuticals and the cold kits from which they are made viz EC, ECD, MIBI, DTPA, Mebrofenin, MDP, DMSA(III) and DMSA(v) using two different dilutions, Maximum Valid Dilution (MVD) and MVD/2, with and without addition of calcium chloride at a final concentration of 300 μM. Results: It is observed that at MVD and MVD/2 all above ^{99m}Tc-labeled kits exhibited interference in coagulin gel formation with the exception of ^{99m}Tc-MIBI, ^{99m}Tc-MDP, ^{99m}Tc-Mebrofenin, ^{99m}Tc-ECD. However, only the cold kits of MIBI and MDP did not show inhibition. An addition of calcium chloride solution nullified this interference at both MVD and MVD/2 in all the ^{99m}Tc-labeled radiopharmaceuticals where interference was observed. Conclusions: In practice, Limulus Amoebocyte Lysate (LAL) testing is not a method of choice for ^{99m}Tc-labeled radiopharmaceuticals since they exhibit interference. However, our study proves the hypothesis that addition of calcium chloride can circumvent this problem. This provides an enhanced biological quality control testing option on the final formulation of ^{99m}Tc-labeled radiopharmaceuticals at the Hospital Radiopharmacy end.

b) Resolving false-positive bacterial endotoxin test results obtained with some radiopharmaceuticals and cold kits due to the presence of cations, colloidal particles or fatty acids

AIM: We have reported that certain ^{99m}Tc-radiopharmaceuticals (Tc-RPs) can give a false-negative BET due to the Ca^{++} in the lysate of the LAL reagent being trapped by the Tc-RPs (**JNMT, 2014**, 42,278-282). We now report instances where certain radiopharmaceuticals can give false-positive results due to the presence of cations, colloidal particles or fatty acids and how this effect can be overcome. MATERIALS: (a) Reagents: 9.6 mM Ca^{++} and Mg^{++} free pH 7.1 PBS, LAL reagents (Sensitivity: 0.03EU/ml) used for BET including LAL-reagent water (LRW), Control Standard Endotoxin, Portable BET Test System (PTS) cartridges (Sensitivity:5-0.05 EU/ml).(b) Radiopharmaceuticals studied: ^{99m}Tc-TRODAT, ^{99m}Tc-GHA, ^{99m}Tc-HSA-nanocolloid, ^{99m}Tc-Sulfur-colloid and their cold kits. ^{99m}Tc-carbonyl-DTPA-Rituximab, ^{99m}Tc-carbonyl-DTPA-Bevacizumab, ^{177}Lu-DTPA-Nimotuzumab, ^{177}Lu-DOTA-Nimotuzumab and their bi-functional chelated monoclonal antibody (BFCMA) cold kits, and ^{131}I-Lipiodol. METHODS: BET assays were performed for the RPs and cold kits using LRW or PBS as dilution agent by both gel-clot method (GCM) and kinetic chromogenic method (KCM) at various Maximum Valid Dilution (MVD) (400, 200,100 and 50) taking care of maximum injection volume and endotoxin limits (EL: 6 EU/ml- RPs, 1 EU/mg - BFCA-MoAb). RESULTS: ^{99m}Tc-TRODAT, ^{99m}Tc-GHA and their cold kits, ^{177}Lu-BFCA-MoAb and its cold kit exhibited false-positive result (enhanced-BET) by GCM when using LRW as diluting agent, but this was resolved using PBS instead. Enhanced-BET in ^{99m}Tc-HSA-nanocolloid, ^{99m}Tc-Sulfur-colloid and their cold kits were resolved by filtering with 0.22µm PES membrane filter before testing. Enhanced-BET in ^{131}I-Lipiodol, by GCM, was avoided by vigorous vortexing at 1:400 MVD in LRW. KCM did not exhibit any difference in BET values (Recovery Positive Product Control < 200%) on using either LRW or PBS. KCM could not be performed on colloid-RPs or their cold kits. CONCLUSIONS: Radiolabeled compounds and cold kits with high cation concentration can cause unusual aggregation resulting in a pseudo-coagulation reaction due to disruption of ionic bonds between divalent cations and PO_4^{3-} moiety of lipo-polysaccharide (LPS). Hence, PBS prevents this in GCM assay. We were successful in overcoming the enhanced-BET seen in GCM-BET assays for the above mentioned radiopharmaceuticals and cold kits having interfering cationic salt concentrations, using PBS for dilution. Enhanced-BET observed with RPs having fatty acids and colloids was successfully taken care of after increasing the dilution and filtering the product respectively before the assay. Enhanced-BET was not observed with KCM as the assay is based on absorbance of released chromophore. However, KCM is not recommended to replace GCM for pharmaceuticals (including RPs) where interference in the latter method is observed.

(iv) Automated Synthesis of Pharmaceutical Grade [^{18}F]FLT using 5'-O-(Benzoyl)-2,3'- anhydrothymidine Precursor

Highlights: This particular method of producing [^{18}F] FLT using 5'-O-(Benzoyl)-2, 3'anhydrothymidine precursor has been approved by Radiopharmaceuticals Committee, DAE. Clinical trials has been started at RMC, BARC.

Automated production of pharmaceutical grade [^{18}F] FLT with solid phase extraction (SPE) purification using 5'-O-(Benzoyl)-2, 3'anhydrothymidine precursor poses a major challenge. The present study is focused on an automated one-pot, two-step radiochemical synthesis of pharmaceutical grade [^{18}F] FLT using Benzoyl. The optimization of SPE purification using a combination of SepPak® cartridges while maintaining radiochemical purity (RCP), chemical purity (CP) and residual solvent levels (RSL) within the specified limits has been the significant achievement. The current method yields clinical grade [^{18}F] FLT, suitable for inclusion as a generic drug product in Indian Pharmacopeia.

[^{18}F]- trapped on an anion exchanger, eluted with 75mM tetrabutyl ammonium bicarbonate. Benzoyl in DMSO was heated to 170°C for 15 min. After base hydrolysis (0.25N NaOH, 65°C, 15 min), reaction mixture passed through SepPak® cartridges (using neutral alumina oxide (Alox-N) →cation exchanger→anion exchanger→ Alox-N→C18) followed by aqueous ethanol wash. Finally, [^{18}F] FLT eluted with 5% aqueous ethanol, while pH and isotonicity were maintained using NaCl and NaH_2PO_4. RCP and CP checked by HPLC using C18-RP column (300 mm L x 4 mm od, 5 µm). Flow rate maintained at 1mL/min in Water/Ethanol 93/7 at isocratic mode. Silica-gel TLC performed using Acetonitrile/Water 95/5 and Ethylacetate/Heptane 2/1. RSL detected by gas chromatography.

Using FXF-N module, a fully automated synthesis of [^{18}F] FLT with only SepPak® purification using Benzoyl precursor with total synthesis time of 55+5 min is achieved. RCP and CP of the [^{18}F] FLT were >98% and >97% (<1.2 µg/ml in terms of concentration) respectively, as evaluated by HPLC and TLC. The amount of acetone, acetonitrile and DMSO were <100ppm, whereas ethanol levels in the final product were 3900ppm. Retention time of [^{18}F] FLT is 10.5 minutes, confirmed with reference standard [^{19}F] FLT. [^{18}F] FLT obtained as a clear and colorless product having pH~6.5 with Rf 0.85 and 0.20 in two different mobile phases. Decay un-corrected radiochemical yield was 3% (n=14).

The synthesis of pharmaceutical grade [^{18}F] FLT by nucleophilic fluorination of benzoyl in a fully automated process and subsequent purification via-use of a combination of different SepPak® cartridges were achieved. Impurities levels in [^{18}F] FLT produced by this method were within specified limits defined by Cancer Imaging Programme, NIH, USA for considering the product as generic drug.

(v) Process for Making Sterile Pyrogen free Evacuated Clear Colorless Glass Vials – Used in Radiopharmaceuticals Production

Highlights: The technology for this particular process of making sterile pyrogen free evacuated clear colorless glass vials has been transferred to RPL, BRIT Vashi in 91st BMC Meeting (MOM of 91st meeting of BRIT Management Committee, Dated: 02/06/2017) The particular item will be a product from BRIT, Vashi. The costing of this product is under progress.

Rationale: Producing sterile, pyrogen free, evacuated colorless glass vials plays critical role in the production of generator based radiopharmaceuticals (RPs) and dispensing PET RPs in closed lead shielded automated dispenser. In this study we have developed a process for making sterile, pyrogen free ready to use USP type-I glass vials without any gamma ray (γ), electron beam (EB) or ethylene oxide (EO) sterilization after evacuation in lyophilizer. Methodology: USP type-I glass vials washed, rinsed (ultrapure water), dried, wrapped (25µm Al foil) and depyrogenated (250°C 1hr) inside hot air oven. Aseptically inside clean room (Class 100) bromobutyl rubber closure (γ-irradiated) were placed on vials mouth with depyrogenated forceps. Vials loaded in lyophilizer with shelf and ice condenser temperature preset at -10°C and -55°C respectively. Pressure brought down by maintaining vacuum between 0.1-0.5mbar for 45 minutes, simultaneously the shelf temperature increased to +10°C to extract vapour from vacuum. Autosealed under vacuum and was aerated using sterile PTFE filter.

Vacuumed vials crimped and tested for vacuum integrity by glow discharge method. In accordance with USP/IP, 10% of batch size was tested for sterility, apyrogenecity (Gel-clot) and acidity/alkalinity (bromothymol-blue titration). Key Results: All 18,000 evacuated vials produced by in-house developed method complies sterility and pH, while endotoxin limit is <0.06 EU/ml without any γ, EB or EO treatment. Produced vials internal vacuum <0.5 mbar with 1% rejections. Research Highlights: We could successfully use these in-housed produced sterile, pyrogen free, evacuated clear colorless glass vials for automated dispensing and elution of radiopharmaceuticals at our facility

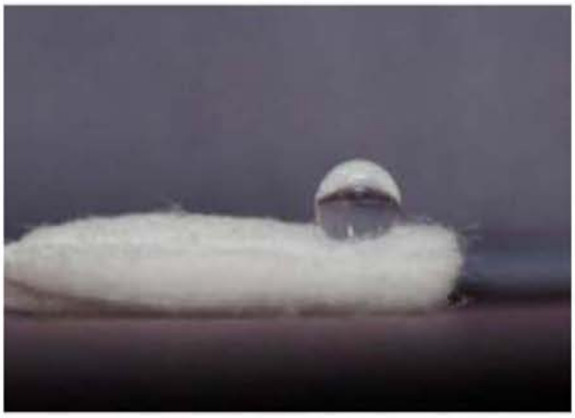
J. Development work carried out at Electron Beam Processing Services, BRIT

An Industrial type 5MeV, 15kW ILU-EB Accelerator Facility is operated regularly for R&D applications and commercial irradiation. We are highlighting here some recent activities, which will give the flavor of our line of activities. Recently, we have done some commercial irradiation as below.

5MeV Industrial Electron Beam Accelerator at Vashi Complex

- Development of New Materials: The electron beam accelerator is being used for research and development purpose in materials science with main emphasis on polymers. These researches involve development of materials for industrial, environmental and social benefits. For instance we have developed an biodegradable multifunctional superabsorbent through molecular scale engineering (topography and surface energy) by electron beam radiation shown in below figure. This separates oil and low surface energy toxic liquids from aqueous media. This can work at high temperature, in acidic, alkaline and neutral media. It can separate oily substance from immiscible as well as emulsions. The material can be used for multiple times.

Scan Horn and Product Conveyor



Cotton for Oil water separation

- Sterilization of medical products: Electron beam is used for sterilization of single-use medical supplies like syringes, implants, catheters, IV sets, surgical gloves, and gauze. It is also ideal for the elimination of organisms from pharmaceuticals such as ointments and solutions, and sterilization of tissue/biological based products. Some of the medical products irradiated at our facility are surgical items, dressings, petri dishes, etc. in packages as shown in below figures.

Petri Dishes

Bottles from Isomed

- Irradiation of Food products: Electron beam irradiation is used to preserve food, reduce the risk of food borne illness, prevent the spread of invasive pests, and delay or eliminate sprouting or ripening. Some of the food products irradiated at our facilities are coriander and mint leaves, spices and fish and meat products for reducing microbial load and to increase storage time in refrigerator temperature instead of frozen temperature.

Fish samples

Spice samples irradiation

Prawns under EB treatment

- Quality assurance and Quality control: Calibrated Cellulose Triacetate (CTA) and B3 dosimeters were used for the dose measurements. The calibration of the dosimeters was carried out by irradiating the dosimeters together with transfer-standard dosimeters (alanine) directly under the electron beam at the facility. Calibrations used in this study are directly traceable to the calibration facility at the Radiation Safety Systems Division (RSSD) of Bhabha Atomic Research Center (BARC), which maintains Indian national radiation standards for high doses.

Table. 1. Prospects for industrial utilization

Product Semi Industrial scale & R&D	Irradiation Purpose	Advantage	Process thickness	Possible throughput @9kW power
Dry powders, ereals, grain etc.	Shelf - life extension	Disinfection	~3cm unit density	2 ton/hr @0.5KGy
Frozen foods fish, meat, prans marine products	Shelf- life extension	Increased storage temp. (@chilled temp.)	Retail packets	200kg/hr @3.0kGy
Medical products	Sterilization	Sterilization	Retail packets	25-30 kGy
Plastic products, O-rings, HS components etc	Cross linking	High temp. & tensile resistance	0.6" unit density	~30000 O-rings/hr @200 KGy

CHAPTER 4

Human Resources Development Activities of BRIT


professionally
Writing Research Paper


Accept the challenges so that you can feel the exhilaration of victory.
George S. Patton

Training Imparted/Lectures given/attended Workshops and/or Seminars / Conferences

1. Dr Anupam Mathur of Radiopharmaceuticals Programme,attended a Symposium at IAEA, Vienna where the theme of meet was" ^{99}Mo (Molybdenum), Current Status and Future availability worldwide " and he presented " Current ^{99}Mo Production and Supply Status and its Availability in India ".

2. Dr (Smt) Jain Reji George was involved in coordinating the first ever Certification Training Course on' Radiation Processing Facilities (Gamma and Electron Beam) for Food, Healthcare & Allied Products' which was conducted at BRIT for Radiation Safety Officer (RSO) Course (organized by RPAD, BARC) during September 8, 2017 to September 27, 2017. In another, in-plant Training Course for Operators for Gamma and Electron Beam Irradiation Facilities was also conducted at BRIT during February 19 to March 14, 2018. This was also coordinated by Dr (Smt) Jain Reji George. Lectures cum demonstration were given by Scientific Officers from Radiation Physics Group, Calibration Services, Electron Beam Services and Radiation Processing Plant, Vashi Complex. Dr (Smt) Jain Reji George imparted lecture on 'Evaluation of an Irradiator facility' to RSO trainees while delivered a lecture on ' Overview of Radiation Processing Facilities' to Operator trainees. Smt. Raksha Rajput was involved in delivering a lecture on'Activities of BRIT.' Lectures on' Design aspects of Gamma Irradiators', 'Management of Radiation Processing Plants', 'Radiation Safety' and' Dosimetry' were delivered by the Officers of Radiation Processing Plant, namely, Shri Ranjit Singh, Shri Atul Tyagi, Shri Rahul Kharat and Kum. Kalpana Khedkar respectively. Shri S.B. Kamble of Calibration Services Group was involved in delivering a lecture cum demonstration about' Calibration of Survey Meters & Pocket Dosimeters'.

3. Dr. Anupam Mathur and Dr. Kiran Mehra imparted lectures related to Radiopharmaceutical Production whereas lecture on' Brachytherapy Sources' was delivered by Dr (Smt) Jain Regi George, Radiation Physics Group, to 56th Batch of Trainees of Diploma in Radiation Physics (DRP).

4. Dr. Geetha Rajagopalan co-ordinated Training Programme for DRM/DMRIT students, delivered a lecture on' General Principles of Radiopharmaceuticals' and conducted BRIT tour. Shri V.V. Murhekar presented a talk on' Quality Assurance of Radiopharmaceuticals' ,' Quality Control Analysis of I-131 Sodium Iodide Solution and Sm-153 EDTMP' while Shri P.B. Dodke demonstrated' Quality Control Analysis of of I-131 Sodium Iodide Solution' to DRM/DMRIT Students during their visit to BRIT.

5. Dr. Geetha Rajgopalan co-ordinated a Training Programme for students of K.M. Kundanani College of Pharmacy, Mumbai, conducted a visit to all the facilities of BRIT and presented a lecture on' BRIT Facilities' and' Radioimmunoassay'.

6. Dr. Tarveen Karir delivered an Invited Talk on' Nuclear Medicine' at National Conference on Radiation Physics (NCRP) organized at Department of Physics, Bengaluru University, Bengaluru, during November 2017.

7. Shri. Pannalal, Smt. Raksha Rajput, Dr. Yojana Singh, Dr. Tarveen Karir, and Shri. Navin Sakhare attended' Vaigyanik Sangoshdhi', Scientific Seminar in Hindi which was organized jointly by BARC and Town Official Language Implementation Committee (TOLIC), where, Dr. Anupam Mathur had delivered a talk on' Radiopharmaceuticals' in Hindi during March 2018. He has also extended lectures on' Radiopharmaceuticals Production and Supply' in Hindi at Atomic Energy Regulatory Board (AERB) and Heavy Water Board (HWB), Mumbai. Dr. Kiran Mehra from Radiopharmaceutical Programme, Vashi Complex had attended Hindi Workshop at AERB,

8. Shri. Soumen Das delivered a lecture on' Production and Application of Radioisotopes in Healthcare' and Practicals were demonstrated on' Elution of COLTECH Generator, Formulation of

Radiopharmaceuticals and its Quality Control Analyses' at IANCAS Workshop conducted at Guru Ghasidas University, Bilaspur, Chattisgarh.

9. A Technical Report Publication is released by Internation Atomic Energy Agency (IAEA) on' Cyclotron production of Tc-99m and development of a new method of separation of ^{99}mTcO4 – from the irradiated molybdenum target' and the authors to this report are Malay Kanti Das, Madhusmita, Sankha Chattopadhyay, Sujata Saha Das, Md. Nayer Alam, Luna Barua, Anirben De, Umesh Kumar, Siddharta Datta in' Cyclotron Based Production of Technetium-99m; IAEA Radioisotopes and Radiopharmaceuticals Report No. 2; English STI/PUB/1743; (ISBN: 978-92-0-102916-4) in June 2017.

10. IAEA has released a Book on' Cyclotron Based Production of Technetium-99m' which shares the authorship with Sankha Chattopadhyay, RCR, Kolkata. http://www-pub.iaea.org/books/IAEABooks/10990/Cyclotron-Based-Production-of-Technetium-99m; English STI/PUB/1743; (ISBN: 978-92-0-102916-4); 59 pp; 48 Figures; Published in June 2017.

11. Shri Ronnie Adhiraj Ghosh, MIG, has authored an article," Role of Atoms in Human Life" and Published in "Science Horizon", Odisha Bigyan Academy, Vol 3, Issue 2, February 2018. In another HRD related activity, he along with other Senior Scientists of Radiopharmaceuticals Programme, namely, Dr. Kiran Mehra, Dr. Shubhangi Mirapurkar, Dr. Sangeeta Joshi, Dr. Yojana Singh were appointed as Judges at CBSE Regional Science Exhibition 2017-18 held in January 2018 held at Jaipriar School, Navi Mumbai.

12. Shri. Ronnie Adhiraj Ghosh, MIG, attended Training Course on "Design & Evaluation of Physical Protection System for Nuclear Material and Nuclear Facilities" at CTCRS, Anushaktinagar during November 2017.

13. Shri. Ronie Adhiraaj Ghosh, MIG, has guided an Engineering student of Sardar Patel Institute of Technology, Andheri, Mumbai for the Project entitled' Thermocouple Based Temperature Sensor with Integrated 4-20mA Current Loop'.

14. Shri. N. Jayachandran attended the NIAS-DST Training Programme on 'Policy for Science and Science for Policies' organized by National Institute for Advanced Studies' Bangalore during January 01-05, 2018.

15. Smt. Preethi P. Nair participated in the workshop on' Prevention of sexual harassment (Laws)' conducted by Administrative Training Institute, Mumbai, Vikram Bhawan, Mumbai.

16. Poster presentation on' Performance evaluation of an indigenous kit for the preparation of ^{99m}Tc-Macroaggregated Albumin (^{99m}Tc-MAA) injection for lung perfusion imaging' and' Development of an *in-vitro* technique of ^{99m}Tc-ECD kit' were presented by Smt. Archana S. Ghodke in 49th Annual Conference of Society of Nuclear Medicine-India (SNMICON) during December 2017 held at Delhi.

17. Paper presentation on' Synthesis and cell uptake studies of novel ^{99m}Tc analogues of I-mIBG prepared via $^{99m}Tc(CO)_3$ synthon for targetting nor epinephrine transporter' and' Synthesis and evaluation of novel $^{99m}Tc(CO)_3$-fatty acid derivatives prepared via' click chemistry' route as metabolic cardiac tracer" were presented by Shri. Navin Sakhare in 49th Annual Conference of Society of Nuclear Medicine-India (SNMICON) during December 2017 held at Delhi.

18. 'Conceptual development of an Irradiator for cross-linking of cables using Co-60 gamma rays' was presented by Dr. (Smt.) Jain Reji George in ICARST-2017 during April 2017 at IAEA, Vienna.

19. 'A study on the feasibility of using waste canisters for sewage processing' was presented by Dr (Smt.) Jain Reji George and' Radiological safety of decayed source removal facility (DSRF) – an Overview' was presented by Smt. Raksha Rajput at the Conference of Indian Association of Radiation Protection (IARPIC-2018) during January 2018.

20. 'Feasibility of using Cs-137 in Gamma Irradiators for Food Processing' was presented by Dr (Smt.) Jain Reji George in the Conference of National Association of Applied Radiation in Industries (NICSTAR-2018) during March 2018.

21. 'A new, portable solvent extraction based ^{99}Mo-^{99m}Tc generator utilizing (n,γ) ^{99}Mo in Sodium Chloride solution for hospital radiopharmacy'. Scientific work was presented by Dr Sankha Chattopadhyay, RCR, Kolkata, in the 49th Annual Conference of Society of Nuclear Medicine, India (SNMICON – 2017) at Delhi during December 2017.

22. Shri. Milind Kumbhare, Microbiology Section of Radiation Processing Plant, Vashi Complex was involved in giving guidance to two M.Sc. Part-II students from the Institute of Science, Mumbai for the research projects, ' Microbiological assessment and establishment of radiation sterilization dose for Tubal ring' and' Microbiological assessment and establishment of radiation sterilization dose for Copper-T'.

23. 'Investigation of radiation resistant bacteria from irradiation cell pool water of Type IV gamma irradiator'. This research paper was presented as poster presentation at the Conference of National Association of Applied Radiation in Industries (NICSTAR-2018) during March 2018.

24. Dr. Yojana Singh represented BRIT for Science and Technology Exhibition held at the Parliment, New Delhi, durting July 28, 2017 to August 14, 2017. She also attended DAE-Journalist meet at Kalpakam, Chennai, during March 2018. She briefed and demonstrated about BRIT activities to the visitors of the occassions.

25. Shri Hukum Singh, RSO, RC, Delhi, was involved in giving lectures, (a) Radio Isotopes Generators, (b) Radioactive Waste Management for Nuclear Fuel Cycle Facilities and (c) Basic Concepts on Radiation Protection and Regulatory Dose Limits, to the students of INMAS (Academic Programme) during October 2017 and to the students of Indian Naval Officers, visiting INMAS for training on'Handling Nuclear Emergency in Medical Applications'during April and December 2017.

26. An Invited talk on' Radioisotope Applications in Healthcare' was delivered by Dr (Smt) Tenna Goel, Regional Centre, Delhi, in Marie Curie Sesquicentennial Conference (MCSC) at Jawaharlal Nehru University (JNU), New Delhi during November 2017.

27. The research work carried out at Radiopharmaceuticals Programme, BRIT, by Smt. Shalaka Paradkar, Dr. Anupam Mathur and Shri S.S. Sachdev, on "The study of the effect of Methotrexate (MTX) in the form of I-125 labelled MTX trapped deformable liposomes through transdermal delivery system for the treatment of Rheumatoid Arthritis in order to achieve its sustained delivery and reduced system toxicity" was published in Maharashtra Times, Dated 3rd February 2018 under the column, 'Shodhavishkar'.

Publications in Peer Reviwed Journals

1. Bulk scale formulation of therapeutic doses of clinical grade ready-to-use ^{177}Lu-DOTA-TATE: The intricate aspects.

   Mathur Anupam, Prashant Vrinda, Sakhare Navin, Chakraborty Sudipta, Vimalnath K.V., Repaka Krishnamohan, Arjun Chanda, Karkhanis Barkha, Seshan Ravi, Basu Sandip, Korde Aruna, Banerjee Sharmila, Dash Ashutosh and Sachdev Satbir Singh

   Cancer Biotherapy and Radiopharmaceuticals 32/7 **(2017)** 266-273.

2. Improved method for preparing Ni(II) complex of (S)-Tyrosine Sciff base and its use in the automated synthesis of O-(2'-[F-18]Fluoroethyl)-L-Tyrosine [FET] using solid phase extraction purification.

   N. Lakshminarayan, Amit Kumar, Sushant Roy, Yogita Pawar, Pradip Chaudhari, M.G.R. Rajan

   Appl. Rad. & Isotop. 127 **(2017)** 122-129.

3. Radiochemical studies, pre-clinical evaluation of ^{170}Tm-EDTMP prepared using in-house freeze-dried EDTMP kit.

   Tapas Das, Ajit Shinto, Koramadai K. Kamaleshwaran, Haladhar D. Sarma, Sahilram Khan Mohammed, Arpit Mitra, Sangita Lad, M.G.R. Rajan, Sharmila Banerjee

   App. Radiat. & Isot. 122 **(2017)** 7-13.

4. Radioactive ion beams of ^{111}In using ECR plasma sputtering method.

   Vaishali Naik, Mahua Bhattacharjee, D. Lavanya Kumar, Prasanta Karmakar, Satyendra Das, Debashis Banerjee, Sankha Chattopadhyay, Luna Barua, Sujata Das, Asit Pal, Arup Bandopadhyay and Alok Chakrabarti

   Review of Scientific Instruments 88 **(2017)** 063308.

5. Production and radiochemical separation of a potential immune-PET imaging agent ^{89}Zr from proton irradiated natY target.

   Sujata Sha Das, Sankha Chattopadhyay, Luna Barua, Md. Nayer Alam, Madhusmita, Umesh Kumar

   Jour. Radioanal. Nucl. Chem. 313/3 **(2017)** 641-645.

6. Preparation of ^{99}Mo/^{99m}Tc generator based on cross-linked chitosan polymer using low specific activity (n,γ)^{99}Mo.

   Chattopadhyay, S., Das, S.S., Alam, M.N., Madhusmita

   Jour. Radioanal. Nucl. Chem. 313/3 **(2017)** 647-657.

Abstract Publication

1. Conceptual Development of an Irradiator for Cross-linking of Cables using Co-60 gamma rays.
   Jain Regi George, B.K. Pathak, K.S.S. Sarma, A.K. Kohli
   Book of Abstracts of International Conference on Applications of Radiation Science and Technology **(ICARST-2017)** pp-320.

2. A Study on the Feasibility of using Waste Canisters for Sewage Processing.
   Jain Regi George, Raksha Rajput, B.K. Pathak
   Book of Abstracts of International Conference of Indian Association of Radiation Protection **(IARPIC-2018)** pp-08.

3. Radiological Safety of Decayed Source Removal Facility (DSRF)-An Overview.
   Raksha Rajput, Jain Regi George, B.K. Pathak
   Book of Abstracts of International Conference of Indian Association of Radiation Protection **(IARPIC-2018)** pp-09.

4. Feasibility of Using Cs-137 in Gamma Irradiators for Food Processing.
   Jain Regi George, B.K. Pathak
   Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 49; pp-79.

5. Neutral Technetium-99m analog of meta-iodibenzylguanidine prepared via Technetium-99m $(CO)_3$ synthon for potential imaging of neuroendocrine tumors.
   Navin Sakhare, Soumen Das, Anupam Mathur, Madhava B. Mallia, Shubhangi Mirapurkar, M. Sheela, H.D. Sarma, S.S. Sachdev, A. Dash
   IJNM 32 **(2017)** OP 31: 093227; pp-S14.

6. Synthesis and evaluation of novel Technetium-99m$(CO)_3^-$Fatty acid derivatives prepared via "Click Chemistry" route as metabolic cardiac tracers.
   Soumen Das, Anupam Mathur, Navin Sakhare, Vishwas Murhekar, Madhava B. Malia, H.D. Sarma, S.S. Sachdev, A. Dash
   IJNM 32 **(2017)** OP 34: 094847; pp-S15.

7. A new, portable solvent extraction-based Molybdenum-99/Technetium-99m generator utilizing (n,γ) Molybdenum-99 in Sodium Chloride solution for hospital radiopharmacy.
   Sankha Chattopadhyay, Sujata Saha Das, Madhusmita, Umesh Kumar, Luna Barua, Asit Kumar Pal, Md. Nayer Alam, Arup Hudait, Sharmila Banerjee
   IJNM 32 **(2017)** OP 38: 131323; pp-S17.

8. Evaluation of viability of microorganisms in ^{68}Ga-, ^{18}F-, ^{99m}Tc- and ^{177}Lu-labelled radiopharmaceuticals.
   Arpit Mitra, Sangita Lad, Sharmila Banerjee, Savita Kulkarni
   IJNM 32 **(2017)** OP 56: 211242; PP-S25.

9. Radiolabelling and biological evaluation of ^{68}Ga-NOTA-Ubiquicidine fragment for prospective infection imaging.
   Archana Mukherjee, Jyotsna Bhatt, Aruna Korde, Haladhar Dev Sarma, Krishnamohan Repaka, Ashutosh Dash
   IJNM 32 **(2017)** OP 62: 172453; pp-S27.

10. Development of an *in-vitro* technique for assessing the biological behaviour of Technetium-99m-Ethylene Cysteine dimer.
    Soumen Das, Preethi Nair, Anupam Mathur, R. Vanaja, S.S. Sachdev
    IJNM 32 **(2017)** PP 25: 101452; pp-S43.

11. Process for making sterile evacuated clear colourless glass vials: Used in radiopharmaceuticals production.
    Arpit Mitra, Sangita Lad, Savita Kulkarni, M.G.R. Rajan, Sharmila Banerjee
    IJNM 32 **(2017)** PP 26: 191544; pp-S43.

12. Rapid physicochemical and biological quality control tests for Technetium-99m radiopharmaceuticals: Adapting at nuclear pharmacy.
    Sangita Lad, Arpit Mitra, H.H. Shimpi, Sharmila Banerjee, Savita Kulkarni
    IJNM 32 **(2017)** PP 29: 205158; pp-S44.

13. Performance evaluation of an indigenous kit for Technetium-99m-Macroaggregated Albumin for lung perfusion imaging
    Archana S. Ghodke, Uma Sheri Kumar, R. Krishnamohan, Seema, Neelam Singh Pilkhwal, R. Vanaja, S.S. Sachdev, A.C. Dey
    IJNM 32 **(2017)** PP 30: 162500; pp S44-S45.

14. Continuous quality control of the ITG ^{68}Ge/ ^{68}Ga generator and production of ^{68}Ga-DOTA-TATE and ^{68}Ga-PSMA-HBED-CC for clinical studies.
    Ashok R. Chandak, Hemant H. Shimpi, Shrinibas Nayak, Geeta Sonawane, Swapna Nabar, Somnath Kar, Sangeeta Lad, Sudeep Sahoo, Sharmila Banerjee
    IJNM 32 **(2017)** PP 37: 115437; pp 47.

15. Automated synthesis of clinical grade [^{68}Ga]-Prostate Specific Membrane Antigen-11 for use in Prostate Cancer patients in Radiation Medicine Centre.
    Shrinibas Nayak, Amit Kumar, Sharmila Banerjee
    IJNM 32 **(2017)** PP 38: 152502; pp S47-S48.

16. Evaluation of biodistribution of fractionated MIBI kit (TCK 50).
    Sutapa Rakshit, Ashok R. Chandak, H.H. Shimpi, Yogita Pawar, Nawab Singh Baghel, Sharmila. Banerjee
    IJNM 32 **(2017)** PP 39: 120018; pp S48.

17. Radiolabelling, stability and in-vitro evaluation of ^{99m}Tc-HYNIC-AE105 for tumor imaging.
    V.V. Murhekar, Shalaka Paradkar, Anupam Mathur, B.L. Malpani, D. Padmanabhan, A.G. Korde
    IJNM 32 **(2017)** PP 41: 214123; pp S48-S49.

18. Application of consistency approach and radio-HPLC to reduce animal usage in radiopharmaceutical ^{99m}Tc-Mebrofenin potency testing.
    R. Krishna Mohan, V.V. Murhekar, B. Sanjeev Kumar, P.Neelam, D. Padmanabhan, Aruna Korde
    Abstract Published in the 8th International Conference of Laboratory Animal Scientists Association (LASA) Proceedings, **(2017)** pp 61.

19. Synthesis of [F-18] Fluoropropyl-S-Tyrosine (FPT) via Ni (II) complex of Chiral Schiff's base with tyrosine precursor.
    Lakshminarayanan, N., M.G.R. Rajan, Sharmila Banerjee
    Abstract Published in the 13th DAE-BRNS Nuclear and Radiochemistry Symposium Proceedings, F-17 **(2017)** pp 502-503.

20. Production and radiochemical separation of a separation of a potential imaging agent ^{89}Zr from proton irradiated ^{nat}Y target.

    Sujata Saha Das, Sankha Chattopadhyay, Luna Barua, Md. Nayer Alam, Madhusmita Umesh Kumar

    Abstract Published in the 13th DAE-BRNS Nuclear and Radiochemistry Symposium Proceedings, F-11 **(2017)** pp 490-491.

21. Preparation of ^{99}Mo/ ^{99m}Tc generator based on cross-linked chitosan polymer using low-specific activity (n,γ) ^{99}Mo.

    Sankha Chattopadhyay, Sujata Saha Das, Md. Nayer Alam, Madhusmita Umesh Kumar

    Abstract Published in the 13th DAE-BRNS Nuclear and Radiochemistry Symposium Proceedings, F-12 **(2017)** pp 492-493.

22. Production of ^{43}Sc, a promising PET imaging isotope from $^{nat}CaCo_3$.

    Sankha Chattopadhyay, Luna Barua, Sujata Saha Das, Madhusmita Umesh Kumar, Md. Nayer Alam, Asit Pal

    Abstract Published in the 13th DAE-BRNS Nuclear and Radiochemistry Symposium Proceedings, F-13 **(2017)** pp 494-495.

23. Design and Development of ISOTRAIN (Irradiator Simulator for Operational Training in Animated Environment).

    Amit Shrivastava

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 8; pp-22.

24. Design and Development of ISODIMM (Interactive Software of Drawing Interfaced Maintenance Management).

    Amit Shrivastava

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 9; pp-23.

25. Investigation of Radiation Resistant Bacteria from Irradiation Cell Pool Water of Type IV Gamma Irradiator.

    Milind Kumbhare, Pooja Shukla, Ranjeet Singh, Piyush Srivastava

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 12; pp-26.

26. Development of New Formulation of $Na^{131}I$ for Parenteral Applications.

    Sundilla Saraiah, A. Thulasidhasan, Anand Gaurav, Richa Tiwary, Kiran S. Mehra, Ravi Seshan, A.C. Dey, S.S. Sachdev

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 33; pp-57.

27. Prostate Cancer Management using ^{68}Ga-PSMA-11 and ^{177}Lu-PSMA-617 as Theranostic Pairs.

    Hemant H. Shimpi, Shrinibas Nayak, Sandeep Basu, Geeta Sonawane, Swapna Nabar, Somnath Kar, Sangeeta Lad, Ashok Chandak, Sudeep Sahoo, Sharmila Banerjee

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 38; pp-62.

28. Production of ^{68}Ga-DOTA-TATE and ^{68}Ga-PSMA-11 by using ITG ^{68}Ge/ ^{68}Ga Generator: Validation in Eckert and Ziegler System.

    Hemant H. Shimpi, Shrinibas Nayak, Ashok Chandak, Geeta Sonawane, Swapna Nabar, Somnath Kar, Sangeeta Lad, Sudeep Sahoo, Sharmila Banerjee

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 39; pp-63.

29. Technetium-99m Labelled Stealth Liposomes: A New Strategy to Identify Metastasis in Tumor Model.

    Swapna Nabar, Tanuja Shet, Manohar Adwankar, Basant Malpani, Sharmila Banerjee, R. Vanaja, Puthusserickal Hassan, Ganeshsunder Nadkarni, A.M. Samuel

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 40; pp-64.

30. Atomic Panaroma: Canvassing the power of Nuclear Medicine and Molecular Imaging in Field of Health Care.

    Yojana Singh

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 42; pp-66.

31. Radiosynthesis and Quality Control of ^{68}Ga-Citrate.

    Swati Satankar, Ashok Chandak, Sharmila Banerjee

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 43; pp-67.

32. Measurement of Radionuclidic Purity of ^{99m}Tc Produced via ^{100}Mo(p,2n)^{99m}Tc.

    A. Gopalkrishna, S.V. Suryanarayana, B.K. Nayak, H. Naik, E.T. Mirgulae, D. Sarkar, S.C. Sharma, Kamaldeep, P. Maletha, S. Banerjee, A. Saxena

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 44; pp-68.

33. Radioimmunoassay (RIA) Procedures for Triiodothyronine (T_3) and Thyroxine (T_4) based on Novel Micro-magnetizable Cellulose Particles containing Manganese Ferrite Core.

    Shripriya Purohit, V.B. Kadwad, S.S. Sachdev, K.B. Shenoy, H.M. Somashekarappa

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 46; pp-70.

34. COCAM-120: A Cobalt based Industrial Radiography Device.

    D.K. Sahoo, M.K. Sharma, Mukhar Sharma, P. Srivastava, A.K. Kohli, G. Ganesh

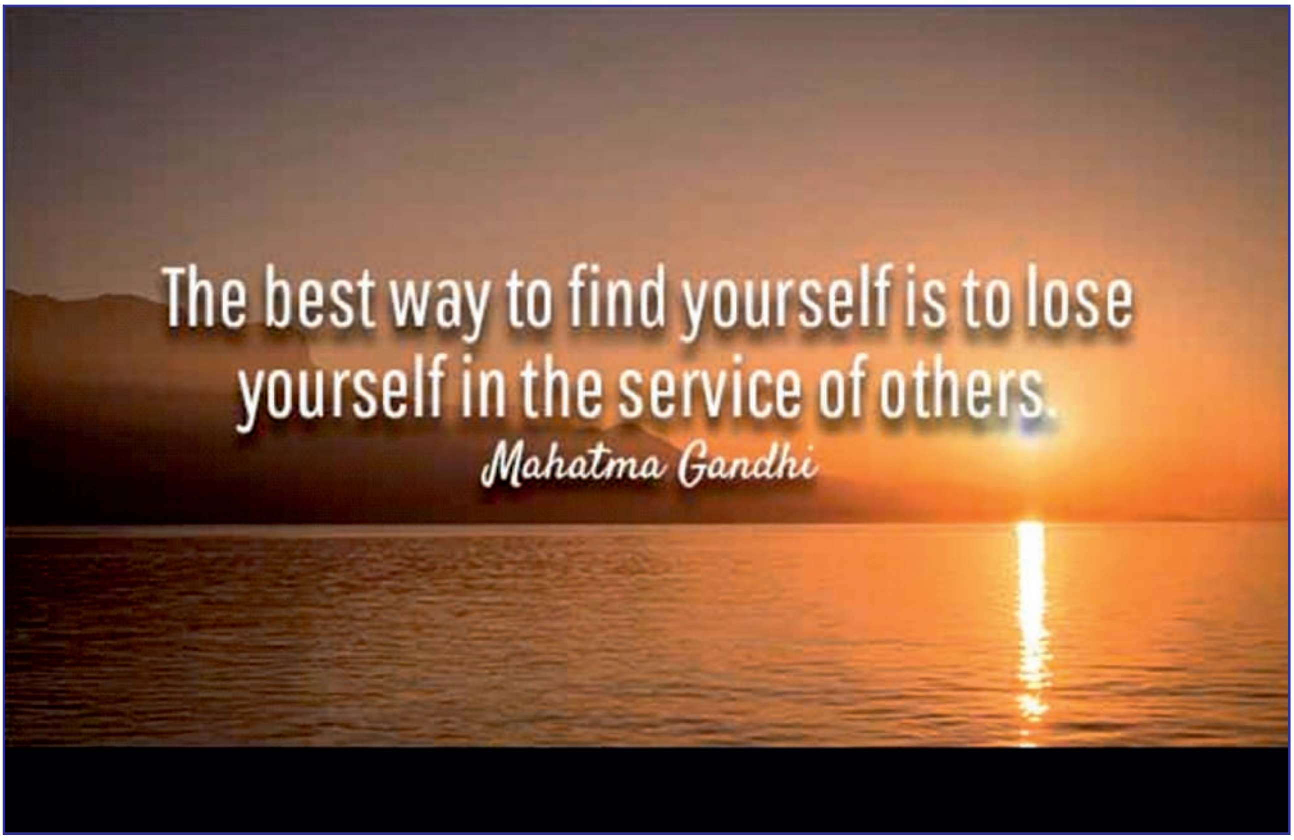
    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 70; pp-106.

35. Safety Aspects of Newly Developed Type-A Package for Iodine-131 Radioactivity Transportation.

    Rohit Kamble, Gundekar, A.S., Pradip S. Bagde, Saraya Sundilla, Chetan Kothalkar, A.S. Chindarkar, S.V. Chavan, D.K. Sawant, A.C. Dey, S.S. Sachdev

    Souvenir of NAARI International Conference on Advanced Applications of Radiation Technology **(NICSTAR-2018)** P 33; pp-57.


A strong, positive self-image is the best possible preparation for success.
Joyce Brothers


The best way to find yourself is to lose yourself in the service of others.
Mahatma Gandhi

External view of the I-125 Seed Plant at BRIT, Vashi Complex

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Compiled, Edited and Published by
Dr. Tarveen Karir
Manager, Scientific Information Resources & Publications,
Corporate Planning Division,
Board of Radiation & Isotope Technology, DAE

Printed by
M/S Raj Printers
Wadala, Mumbai