BOARD OF RADIATION & ISOTOPE TECHNOLOGY (BRIT)

DEPARTMENT OF ATOMIC ENERGY

सत्यमेव जयते

GOVERNMENT OF INDIA

ANNUAL REPORT

2021-2022

GOVERNMENT OF INDIA

DEPARTMENT OF ATOMIC ENERGY (DAE)

BOARD OF RADIATION & ISOTOPE TECHNOLOGY (BRIT)

ANNUAL REPORT 2021-2022

Front Page : Illustrations indicating various on-going activities of BRIT depicted under different Sections, within the Annual Report 2021-22.

Back Page : Logo's of Azadi Ka Amrit Mahotsav (AKAM) 2021-23

From the Desk of Chief Executive

Greetings!

BRIT Annual Reports are regularly being prepared to highlight the performances made during the Financial Year. This also enables to reach out the impactful information showcasing the steady progress to reach much larger reader community. As BRIT is involved in production, supply and marketing of Products and Services related with the applications of radioisotopes and radiation technology in various fields for societal benefits, bringing out the Annual Report issues helps in increasing the awareness concerning the benefits of such technologies, both within and outside the DAE fraternity.

The past year has been nothing short of extraordinary for BRIT. We have weathered unprecedented challenges with resilience, adaptability, and an unwavering commitment to our mission. Despite the uncertainties, our team remained steadfast in pursuing our vision of shaping a better future through ground-breaking advancements and transformative solutions.

Total Sales Performance for the Financial Year 2021-22 is Rs. 178.92 Crores, which depicts the highest ever turnover in the history of BRIT.

The success of BRIT can be attributed to the exceptional talent within our organization. Our brilliant minds, guided by a shared purpose, have embraced challenges as opportunities and turned dreams into reality. Their relentless pursuit of excellence has propelled us towards innovation, as we continue to push boundaries and explore uncharted territories in pursuit of an ever better future.

I extend my heartfelt gratitude to our valued customers, whose unwavering support and belief in our vision have been instrumental in our success. I also express my sincere appreciation to our dedicated employees, whose passion, determination, and ingenuity are the bedrock of our accomplishments. Together, we will navigate uncharted waters and unlock the immense potential that lies within.

As we present this annual report, I invite you to join us in celebrating the milestones we have achieved together. Let us take a moment to reflect on our journey thus far and the profound impact we have made. May it serve as a catalyst for renewed enthusiasm and embolden us to continue pushing boundaries, challenging norms, and transforming possibilities into realities.

Thank you for your unwavering support, and I look forward to an even more remarkable year ahead.

In service and gratitude,

Pradip Mukherjee
Chief Executive, BRIT

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CHAPTER 1

HIGHLIGHTS

2021-2022

Board of Radiation and Isotope Technology (BRIT), a unit of DAE, is focussed towards bringing the benefits of the use of radioisotope applications and radiation technology across industry, healthcare, research and agricultural sectors of society. BRIT has independently created a separate visible area of contribution by harnessing the spin-offs from the mainstream programmes of DAE, such as various Research and Development Programmes, viz. BARC, IGCAR, RRCAT etc. and the electricity-generating Nuclear Power Plants run by NPCIL.

Application of radioisotopes in healthcare, industry, agriculture and research is one of the most wide-spread peaceful uses of nuclear sciences. Realizing the significance of the use of the radioisotopes for societal benefits and national development, DAE has, over the years, built up adequate infrastructure facilities for the production and applications of radioisotopes by establishing BRIT as a separate unit on March 01, 1989, under the I&M Sector of DAE, primarily to commercialize the radiation technology and benefits of radioisotope applications developed by BARC/DAE, in the fields of healthcare, agriculture, research and industry for societal benefits. BRIT continues its endeavour towards service to mankind by meeting the demands of its myriad users in the fields of nuclear medicine, healthcare, engineering and radiation technology equipment for medical and industrial uses, radiation processing services, isotope applications and radioanalytical services.

The 33rd anniversary of BRIT Formation Day was celebrated on March 1, 2022. The occasion was graced by the presence of internationally renowned surgeon and oncologist, Padma Shri, Dr. Rajendra Badwe (Director, Tata Memorial Centre), as the Chief Guest. Dr. Badwe also inaugurated the New Security Entry Portal.

The other venerable guests included several scientists and engineers, all of whom have held leadership positions in BRIT in the past. The celebration commenced with the playing of an audio message from Dr. A.K. Mohanty (Chairman, BRIT Board and Director, BARC) which paid tribute to BRIT's stellar contribution to the nation in the realm of peaceful applications of radioisotopes and radiation technology. This was followed by the welcome address delivered by CE, BRIT, and an elaborate talk and presentation by Chief Guest, Dr. Rajendra Badwe, Director Tata Memorial Centre, on the increasing incidences of various types of Cancers in India and in the global context. He also emphasized on the role of antibody based newer radiopharmaceuticals to be developed for diagnosis and treatment to tackle these Cancers. The presentations given by the distinguished guests covered the spectrum of BRIT's entire history, since its inception. The inaugural talks were reminiscences and reflections about the manner in which BRIT came into existence three decades ago to fill the lacuna acutely felt then by the Nuclear Medicine fraternity and the culminating talks summarized BRIT's latest accomplishments including BRIT's successful foray into the area of ^{68}Ga- and ^{201}Tl- based PET radiopharmaceuticals and the successful completion of the Cyclone 30 and Fission Moly Projects. The programme ended with a vote of thanks delivered by GM (RPL & FMF, BRIT) followed by the playing of the National Anthem.

Chief Guest, Dr. R. Badwe, inaugurating the "New Security Entry Portal at BRIT" on March 01, 2022, 33rd Anniversary of BRIT Formation Day

Glimpses of Celebration of 33rd Anniversary of BRIT

A. Products

I. Healthcare

BRIT continued the production and supply of medical radioisotopes and ready-to-use radiopharmaceuticals to Nuclear Medicine (NM) centres all over India. It 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 radiochemical required for varied research purposes. **The sale of Radiopharmaceutical Products and Labelled Compound Products, during the Financial Year 2021-22, amounted to Rs. 51.9 Crores.**

(a) Radiopharmaceuticals Production (RPhP), Vashi

Radiopharmaceuticals are *in-vivo* products, used for diagnostic and therapeutic purposes in NM Departments, and are hence made in compliance with strict Good Manufacturing Practices (GMP) specifications. In recent times, Positron Emitting Tomography (PET) has emerged as a powerful imaging modality which provides *in vivo* visualization of molecular processes. ^{18}F-FDG is currently the most widely used PET radiopharmaceutical in clinical oncology and it also finds wide application in clinical cardiology and neurology. There is a growing importance of PET diagnostics in the field of molecular imaging since a large number of cancer markers are now amenable to labelling with PET isotopes. Radio-Immuno-Assay (RIA) and Immuno-Radio-Metric-Assay (IRMA) Kits are used for *in-vitro* quantification of various hormones, whereas ^{14}C-Urea capsules are of diagnostic use in cases of *Helicobacter pylori* infections. Regular, uninterrupted, production and supply of these radiopharmaceuticals, to users all over India, was continued during the year. RPhP also made efforts to improve its pipeline of new products by introducing novel radiopharmaceuticals based on ^{99m}Tc, ^{177}Lu, ^{68}Ga and ^{188}Re radiopharmaceuticals.

- BRIT continued the regular supply of TCM-1 (Alumina-based COLTECH), TCG (GELTECH) ^{99}Mo/^{99m}Tc generators and TCM-2 (^{99}Mo supplied as sodium molybdate solution for solvent extraction generators) to NM centres, to avail ^{99m}Tc at the hospital end, in 1309 consignments, across the country. Demand for Coltech generators saw an upward trend during this period.

- The supply of 13975 consignments of ^{99m}Tc and ^{177}Lu based cold kits, used for the preparation of radiopharmaceuticals at hospital radiopharmacy, was continued during the reported period. A major part of the supply comprised 19 cold kits for ^{99m}Tc labelling (TCK Kits), towards preparation of ^{99m}Tc radiopharmaceuticals, for the functional imaging of various organs and early disease diagnosis. More than 2.25 Lakh diagnostic procedures were carried out using these kits. HYNIC-TATE and HYNIC-RGD kits were introduced for SPECT-based cancer detection. ^{177}Lu cold kits were also supplied to the NM centres for in-situ preparation of therapeutic radiopharmaceuticals at the hospital end.

- Iodine-131 radiopharmaceuticals continued to be the most used therapeutic radiopharmaceuticals. ^{131}I-NaI was supplied in the form of oral solution and capsules for treatment of thyroid cancers and other thyroid related disorders. ^{131}I-mIBG was produced and supplied for treatment of neuroendocrine tumors and ^{131}I-Lipiodol (used for the treatment of

Hepatocellular Carcinoma) were also supplied to NM hospitals. ^{131}I products (as capsules and/or solutions for detection of thyroid disorders; ^{131}I-mIBG radiopharmaceuticals used for diagnosis of NET) are also being used as diagnostic radiopharmaceuticals During the period under report, these ^{131}I based products benefitted more than 30,000 cancer patients, all over India, utilizing ~751 Ci of ^{131}I radioisotope.

- 3135 consignments of injectable radiopharmaceuticals were produced and supplied to different Nuclear Medicine centers, all over India, which includes, ^{177}Lu and ^{153}Sm based radiopharmaceuticals. **Significant increase in demand for ^{177}Lu radiopharmaceuticals, namely, ^{177}Lu-DOTA-TATE for treatment of metastatic (somatostatin receptor positive) neuroendocrine tumors (NET) & ^{177}Lu-PSMA for the treatment of Prostate Cancer, was observed,** and these were successfully catered to during the reported period.

- **Newly launched therapeutic products supplied by BRIT, in 2021-22, included the ^{90}Y-Hydroxy Apetite (HA) and ^{177}Lu-HA, for the treatment of Rheumatoid Arthritis.** These products serve as indigenous alternatives to the ^{90}Y products, which are being imported into the country for the purpose. Till date, 20 treatment doses of these therapeutic products were supplied to Nuclear Medicine centres in India.

- Regular production of ^{177}Lu-PSMA-617 was initiated in the **'New Production Plant'.** This plant was installed under the 12th Plan project 'Advanced Facilities for Radiopharmaceuticals production' (AFRP), which concluded in March 2021.

Fig. 1: Newly installed production facility for ^{177}Lu-PSMA under AFRP Project

- Tissue culture laboratory was maintained for carrying out the *in-vitro* uptake studies of new radiopharmaceuticals. AR-42 J and LNCaP cell-lines were propagated and cell uptake studies were carried out for testing no carrier added (NCA)- ^{177}Lu-DOTA-TATE and NCA-^{177}Lu-PSMA respectively. LNCap cell line specific for prostate cancer was also propagated and used for *in-vitro* cell uptake studies of ^{177}Lu-PSMA-617, ^{68}Ga-PSMA-11 and ^{99m}Tc- HYNIC-PSMA.

- Around 1,048 radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were supplied to the various Nuclear Medicine centres, diagnostic laboratories and research institutes throughout India.

- Two proposals on "no carrier added (NCA)-^{177}Lu" are planned to be submitted to Radiopharmaceutical Committee (RPC), DAE, to obtain approval for their regular production & supply. The proposals are i) nca-Lu-177 as an Active Pharmaceutical Ingredient (API) for radiopharmaceutical end-use and ii) nca-^{177}Lu-DOTA-TATE and nca-^{177}Lu-PSMA-617 for treatment of neuroendocrine tumors and prostate cancer respectively. The studies towards development/standardization were completed successfully and the two proposals were submitted for approval in forthcoming RPC meeting in early 2022.

(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, radiochemical, TCK cold kits, certifying the product and the timely release of QC reports. During the year 2021-22, following were the QC activities:

- **Routine sample analyses:** Around 577 batches of radiopharmaceutical samples and 40 batches of ^{99}Mo-^{99m}Tc COLTECH Generators were routinely analysed and certified by QC during this period 2021-22. These samples are tested for their performance in physico-chemical analyses, sterility, tests, bacterial endotoxin tests and animal biodistribution studies (wherever necessary). Routine maintenance and documentation activities such as microbiological environment testing of Clean Rooms and production facilities during production were carried out on routine basis. QC testing equipments such as Radio TLC scanners, HPLC, Spectrophotometers, micropipettes, Biological Safety Cabinets etc., were also routinely calibrated and maintained in the laboratory. All analyses reports were checked and results were documented as per approved format for each batch of analyses. The deviations (if any) in procedures or non-compliance of specifications were reported and documented.

- **Testing Services:** One imported TCK cold kit of ^{99m}Tc-labelled Tetrafosmin (Myoview) was analyzed on request from DGCI and Certificate of Analysis (COA) was provided after evaluating the performance of the kit, in terms of physicochemical tests, Sterility and Bacteial Endotoxin tests (BET) and animal biodistribution studies.

- **ISO 9001:2015 Certification was awarded for Quality Control/Quality Assuarance Group.**

- **Installation of HPGe detector:** HPGe detector has been installed in QC laboratory and calibrated for energy and efficiency. Adoption to our testing requirements is being done. This is an important step for compliance with national and international pharmacopeias.

Quality Assurance (QA): Production and Quality Control Testing processes were routinely monitored and documented by QA Section [Batch Manufacturing Production Records (BMPR)] and appropriate QA certification for a total of 401 batches of radiopharmaceuticals were released

during the reported period. Regular QA activities were carried out for each batch of Radiopharmaceuticals supplied by BRIT, which includes approving and releasing the requisite documents for production, QC & despatch of the product, in-process checking & documentation of the premises & procedures during production & product analyses, issuing the batch release certificate followed by checking the despatch documents, Data records of calibration of pipettes, electronic balances, dose calibrators & gamma counters, from Production, QC & Electronics group, BRIT, were obtained, verified & documented, so as to ensure the precise & accurate validity of the respective devices.

(c) Medical Cyclotron Facility (MCF), RMC, Parel, Mumbai

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

- Regular operation of Medical Cyclotron (16.5 MeV) and production of ^{18}F radioisotope and uninterrupted supply of nearly 250 Ci of of PET radiopharmaceuticals such as ^{18}F- FDG, ^{18}F-NaF, ^{18}F-FET & ^{18}F-FLT, to various hospitals in and around Mumbai, was carried out during the year 2021-22. **More than 15000 patients benefitted with PET investigations in the reported year.**

(d) Medical Cyclotron Facility at RCR, BRIT, VECC, Kolkata

- Uninterrupted, production, quality control & quality assurance of PET radiopharmaceuticals, [^{18}F]-FDG and [^{18}F]-NaF, (89.07 Ci) were made before their regular supply to cancer hospitals and PET centres, in and around the eastern part of the Country.

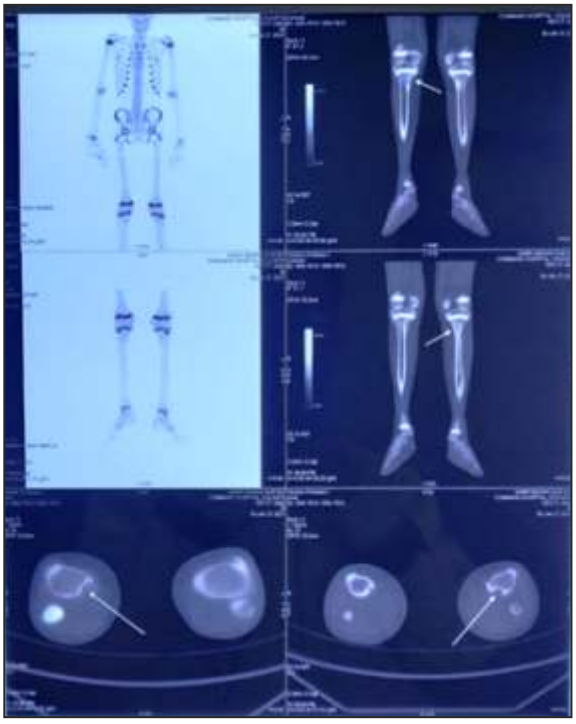


Fig. 2: [^{18}F]NaF PET/CT image of McCune Albright syndrome patient with fibrous dysplasia

- Regional Centre, Kolkata, BRIT, jointly with VECC, Kolkata, has also introduced another important PET radiopharmaceutical product, Thallium-201 Chloride (^{201}Tl), in the market (First time in India). This radiopharmaceutical is considered as the gold standard for cardiac imaging and is used for the early diagnosis of heart ailments. The PET radiopharmaceutical was supplied to NH Rabindranath Tagore International Institute of Cardiac Sciences, Kolkata.

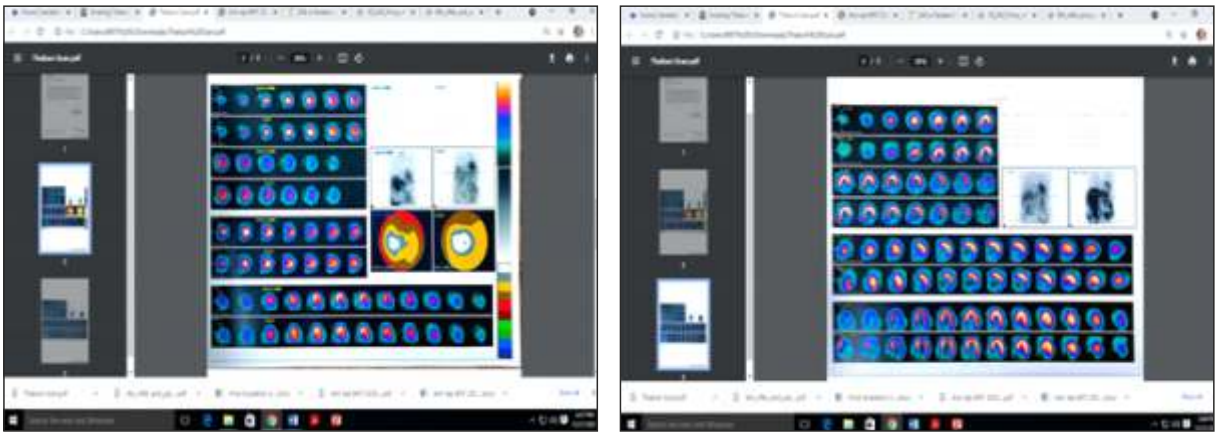


Fig 3: SPECT imaging for cardiac studies: A comparison between ^{99m}Tc-MIBI and ^{201}TlCl

(e) Labelled Compounds (LC)

Labelled Compounds Programme of BRIT is involved in the synthesis & supply of a variety of ^{14}C, and ^{3}H labelled products (308 Consignments) and various types of Tritium-Filled Self-Luminous sources.

- During April 2021 to March 2022, Labelled Compounds Programme has supplied **24678 Nos. of Tritium Filled Self-luminous (TFS) sources of various sizes and shapes to defence establishments** and used for illumination of various types of gadgets and instruments.

- Towards setting up of tritium gas facility at CIRUS reactor building, BARC, Trombay, the facility is in the advanced stage of completion. Once this facility is ready for operation, the production activities of these products will be shifted to CIRUS facility. Collaborative work for assembling a module for the Laser cutting and sealing of glass tubes as part of bulk production of certain TFS is in progress at RRCAT, Indore.

- Custom synthesis and supply of radiolabelled compounds, mainly, C-14 based compounds, is provided to research institutes. These find extensive applications as tracers in the field of biology.

- Labelled Compounds Laboratory also continued 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 supplied had >98% Deuterium abundance.

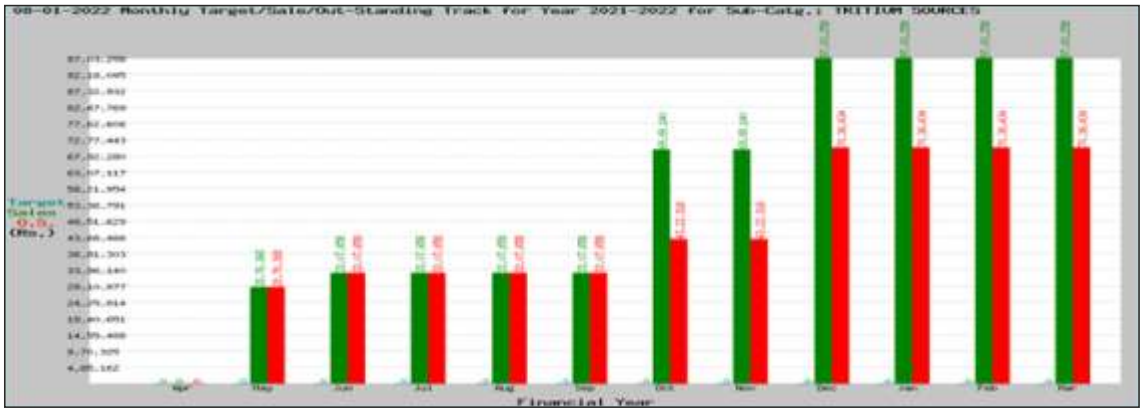


Fig. 4: Monthly sales data of Tritium Filled Light sources

Fig. 5: Tritium Filled Light Sources

II. Engineering

The various engineering products offered by BRIT included the supply of more than 4700 kCi of radioactivity in various forms and for varied uses. **The total revenue obtained by supplying Engineering Products, Equipment's & Devices, during the Financial Year 2021-22 is Rs. 106.87 Crores.**

(a) Sealed Radiation Sources

- BRIT-RAPPCOF continued the tasks related with the safe supply of ^{60}Co for various uses. All the operations requred for sealed source fabrication, viz., transportation of the adjuster rods from various Indian PHWR power reactors (a by-product of neutron regulation), processing of the activity, fabrication of sealed sources, supply of ^{60}Co sources (Cancer treatment ^{60}Co Teletherapy Sources and Multi Purpose Gamma irradiator sources) and source loading at various irradiators, were carried out during the Year 2021-22.

- Processed 6.7 Million Ci of ^{60}Co activity for fabrication of indigenous ^{60}Co Teletherapy Sources (CTS) and High intensity Multi-Purpose Gamma Irradiator Sources from Adjuster rods which were received from various Nuclear Power Plants in the country, in spite of COVID restrictions.

- Fabricated Four Hundred & Ten (410 Nos.) of Multi-Purpose Gamma Irradiator Sealed Sources, which includes Three Hundred & Two (302 Nos.) of BC-188 type and One Hundred & Eight (108 Nos.) of W-91 type sealed sources used for radiation processing applications such as Medical sterilisation, post-harvest food preservation, sludge hygienisation, etc., supplied to various Multipurpose gamma irradiators in the country and abroad. Four (04 Nos.) of high intensity Cobalt Teletherapy Sealed Sources were also fabricated and supplied safely.

- **Exported total of Seventy-Two (72 Nos.) of BC-188 type Multi-Purpose Gamma Irradiator Sources with total activity 750 kCi to various countries which include 250 kCi to M/s. Ansell Lanka, Sri Lanka and 500 kCi to M/s. Ansell, Malyasia. Apart from this, 1000 kCi of ^{60}Co Irradiator source was exported to M/s. Nordion Inc., Canada.**

- **Co-60 CMR Sources: 50 Nos.** of Custom-Made Reference (CMR) Sealed Sources, with total activity 3548 mCi, were fabricated and supplied up to **March 2022.**

- **Ir-192 & Co-60 Radiography Sources: 736** Nos. of ^{192}Ir radiography sealed sources, with total activity **29087.34** Ci, were fabricated & supplied up to March 2022. Three ^{60}Co radiography Sealed Sources, with 130.31 Ci, were supplied up to March 2022.

- Out of the five institutes, the devices lying at NTPC, Korba, is verified and some suggestions were made and devices are to be transported to BRIT, Vashi, after getting confirmation from NTPC. Remaining institutes will be visited after getting confirmation from them.

- 72 nos. of sources were transferred from HTC flask to water pool of HIRUP hot cell for safe management.

- Nine Nos. of Neutron Sealed Sources were removed at IFRT, Vashi, and transported to WMD, BARC for safe management and remaining sources from 5 devices are to be removed as per availability of suitable containers which will be transported to RSMS after getting required transport approval from AERB. 244 Nos. of Sealed Sources were verified from the devices at RSMS, BARC, for safe management and the same will be removed as per suitability and requirement.

Fig. 6: Multi-Purpose Gamma Irradiator Sealed Sources consignments (national and international)

(b) Radiation Equipment Devices

- **Radiography Device: A total of 30 Nos. of Industrial Radiography Devices, which includes 33 Nos. of ROLI series, and 02 Nos. of recently launched COCAM-120 radiography devices, were supplied to various NDT users, across India** during the reported Year 2021-22. **A total of 706 Nos. of industrial radiography devices (both, indigenous and imported) were received, serviced and inspected after critical decayed source removal** in the financial year 2021-22.

- **Blood Irradiators: Three units** Blood Irradiators-2000 with ^{60}Co source have been supplied to hospitals in India during April 2021 to March 2022. **One old BI-2000 unit was decommissioned, while repair services was provided for 8 units.**

- **Gamma Chamber 5000: One unit of GC-5000 with ^{60}Co source was supplied, while one unit each of GC-4000A, GC-1200 & GC-900 were decommissioned,** during the reported year 2021-22. **Inspection & servicing was provided for one unit of GC-5000 and Replenishment of source was completed for another Unit of GC-5000.**

B. Services

BRIT also offers Services in various fields, such as, Isotope Application Services (IAS), Radiography Camera Services, Calibration Services, Industrial Services, Neutron Irradiation Services, Services from ISOMED (for sterilization of medical & healthcare devices), located at BARC, Mumbai, and Radiation Processing Plant at Vashi Complex, KRUSHAK Services, Radioanalytical (both, at Vashi Complex and RCR, Bengaluru), Radiopharmaceutical Services provided by Regional Centres of BRIT etc. **The total revenue collected by providing these Services during the Year 2021-22 amounted to Rs. 20.16 Crores.**

I. Consultancy and MoU for Radiation Processing Plants

Fig. 7: MoU signed between BRIT and Chattisgarh Rajya Beej Evam Krishi Vikas Nigam Ltd.

- MoU was signed with Chhattisgarh Rajya Beej Evam Krishi Vikas Nigam Limited in presence of Honourable Chief Minister of Chhattisgarh, for setting up a Gamma Radiation Processing Plant in Chhattisgarh, for treatment of agro products such as spices, herbal products, dehydrated onion powder etc. as permitted by the relevant regulations.

Fig. 8: MoU signed between BRIT and M/s Acumax Lab Devices Pvt. Ltd.

- MoU was signed with M/s Accumax Lab Devices Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for disinfestation, shelf life extension of food products and sterilization applications of healthcare products, at Mehsana, Gujarat.

Fig. 9: MoU signed between BRIT and M/s Advanced Micro-devices Pvt. Ltd.

- MoU was signed with M/s Advanced Micro-devices Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for disinfestations, shelf life extension of food products and sterilization applications of healthcare products, at Ambala, Haryana.

- **Gamma radiation processing plant of M/s Solas Industries, Noida, M/s AV Gamma Tech, Mumbai & Indore Municipal Corporation were commissioned.**

II. Gamma Radiation Processing Services (GRPS)

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

Gamma Radiation Processing Plant facility at ISOMED for terminal sterilization of the medical products is being revamped and is under renovation during the reported period 2021-22.

- A project, viz. 'Safety System Upgradation and Refurbishment of ISOMED facility', has been undertaken by BRIT with effect from November 2020.

- Rectification of the perennial issue of source interference (in compliance to regulatory recommendation) is required, due to which round the clock commercial operations of the facility for terminal sterilisation of healthcare products have been kept in abeyance (after 44 years of impeccable service to the nation).

- Completely renovated and upgraded set of safety systems, as per the latest safety regulations, to ensure reliability of uninterrupted commercial operations for the healthcare industry in future, is underway.

- Completely renovated facility building, thus ensuring full compliance to cGMP licensing requirements, as per the latest provisions of Drug and Cosmetics Act - 1940 of the Government of India, is also kept in mind while renovating the facility.

Currently the structural repairs work of the facility building is under progress. Also, as a parallel activity, the task of removing and shifting 72 nos of Cobalt-60 sources, is under speedy progress. The removal of sources would pave the pay for the installation of new set of systems related to Coablt-60 Source Assemblies in the underground Source Storage Pit with the

improved / modified design. The design for the new set of Horizontal Transportation Casks, custom built to cater to the requirements of Category II type Land Based Stationary Gamma Irradiators, is being undertaken.

The group has also been involved in the tender related activities towards the proposed task of outsourcing of the PAN India logistics for the radiopharmaceuticals and radiography cameras, being commercially produced by BRIT.

Fig. 10: Structural repair work of the ISOMED facility under progress

(b) Radiation Processing Plant (RPP), Vashi

- Radiation Processing Plant, Vashi has provided gamma radiation processing services for Spices and allied products to various exporters from all over the country. Thirty Six new customers were registered during the current year. Main products processed were spices (whole & ground both), pet feed, ayurvedic raw materials & healthcare products. Industrial samples, viz. induction motor, armoured cable, transmitter etc were received from NPCIL vendors & exposed to desired doses of gamma radiation as per qualification test criterion.

- BRIT has helped in commissioning of three new Gamma Irradiators in Private & State run Government Sectors, (a) M/s Andhra Pradesh Medtech Zone Ltd., Vishakhapatnam, AP; (b) M/s Himedia Labs Pvt. Ltd., Ambernath, Maharashtra; (c) M/s Akshar Gamma Sterile LLP, Ambernath (E), Maharashtra.

- During the current financial year, 4520 MT of spices, Ayurvedic raw material, healthcare products and other products, were processed.

- Surveillance audits for ISO 9001:2015, 22000:2018 and ISO 13485:2016 were carried out by certifying agency and found in full compliance with the Standard's requirement.

(c) Dosimetry Services and Biological Indicators Services from Vashi Complex

Dosimetry Laboratory carried out the following work during the period.

- Plant commissioning dosimetry for medical products was carried out in gamma plant of M/s. Solas Industries, Mathura, and commissioning dosimetry for medical products sterilization and Class VI food products, was carried out at M/s. A.V.Gamma Tech, Ambernath.
- Plant recommissioning dosimetry for radiation sterilization of medical and food products was carried out in 5 Nos of gamma plants namely M/s. Universal Isomed, Vadodara, M/s Hi Media – Ambernath, M/s Alligned Industries – Haryana, M/s. Agrosurg Irradiator- Vasai, and M/s EMI – Vadodara.
- Production and supply of 2.0 lakhs Ceric-Cerous dosimeters was made to various gamma irradiators in the country, for absorbed dose measurement.
- **Export of 5000 Nos. of Ceric-Cerous dosimeters & 15 Nos of irradiated standard dosimeters were supplied to Atomic Energy Regulatory Board, Sri Lanka, during the reported year 2021-22.**
- ISO 9001:2015 Certification was obtained for Dosimeter Production Laboratory, Vashi.
- Dose rate certification of 3 Nos. of Blood irradiator and One Gamma chamber - 5000 was completed.
- Production and supply of ~2000 Biological Indicators was done to the customers of Radiation Processing Plants in the country for monitoring of the sterilization procedure. 44 lots of tissue grafts received for testing from M/s. Biocover laboratories, Tissue Bank, TMC & Novo Tissue bank tested for sterility & bio-burden tests.
- Conducted internal quality audits/surveillance audits for quality management systems (QMS/FSMS/MDQMS) of RPP. Successfully obtained licenses from CDSCO for radiation sterilisation of class C & D medical devices.

III. Isotope Application Services

Isotope Application Services (IAS) Section, BRIT, offered its valuable, timely and elegant services and solutions to various industries across the nation. During the reported period of 2021-22, following Services were provided by BRIT:

(a) Gamma Scanning of Reactor-Regenerator System (RRS) of Catalytic Cracking Unit (CCU), BPCL, Mumbai Refinery

In the Catalytic Cracking Unit (CCU) of a leading petroleum refinery of India, high catalyst losses and reactor overhead oscillations were observed post start-up of the damaged bellow valve replacement. Some mechanical damage or plugging of the internals in the RRS was suspected by refinery engineers.

BRIT received an enquiry for the above stated problem. A technical discussion was held with the refinery engineers. It was decided to perform gamma scanning of the regenerator cyclones, air grid area, reactor cyclones, riser pipe and stripper vessel by using 80 mCi of ^{60}Co radioactive source.

Prompt action was taken by BRIT as per the urgency of the job. Mechanical fitting was done for all the equipment to be scanned as per the scan line orientation. Scanning was performed with the help of automatic column scanner which consists of a source holder, BGO detector assembly, source/detector operator, control unit and laptop.

Fig. 11: Gamma Scanning of Reactor Regenerator System of BPCL, Mumbai Refinery

The scan profiles were interpreted and mechanical damages were not observed in the cyclones. Some plugging was observed in the reactor cyclones and bottom regenerator air grid. Riser pipe bottom was also showing normal behaviour. The gamma scanning report was very useful to assess the health of the internals and operational anomalies in the RRS.

(b) Radiotracer Study for Leakage Detection in Underground CRWS/OWS Pipeline Network at MRPL, Mangalore Refinery

Oil leakage was observed at various locations inside a petrochemical plant. The traces were enormously increased during the monsoon. Mixing of this oil to the ground water and outside water body was not permitted due to strict environmental norms. Identification of the source of this leakage was very important to avoid the product losses as well as the environment pollution.

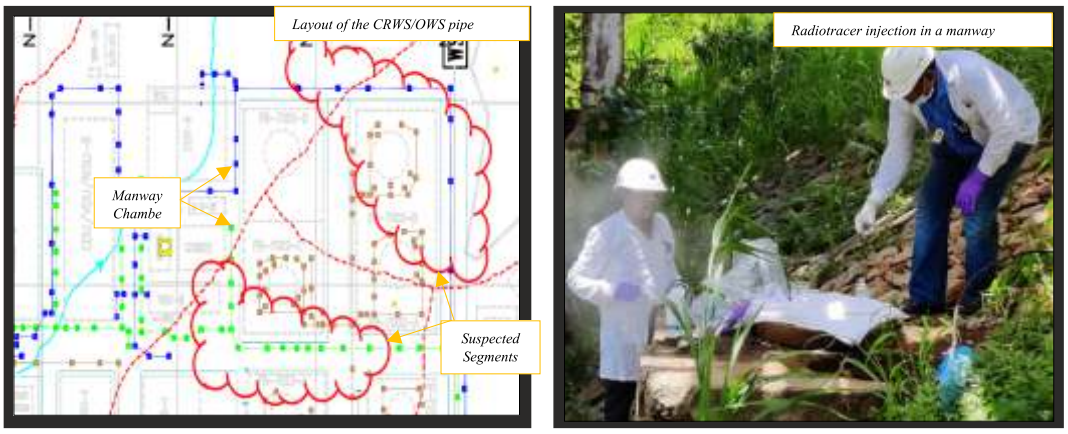


Fig. 12: Radiotracer study for Oil Leakage Detection in a Petrochemical Plant

It was suspected by plant engineers that drainage pipe segments of contaminated rain water sewer (CRWS)/Oily water sewer (OWS) network may be leaking. These are hume pipes (dia. 300 mm approx.) buried around 3-4 meters depth underground connected with manway chambers located at every 20 m length.

A radiotracer study was performed by multiple injection of ^{99}Mo as sodium molybdate in different manway chambers. Radiation detectors were placed at the inlet and outlet of the pipe segments. Travel of the radiotracer through these pipe segments was recorded by multi-channel data acquisition system. Analysis of the radiation data indicated presence of leak in the two pipe segments. The plant was a zero liquid discharge facility. In that scenario, this study was very helpful to identify the source of the leakage. The plant engineers were able to plan for the problem rectification as well as to meet the strict environmental norms.

The above said industrial diagnostic services were able to provide benefits to the industries in terms of taking decisions on shutdown, pinpoint the malfunctions in running condition, minimize the downtime of the plant and avoid the huge financial losses as well as earning a valuable revenue for BRIT.

IV. Radiation Physics Services Group

1. Theoretical dose evaluations were done for two newly commissioned Gamma plants 1) M/s AV Gamma Tech., Ambernath and 2).Indore Municipal Corporation, Indore. The results were validated with commissioning dosimetry.

2. The shielding assessment of the Radiation Shielding Window 1 (RSW 520) of the Fission Moly Plant was carried out with mainly lead glass and SS 304 lining as the shielding materials.

3. The shielding assessment was done for the new column generator (COLTECH) production facility of BRIT. The assessment was done to decide upon the maximum capacity of ^{99}Mo that can be handled in the facility. The facility has mainly 3 cells. Cell-1 is for handling ^{99}Mo which is having 100 mm lead shielding. The evaluations were carried out for handling 50 Ci of ^{99}Mo in this hot-cell and the modifications were suggested.

4. CTTT is a container designed for target transfer from the Dhruva reactor to the ^{99}Mo production facility of BRIT. The container is designed to carry 6 target plates. The shielding assessment is done based on the drawings provided for CTTT cask and the proposed activity to be transported.

5. The cask is designed as a Type B(U) package for the transport of 30 kCi of ^{60}Co in the form of Irradiator pencils. There are 8 slots with a PCD= 56 mm & 4 slots with a PCD=21 mm in the source cage, for holding the source pencils. Lead is the shielding material used. The shielding assessment is carried out and the cask is found to be adequately shielded.

6. Source (W-91/ BC-188) Loading configurations were designed for the following 20 gamma irradiators with a view to get the desired Dose Uniformity Ratio well within the prescribed limits for the concerned products which are to be radiation processed in each plant.

- MGIF/SLAEB, SriLanka (added 250 kCi in 22 pencils)
- Akshar Gamma, Ambernath (added 250 kCi in 10 pencils)
- Solas Industries, Mathura (300 kCi in 26 pencils – first loading)
- AVPPL, Ambernath (added 125 kCi in 5 pencils)
- AV Gamma Tech., Ambernath (200 kCi in 8 pencils – first loading)
- Akshar Gamma, Ambernath (added 450 kCi in 18 pencils)
- Microtrol, Bawal (added 250 kCi in 11 pencils)
- Gujarat Agro, Ahmedabad (added 200 kCi in 7 pencils)
- Jamnadas Industries, Dewas (added 160 kCi in 14 pencils)
- RPP, BRIT (added 150 kCi in 5 pencils)
- UML, Vadodara (added 300 kCi in 10 pencils)
- Aligned Industries, Rewari (added 200 kCi in 7 pencils)
- EMI, Vadodara (added 300 kCi in 92 pencils)
- Avantee Food Park, Dewas (added 200 kCi in 20 pencils)
- OGFL, Kolkata (added 125 kCi in 4 pencils)
- KRUSHAK, Lasalgaon (added 53 kCi in 2 pencils)
- AIIPL, Vasai (added 125 kCi in 4 pencils)
- MSAMB, Vashi (added 150 kCi in 6 pencils)
- Indore Municipal Corporation, Indore (150 kCi in 14 pencils – first loading)
- NIRPO, Satara (added 220 kCi in 17 pencils)

12. Radiological Surveillance of the Radiation Processing Plant (RPP), BRIT and the Radiological Safety of the check sources: Regular inspection of safety systems, area monitoring and personnel monitoring were carried out. Four Safety Status Reports (SSR) of RPP were prepared and forwarded to AERB.

V. Calibration Services for Portable Radiation Monitoring Instruments

➢ BRIT is providing calibration services for gamma radiation monitoring instruments. A total of **140** numbers of radiation monitoring instruments, such as, survey meters, dosimeters and portable area monitors, were calibrated during the period, 2021-2022. So far, BRIT has calibrated more than 1100 Nos. of instruments of various type. Also, BRIT has entered into an Agreement with Space Application Centre (SAC)/ ISRO, Ahmedabad, to test Radiation Sensors to be used in future manned missions of ISRO. The Trial testing of a sensor is already completed and SAC team is satisfied with the results.

VI. Radioanalytical Laboratory Services

➢ Radioanalytical Laboratory, BRIT Vashi Complex carried out the measurement and certification of radionuclide content in commodities such as food items meant for human & animal consumption, water samples, metal & metal products, environmental samples such as coal, flyash, soil, rock phosphate, phosphogypsum etc. The laboratory is accredited by NABL also empaneled by BIS for the testing of gross alpha and gross beta content in water samples.

During the period 2021-22, RAL has carried out nearly 7355 tests on export/domestic commodities and water samples. In addition, one on-site survey was also carried to monitor the surface radiation dose of one steel consignment.

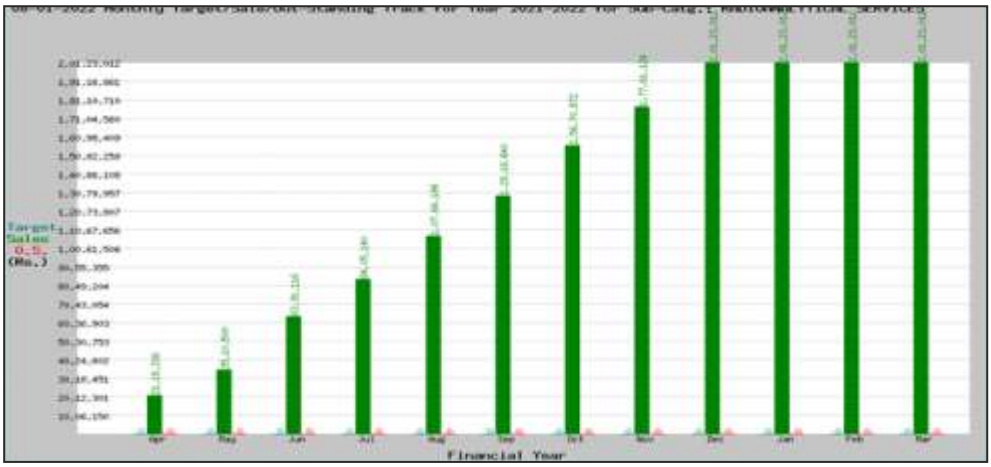


Fig. 13: Monthly track graph of RAL revenue

Fig. 14: RAL Laboratory at BRIT, Vashi

VII Services extended by Regional Centres of BRIT

Regional centres at Delhi, Dibrugarh & Kolkata, Hyderabad (also known as Jonaki), Bengaluru, and Kota continued their respective services towards the supply of ready-to-use-radiopharmaceuticals to surrounding Nuclear Medicine hospitals, rendering RIA & IRMA diagnostic services for the benefit of patients in the entire North-Eastern region, PET Radioisotopes production in Cyclotron (VECC), preparation & supply of labelled compounds, radioanalytical certifications and processing of ^{60}Co sources for their various uses in Engineering Programme of BRIT. Around 3,000 consignments of in-vivo and in-vitro kits were supplied to RCR's for providing extended services to nearby hospitals, research centres, or institutions at and surrounding these cities.

RCR, Kolkata & Dibrugarh:

- **Services at Regional Centre, 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, which includes Assam Medical College, OIL Hospital, ONGC Hospital, Air Force Hospital, Jorhat, RRL Hospital, Jorhat, Railway Hospital, Dibrugarh & Maligaon, Tea Garden Hospital & also patients from District Jail, BVFCL, Namrup etc. The Radiopharmaceutical products produced and supplied by BRIT, Vashi complex are extensively used by the Regional Centre, Dibrugarh, for the diagnosis & investigation of various diseases. **More than 2000 patients of the region avail the (RIA & IRMA tests as well as RPhs products supply) services from this centre.** The centre is currently analyzing the hormones, such as, T_3, T_4, TSH, Free T_4, Insulin etc. A total of 4113 Nos. of tests were carried out with almost 3513 Nos. of patients.

Services extended by Regional Centre, Kolkata:

- **Sale of cold kits for Tc-radiopharmaceuticals from the retail outlet at RC, Kolkata:** During the year 2021-22, approximately 206 Nos. of Technetium cold kits for formulation of ^{99m}Tc-radiopharmaceuticals were supplied to various Nuclear Medicine Hospitals in Kolkata.

- Production and supply of ^{18}F-FDG & ^{68}Ga-PSMA (total activity ~ 89.12 Ci) was made to different hospitals from DAE Medical Cyclotron, CYCLONE- 30, Kolkata.

- **Around 150 batches of ^{18}F-FDG were routinely analysed and certified by Quality Control during this period. Regular Quality Assuarance was performed before the batch release of all the RPhs which were supplied through the Centre during the reported period.** Regular production and supply of ^{18}F-FDG to different hospitals from DAE Medical Cyclotron, CYCLONE- 30, Kolkata. The Centre continued to supply ^{18}F-FDG even through the lockdown period. A few batches of [^{18}F]NaF, PET agent for bone imaging, was also routinely analysed and certified by QC during the reported period. Regular Quality Assurance was performed before the batch release of all the radiopharmaceuticals which were supplied during the reported period.

- **Thallium-201 Chloride (^{201}Tl) has been produced (First time in India) at MCF, at RC, BRIT, Kolkata. This product is used for myocardial perfusion and parathyroid imaging. It is mainly used for early diagnosis of heart ailments, and supplied to NH Rabindranath Tagore International Institute of Cardiac Sciences, Kolkata.**

RCR, Bengaluru:

- Regional Centre Bengaluru has a Radioanalytical laboratory for the measurement and certification of residual radioactivity in various commodities such as food items for human & animal consumption, medicine and other miscellaneous items. The laboratory got accredited with ISO 17025:2017 by NABL (National Accreditation Board for Testing and Calibration Laboratories). RC, Bengaluru has analysed around 150 samples from different customers during the reported period.

Fig. 15: RAL Laboratory at RC, Bengaluru

National Accreditation Board for Testing and Calibration Laboratories

NABL

CERTIFICATE OF ACCREDITATION

RADIOANALYTICAL LABORATORY, BRIT-RC, BENGALURU

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2017

"General Requirements for the Competence of Testing & Calibration Laboratories"

for its facilities at

REGIONAL CENTRE,KIDWAI CAMPUS, BENGALURU, KARNATAKA, INDIA

in the field of

TESTING

Certificate Number: TC-5118

Issue Date: 23/11/2020 Valid Until: 22/11/2022

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Signed for and on behalf of NABL

N. Venkateswarlu
Chief Executive Officer

Fig. 16: NABL Accreditation for RAL, Bengaluru

- **Commissioning of Gamma Blood irradiator (^{137}Cs source), which was received from BRIT Mumbai, was carried our successfully in the month of November 2021 at Kidwai Memorial Hospital Campus, Bengaluru.** Daily, around 100 numbers of blood and platelets bags are irradiated at this Centre. RC, Bengaluru, has irradiated more than 2000 bags during 2021-22.

- Regional Centre BRIT, Bengaluru has supplied approx. 97Ci of ^{99m}Tc to various (7 regular customers) Hospitals and Diagnostic Centers. ^{99m}Tc from RC,Bengaluru is utilized by more than 8000 patients per year in Bengaluru City. Around 650 TCK cold kits (20 regular customers) were supplied for preparation of ^{99m}Tc radiopharmaceuticals.

RCR, Delhi:

- Regional Centre for Radiopharmaceuticals, Delhi, continued the supply of clinical grade, ready to use diagnostic ^{99m}Tc-radiopharmaceuticals injections in compliance with GMP and RPC, COLTECH/GELTECH Generators and TCM-2 (^{99}Mo Generator kit for Solvent Extraction) (^{99m}TcO4-), for the Nuclear Medicine centres in Delhi and NCR regions.

- Quality Control of ready-to-use ^{99m}Tc & its labelled RPhs from 185 batches was done during the said period. ~704 Nos. of TCK Cold kits have been supplied from retail outlet of Regional Centre, BRIT, Delhi, to different private and Government Nuclear Medicine Centres in Delhi, NCR & Northern region of India.

RCR, Hyderabad (Jonaki):

- During the period, Regional Centre of BRIT, Hyderabad (Jonaki) supplied ready-to-use ^{99m}Tc, in the form of Sodium Pertechnatate (16.70 Ci) to local Nuclear Medicine Centres. It has supplied 562 Nos. of TCK Cold kits (produced at BRIT, Vashi Complex) from retail outlet of Regional Centre, BRIT, Hyderabad.

- It has initiated the setting up of Radiopharmaceuticals laboratory for the preparation and supply of ready-to-use ^{99m}Tc and ^{68}Ga formulations to the local Nuclear Medicine Centres and Radioanalytical facility for providing radioanalytical services to the users.

- Also, during the Year 2021-22, RC, BRIT, Hyderabad, continued the synthesis and supply of ^{32}P-labelled nucleotides (122.25 mCi) and molecular biology reagents 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.

RCR, Kota (RAPPCOF):

- RAPPCOF facility continued the tasks related with the safe supply of ^{60}Co for various uses, right from receiving the adjuster rods from various Indian PHWR power reactors (a by-product of neutron regulation), processing of the activity, fabrication of sealed sources, to supply of ^{60}Co sources (irradiator sources & teletherapy sources), are all carried out.

- During 2021-22, RC, Kota, processed 6.7 Million Ci of ^{60}Co activity. This is mainly used for fabrication of indigenous ^{60}Co Teletherapy Sources (CTS) and High intensity Multi-Purpose Gamma Irradiator Sources. Successful fabrication of Two hundred and Sixty-Five (265) Multi-Purpose Gamma Irradiator Sources, which included One hundred and Seventy-Six (176) number of BC-188 type and Eighty Nine (89) number of W-91 type sealed sources were made.

- Total 4792 kCi of ^{60}Co sealed sources are supplied in 48 number of consignments which included Eleven Cobalt-60 Teletherapy sources (CTS) and Two hundred and Ninety-Seven (297) Multi-Purpose Gamma Irradiator Sources, consisting of Two hundred (200) number of BC-188 type and Ninety-Seven (97) number of W-91 type sealed sources. These were used for radiation processing applications such as Medical sterilisation, post-harvest food preservation, sludge hygienisation, etc., to various Multipurpose gamma irradiators in the country and abroad.

- Source loading operation of Seventeen (17) Multi-Purpose Gamma Irradiators in various part of the country was carried out in 2021-2022.

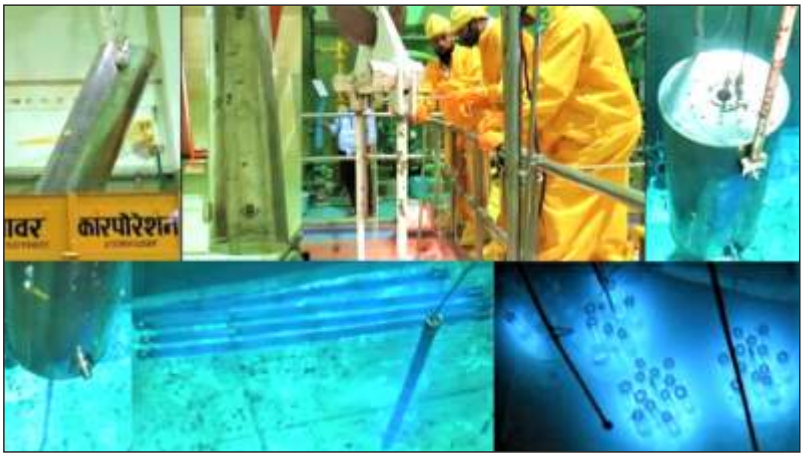


Fig. 17: Handling of ^{60}Co Adjuster rods in BRIT-RAPPCOF storage pool

बड़ी उपलब्धि • कैंसर के इलाज और फूड प्रोसेसिंग में कोबाल्ट सोर्स का उपयोग, विश्व के चुनिंदा निर्यातकों में भारत शामिल

रावतभाटा में निर्मित कोबाल्ट सोर्स मलेशिया निर्यात, अब यूके, कनाडा व रूस भी भेजे जाएंगे

गर्व की बात...20 साल पहले हम विकसित देशों से कोबाल्ट सोर्स मंगाते थे, अब कर रहे निर्यात

देश : 500 अस्पतालों को रावतभाटा दे रहा है कोबाल्ट सोर्स, लाखों कैंसर रोगियों को राहत

भास्कर नॉलेज

क्या है कोबाल्ट 60:

कैसे बनता है:

कई उपयोग...कैंसर के उपचार से लेकर रेडियोग्राफी तक कोबाल्ट 60 का उपयोग

कीर्तिमान...भारत विश्व में सबसे बड़ा उत्पादक बनने की ओर, 3 साल में होगा दोगुना विस्तार

Fig. 18: "Dainik Bhaskar" A local (Rawatbhata) Newspaper article showcasing the work carried out at RAPPCOF facility and the uses of ^{60}Co

C. Engineering Design & Development

1. BRIT dedicated the Indegionous ^{60}Co-based Industrial Radiography Device (COCAM-120) along with New Light-weight Remote Controlled Cranking Device to the NDT industry

BRIT is providing its exemplary services and playing a pivotal role since last three decades in the country's NDT industry. BRIT is developing different industrial radiography devices of international standards and also providing complete services connected with the radiography devices. BRIT is pleased to **announce** that the newly launched **indigenous developed ^{60}Co-based Industrial Radiography Device "COCAM-120"** is now **commercially available** for the NDT industry. The **first device** was **handed over** to the NDT user by the Chief Executive, BRIT, in an event held on 18th September, 2021. The COCAM-120 is designed as an exposure device cum transport container for **4.44 TBq (120 Ci) of ^{60}Co source**. It uses a unique **hybrid shielding** arrangement comprising of depleted uranium, tungsten alloy and lead 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 device can be used for the **non-destructive examination** of material of thickness

Fig. 19: COCAM-120 being handed over to the NDT industry by Chief Executive, BRIT for its commercial utilization

Fig. 20: COCAM-120 radiography device unit being despatched to NDT user in Coimbatore for its commercial utilization

ranging from 40 mm to 200 mm in steel. The device is designed, manufactured, tested & approved as a **Type B (U) package** by AERB vide. IND/40/B(U)-96 and as Category-II IGRED vide. 18-COMSUPPTA-335710.

The COCAM-120 is proving itself as an **import substitute** and contributing towards **"Atmanirbhar Bharat".** The commercial introduction of the device has been whole-heartedly **welcomed** by the NDT industry. The tremendous response & enthusiasm shown by the NDT industry towards the COCAM-120, in terms of registration of many orders for its purchase, is definitely noteworthy.

2. Conceptualization and Design of Indegionous Modified ^{60}Co-based Industrial Gamma Radiography Device; COCAM-A

Board of Radiation and Isotope Technology (BRIT), India has indigenously designed a ^{60}Co based Industrial Gamma Radiography Device; **COCAM-A**. The device has been designed as a mobile type, Cat. II radiography device and having a maximum source capacity of **0.296 TBq** (8 Ci) of **^{60}Co** radio-isotope. The device is designed using **lead** as shielding material to keep the radiation level within limit and optimize its weight against material availability and the **cost**. This shielding material are encased in a 6 mm steel (AISI SS304L grade) enclosure. A stainless-steel tube in form of "S" shaped pass through the centre and facilitate the movement of the radiation source while avoiding any possible radiation streaming. The device is provided with an **interlock mechanism** so that unintentional operations can be avoided. The exposure device weighs approximately **280 kg** with major dimension 650 mm x 370 mm x 475 mm (height). The device can be used for the NDT of material of thickness ranging from 40 mm to 200 mm steel. COCAM-A has been designed to meet the requirements to qualify as a Type A transportation package & as an industrial mobile radiography device. The design of the device has been completed and the first prototype is under fabrication.

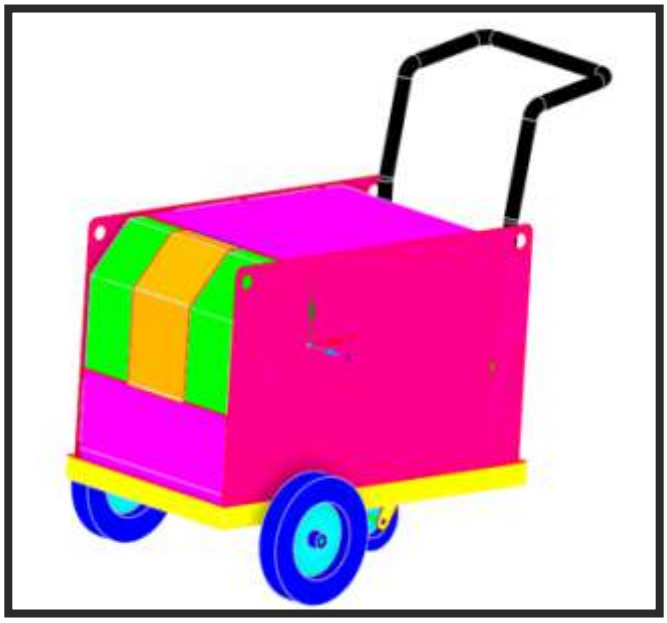


Fig. 21: Overview of COCAM-A, an Industrial Gamma Radiography Exposure Device

3. Design of Mobile Food Irradiator and preparation of Security Plan

Mobile Food Irradiator (MFI) has been designed to irradiate low dose food products such as fresh fruits, vegetables, cereals, pulses, frozen food products etc. The concept of Mobile Food Irradiator is based on the idea of making the irradiator itself capable of reaching to the location of food produce. The irradiator will be mounted on a 40 feet trailer bed and can be moved to different places as per the irradiation schedule. The mobility of irradiator effectively reduces post-harvest transportation losses as well as cost incurred in transportation. Mobile Food Irradiator is a Category II, panoramic, dry storage type gamma radiation processing plant. It is designed for 3700 TBq (100 kCi) of ^{60}Co, which is expected to give a typical through put of 12-13 tons/day for low dose food products.

The security of radiation sources in the MFI required mechanism to prevent theft or damage and to prevent any unauthorized person from carrying out any of the operations at the irradiation facility that could also result in significant radiological consequences. For safe operation, irradiator is designed using defence in depth approach. With this approach, multiple level of protection is provided, thus minimizing the need for human intervention. Electrical and mechanical safety Interlocks are provided to prevent over exposure to the personnel and to ensure the safe operation of the MFI.

In order to address the threats from malevolent acts involving radioactive sources, a detailed "Security Plan" has been prepared (as per applicable AERB safety guide AERB/RF-RS/SG-1) which includes measures for a combination of deterrence, early detection and delay of attempts of un-authorized access, mitigation of probable consequences and early response. The security plan is in advance approval stage from competent authorities.

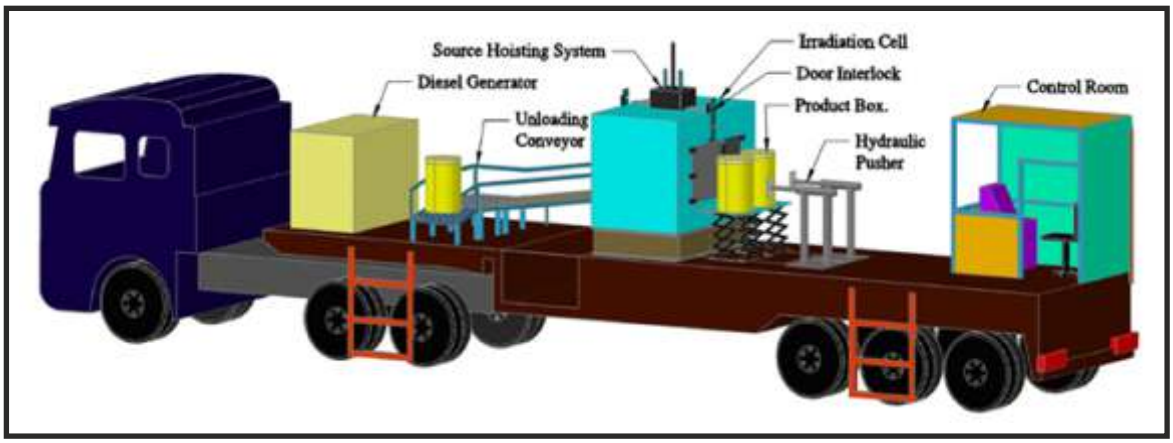


Fig. 22: External view of Mobile Food Irradiator

4. Development of Hand-held Cranking Unit

BRIT has developed a new ergonomic, user-friendly, hand-held & extremely light weight cranking unit for the safe remote operation of the indigenous industrial radiography device. This cranking unit will enable user to operate the radiography device in a comfortable standing position.

It has also been ensured that the unit can be operated efficiently in any orientation while comfortably hand-held by the user. In the cranking unit, the Teleflex cable used to provide the necessary motion has also been the developed in India with on-par quality as its imported counter parts. The indigenously developed teleflex cable being used in the cranking unit has 26 strand spring steel wire wound together to achieve the necessary flexibility, corrosion resistance & strength. The protective sheath over the Teleflex has also been developed with 5 layer of protection using Teflon tube, stainless steel braiding (with 96 nos. of wire), PVC covering etc. The final prototype of the hand-held cranking unit will be ready soon.

Fig. 23: Overview of an initial prototype of the Hand-held Cranking Unit

5. Development of Cryo Irradiator

The existing Install and Operate type Irradiator have been upgraded to Cryo Irradiator to make it suitable for irradiating marine products. Cryo Irradiator is specially design to irradiate the marine products, as maintaining the cold chain is necessary in marine products supply chain. Cryo Irradiator is basically a category-I batch type irradiator in which source is stored in a dry container and it always remains shielded and no human access is physically possible where source is kept. The plant is designed as a batch type irradiator which can cater to all other products including food and medical products, which are permitted to be radiation processed. Cryo Irradiator can accommodate a maximum of 400 kCi of ^{60}Co in form of 40 numbers of standard BC-188 pencil placed in circular fashion in a source cage. Cryo Irradiator has a through put of 6 Ton/day with a dose rate of 7 kGy/hr. The Cryo Irradiator consists of a building with concrete pit in which the cask containing the source is placed. The cask is made up of stainless steel and lead. Stainless steel is used as incasing material and lead as a shielding material. The other components of Cryo irradiator are Duplex plug, Upper shield, Product Carrier, Support Structure, Product incoming and outgoing conveyor, Hoist System with counter weight to move the product box up and down, ventilation system and a chilled air supply system. The figure below shows a sketch of Cryo Irradiator. Fabrication of the plant is at an advanced stage.

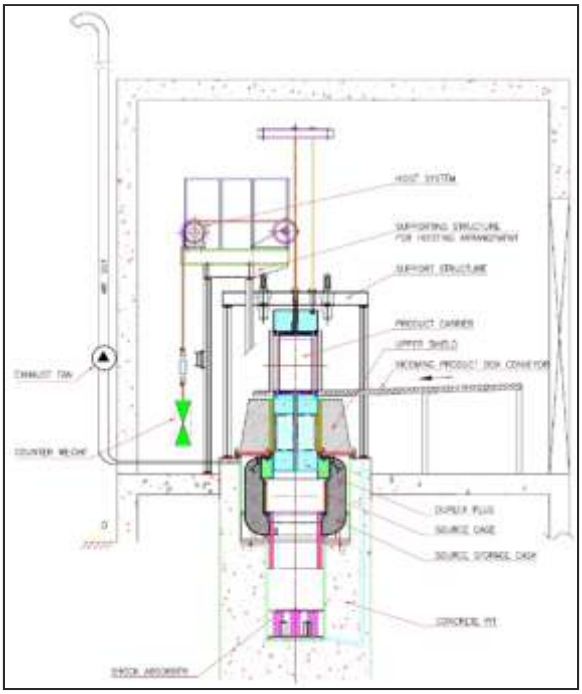


Fig. 24: Cryo Irradiator

6. Designing of Cobalt Export Flask (CEF-30)

Cobalt Export Flask (CEF) is a type B(U) transportation cask designed to transport 30 kCi of ^{60}Co in sealed form. The main objective of designing this transportation package is to meet the burgeoning demand of ^{60}Co in the international market. Using this cask BRIT can export ^{60}Co sealed sources to Industrial Irradiators established in other countries.

The Flask is made up of AISI SS304L as encasing material and Lead as a shielding material. Fins are provided on the outer surface for lifting as well as for dissipating thermal heat generated by decay of ^{60}Co. The overall size of the package is 1200 mm x 800 mm x 800 mm. The weight of the package is less than 3 Ton.

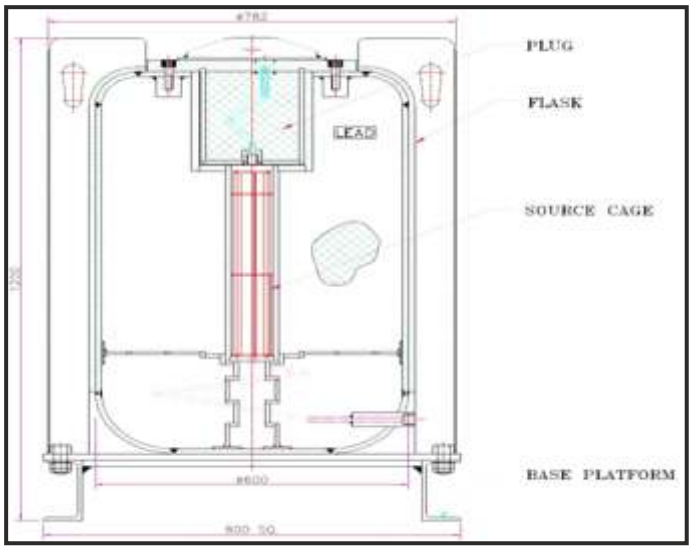


Fig. 25: Sectional View of CEF-30 Flask

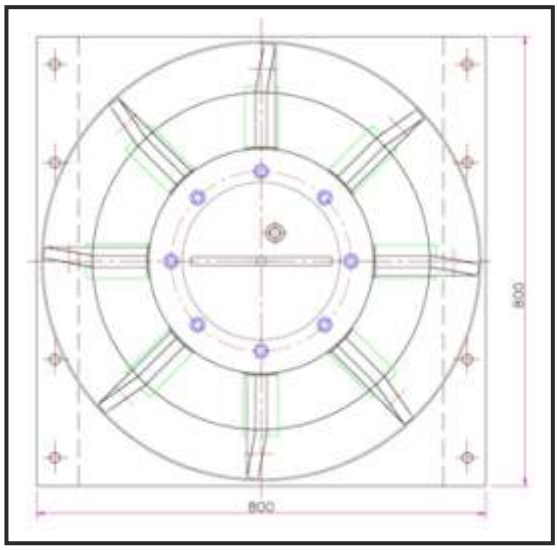


Fig. 26: Top View of CEF-30 Flask

D. 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 equipment to about 2000 user institutions in the healthcare, industrial, research and agricultural sectors.

- Processing of orders for tritium filled sources, low level reference sources and nucleonic gauge sources, were started online through BRIT eportal.
- The deployment of online modules for online order processing for ^{60}Co teletherapy sources, irradiation services and isotope application services are in advance stage and likely to be implemented soon.
- BRIT was registered as a seller in Government eMarketplace (GeM) to capture the public sector market which posts enquiries in GeM portal.
- 35 customers were added in off-line mode and 11 new customers were added in online mode from 01.04.2021 to 24.12.2021 (total 46 new customers) for non-medical products.
- **Executed two export orders for the supply of ^{60}Co irradiator source with a revenue of approx. 16 Cr in foreign exchange.**
- The Customer Relation Cell, RPL, is involved in sales and supply of Radiopharmaceuticals to Nuclear Medicine centres across the nation. 30 new customers were registered on the eportal during the period April 2021 to March 2022.
- The revenue from sales of Radiopharmaceutical products have increased approx 50% during the period Aug to Nov, 2021 compared to the sales during the period April to June 2021.

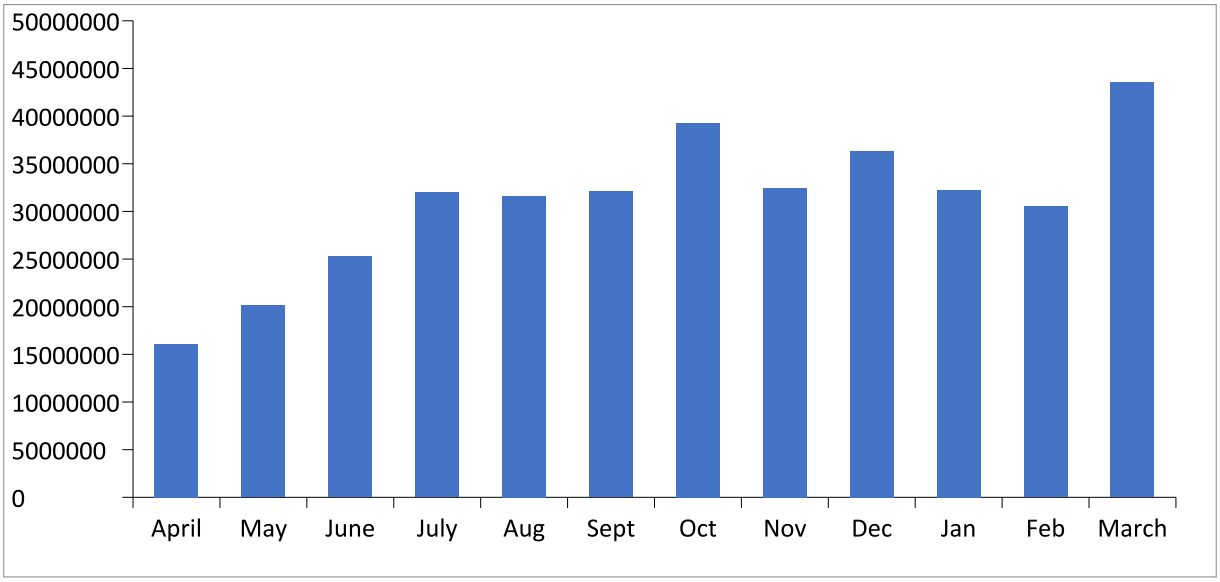


Fig. 27: Revenue collected from Sales of Radiopharmaceuticals during the Financial Year 2021-22

- Channelized efforts were taken up to increase the sales of the TCM-1 Coltech generator by bringing back old customers and adding new customers. The door delivery of RPL products have tremendously increased the customer satisfaction, especially the pick-up of spent generators.

- Several customer feedbacks were conducted through the google forms platform. Some of the insights from the feedback were positively implemented resulting in a harvest in the form of increased sales revenue. For eg. a survey on the ^{177}Lu-based radiopharmaceuticals revealed that it was a popular demand to increase the supply frequency. An increase in supply frequency has lead to an increase in revenue from these products.

- Compliance to regulatory requirements were adhered to by obtaining registration of radioactive products, renewal of type approvals of transport containers, approvals for import of radioactive material and export license, approvals for transport of radioactive material and providing non-compliance reports.

- Customer relation cell was actively involved in giving technical support with respect to the "BRIT at doorstep" initiative in implementing door delivery of BRIT products. Door delivery of BRIT products has been well accepted and appreciated by BRIT customer base across the nation.

E. Activities related to Official Language (OL) Implementation

- Along with its scientific activities, BRIT is committed to the implementation of Official Language Policy of the Govt. of India and directives issued by DAE from time to time in its day-to-day work.

- **Due to the commitment and enthusiasm of BRIT employees towards OL, Hindi, and its implementation, BRIT was awarded with the second prize (Rajbhasha Puruskar) for the year 2021-22 by Navi Mumbai Town Official Language Implementation Committee (TOLIC) which consists of more than 100 Central Govt Offices/Corporations/PSUs.**

- BRIT staff members took active participation in the competitions held by TOLIC and had brought home many prizes.

- Due to Covid-19, periodical meetings and programmes were conducted through virtual medium with a satisfactory level of participation from all staff members.

- A two-days Joint Workshop was organized on August 25-26, 2021.

- Virtual Hindi Diwas function was organized on 14th September, 2021 under the aegis of Joint Official Language Coordination Committee. On this occasion, Hindi Diwas messages issued by Hon'ble Home Minister, Government of India and Secretary, Department of Atomic Energy were read out. Heads of the five DAE units (AERB, BRIT, DCSEM, DPS and HWB) addresses regarding the present status, promotion and implementation of the official language in their respective offices. During September 25-30, 2021, quiz, noting-drafting, translation, essay and elocution competitions were organized in which the employees of BRIT participated enthusiastically.

- Virtual World Hindi Day celebration was organized on January 11, 2022 under the aegis of Joint Official Language Coordination Committee. Heads of all the five units delivered addresses on the occasion. An official language talk was also organized.
- Hindi Essay Writing Competition, Hindi Poetry Recitation Competition and Hindi Speech Competition were organized jointly by Joint Official Language Coordination Committee consisting of 5 Units.

Glimpses of Joint Hindi Workshop followed by Prize Distribution conducted at BRIT Vashi Complex during August 2021

Various Hindi Competitions conducted at BRIT Vashi Complex during September 2021

Participation of BRIT in the 36th Inter-DAE Sports & Cultural Meet - Carrom Championship: "Achievements of Team Ellora"

Responsibility of selecting the Ellora team players for Carrom event to represent "All India 36th DAE Sports and Cultural Meet 2021-22" at KAPS, Kakrapar, Gujarat, was entrusted to BRIT Staff Sports & Cultural Club. Accordingly, BRIT Staff Club has arranged for the selection trials (during 22nd - 24th Feb. 2022) at RPL, BRIT. Chief Executive, BRIT, inaugurated the opening ceremony of the selection trials with a motivating speech. **Forty participants from 9 DAE units of Ellora (BRIT, NPCIL, TIFR, DCSEM, HWB, DPS, DAE, TMH, ACTREC) participated in the selection trials with good spirit and enthusiasm.** Shri Parvinder Singh Grover, National & International Panel Umpire-cum-Chief Referee was entrusted the responsibility of selecting the deserving players. After the fair selection conducted at Vashi Complex, BRIT, 4 players each (Men & Women Category) were selected to participate in the event at KAPS, Kakrapar, Gujarat, whereby, Shri. D. P. Pawar, Sr. Tech-J, BRIT, was appointed as the **Team Manager by BRIT Staff Club**.

Ellora team has performed extremely well at the Carrom event held at KAPS, Kakrapar, Gujarat, during 7th to 11th March 2022, and won the Team championship for the following Six titles in the Event-

- **Shri. D. P. Pawar, Best Manager - Winner**
- **Men Team Championship - Winner**
- **Men Doubles - Winner**
- **Women Single - Winner & Runner-up**
- **Women Team Championship - Runner-up**
- **Women Doubles - Runner-up**

BRIT Staff Sports & Cultural Club congratulates the winners for the outstanding victory and the great achievements. Best wishes to the team for achieving greater goals in future endeavors.

F. Plan Projects

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

Work at the Fission Moly Project site resumed in June 2021 after the COVID-19 related lockdown. All the required machineries & equipment was supplied by the vendor and all consignments of consumables & sealed sources were received. Installation and commissioning of Hot cells, HVAC system, fire alarm system & security system was completed. Cold commissioning are in progress.

Fig. 1: ^{99}Mo Production Facility (Outside view)

Fig. 2: ^{99}Mo Production Facility (Inside view)

(b) Advanced Facilities for Radiopharmaceuticals Production

- Setting up and commissioning of a GMP-compliant production facility for:
  (a) production of ^{131}I-meta iodo benzyl guanidine (^{131}I-mIBG) for clinical management of neuroendocrine tumors &

  (b) production facility for ^{177}Lu radiopharmaceuticals,

  These were completed and the facilities were inaugurated by Director, BARC, during the period 2021-22.

- Setting up of new facility for production of tritium filled sources is in progress.

- Commisioning of low level exempt liquid waste storage facility at (a) Radiopharmaceutical Laboratory & (b) Labelled Compounds Laboratory, at BRIT Vashi Complex were completed and inaugurated by Director, DCSEM.

(a)

(b)

Fig. 1: Inauguration by Director, BARC, of GMPcompliant facility for (a) Production of ^{177}Lu Radiopharmaceuticals, and (b) Production of ^{131}I-mIBG, at RPL, BRIT

(a)

(b)

Fig. 2: Inauguration by Director, DCSEM, DAE, of Low-level exempt liquid waste system at (a) Radiopharmaceutical Laboratory Facility, BRIT & (b) at Labelled Compounds Facility, BRIT

BRIT e-portal & Website

The responsibility of Computer & Network Management (C&NM) Section of BRIT is to maintain the accessibility, availability and security of the information infrastructure and various applications.

BRIT unified e-commerce application e-portal is accessible through internet to the BRIT users and customers all over India. The application has enabled customers to reach out to BRIT more effectively. It offers online placement of order, real-time tracking of orders and provision for making online payment. Notification and alert are sent to the customer at various stages from order placement, until, its delivery. Efforts were taken to design the API to integrate the BRIT e-portal with logistics software so that logistics milestone could be communicated to the customer during transportation.

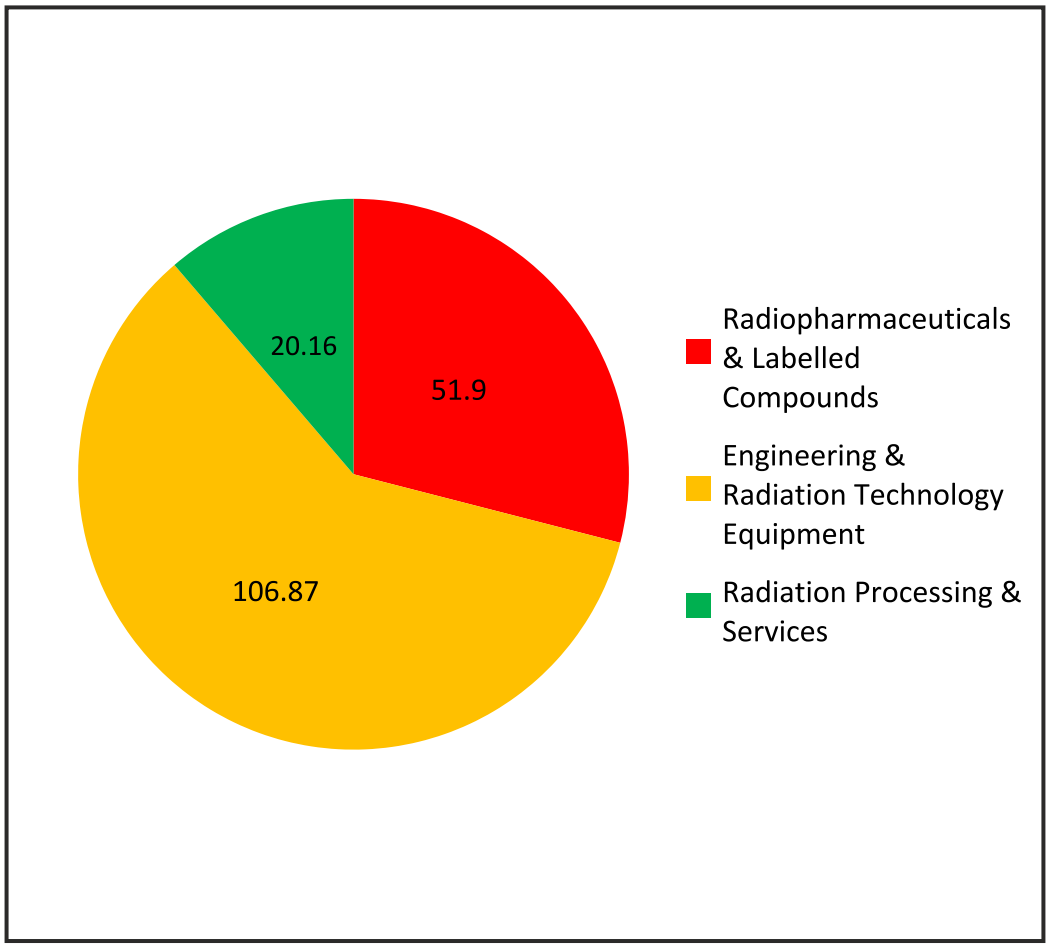
Approximately 400 Nos of Customer are on-boarded to e-portal. Approximately 30,000 orders and 25000 invoices are generated for various products and services this year.

BRIT has its Websites in bilingual form and it is updated regularly. BRIT website facilitates presentation of data for various key performance indicators (KPI), BRIT accomplishments, RTI and publications. New Announcement and upcoming BRIT Technologies are also published under NEWS Section. Updated procurement plan and tender/Minor tender information are published on BRIT Website for vendor. So far approximately 1273056 Nos. of visitors have visited BRIT website.

Information infrastructure including BRIT e-portal and BRIT website are audited to assess compliance, identify vulnerabilities, and ensure its security.

Sales Turnover

Sales data of BRIT Products and Services (Revenue in Crores) during 2021-22



Total Sales Turnover

Rs. 178.93 Cr

CHAPTER 2

RESEARCH & DEVELOPMENT ACTIVITIES

A. Radiopharmaceuticals Production Programme (RPhP), Vashi Complex

(a) Development and analytical validation of RIA kit for C-Reactive Protein (CRP)

Development and analytical validation of human C-reactive protein RIA kit for the diagnosis of illness related to an inflammatory or no-inflammatory conditions was completed in collaboration with Mangalore University. Kit standards were calibrated against WHO reference standards. Clinical validation is in in progress.

(b) Modification of ^{99m}Tc-TRODAT (TCK-55) Cold Kit for Improved Formulation

^{99m}Tc-TRODAT (TCK-55) is an established radiopharmaceutical for early diagnosis of Parkinson's disease. The initially developed lyophilized kit formulation for the preparation of the aforementioned product (TCK-55) has been reported to exhibit sub-optimal and inconsistent radiolabeling yields. In this context, work investigating the role of various kit excipients/physicochemical parameters to devise an improved formulation for patient use was undertaken. Kit labelling parameters were thoroughly re-investigated by varying various parameters such as ^{99m}Tc activity content (10-50 mCi/mL), reaction volumes (1-5 mL with 20 mCi), pH (4-7) and temperature (boiling water and autoclavable conditions). pH of the kit (20-30 mCi; 2-3 mL reaction volume) was varied using 0.05 M HCl/0.1 M phosphate buffer/0.1M NaOH solution. Labelling performance for each parameter was characterized by performing ITLC-SG and HPLC. It was found that pH of ^{99m}Tc-TRODAT formulation was responsible for the variable performance of kit. Maintaining pH in the narrow range 6.5-6.8 was found to be effective in preventing ^{99m}Tc colloid formation. Both 0.1 M phosphate buffer/0.1M NaOH were able to achieve the narrow pH range but a better pH control was achieved using phosphate buffer. Addition of phosphate buffer in existing kit formulation has been found to resolve the inconsistency in yields, thereby providing a robust kit for safe human use. Efforts are underway to put up a revised RPC approval of the above formulation for its regular production and supply.

B. Regional Centre, (RC, BRIT), Kolkata

Cyclotrons are used to produce radioisotopes for diagnostic and therapeutic use for cancer care. IBA Cyclone-30, 30MeV, 350mA proton cyclotron - the biggest cyclotron in India to produce radioisotopes /radio pharmaceuticals for medical application - became operational in September, 2018. SPECT *(Single-Photon Emission Computed Tomography) Isotopes* (^{67}Ga, ^{123}I, ^{201}Tl etc) PET *(Positron Emission Tomography)* isotope (^{18}F, direct production of ^{68}Ga, ^{68}Ge/^{68}Ga generator for *in-situ* production of ^{68}Ga, ^{124}I, ^{64}Cu, ^{89}Zr etc.) and therapeutic isotopes ^{103}Pd, ^{225}Ac could be produced in the Cyclone-30. During 2021-22 the following R&D assignments were carried out:

(a) Preparation of targets (enriched ^{203}Tl and ^{68}Zn) from depleted bath by pulse current electrodeposition for production of ^{201}Tl and ^{68}Ga & ^{67}Ga respectively

For production of radioisotopes ^{201}Tl, ^{68}Ga and ^{67}Ga in cyclotron via ^{203}Tl(p,3n)^{201}Pb → ^{201}Tl, ^{68}Zn(p,n)^{68}Ga and ^{68}Zn(p,2n)^{67}Ga nuclear reactions, enriched target materials ^{203}Tl and ^{68}Zn are being irradiated with high energy and high intensity proton beam. Since the enriched materials are very

costly minimum amount of enriched materials need to be irradiated to reduce the production cost. Enriched ^{203}Tl and ^{68}Zn Solid targets have been prepared by pulse electrodeposition technique for production of ^{201}Tl and ^{67}Ga at Medical Cyclotron.

Procedure:

The main purpose of the electrodeposition unit is to prepare simultaneously four electrodeposits of enriched material onto copper backings. The major physicochemical quality criteria of the electrodeposits may be summarized as follows:

- The target layer should adhere strongly to the copper target carrier (generally copper) at a temperature about 50ºC below the melting point of the corresponding metal
- Target layer should be homogeneous all over the surface area (±5%) & show a well-defined thickness that may vary from a few tens to several hundred microns
- Target layer should be smooth (not spongy), dense (no occlusions nor vacuoles) and stress-free
- The metal deposit & the carrier layer interface should be free of organic plating additives. Pulsed current electroplating technology is required to get the desired quality of the electrodeposited target layer, where pulsed current and voltage waveform and its parameters are different for different materials which need to be optimized experimentally for individual metal. The electrodeposition vessel is a hollow Perspex cylinder fitted with a central Pt-anode, four slots for copper carriers for simultaneous production of four targets and a stirrer-motor combination.

^{203}Tl Electrodeposition for ^{201}Tl Production

The electrodeposition bath was prepared by dissolving an amount of $^{203}Tl_2O_3$ (corresponding to the Tl weight of 4 targets) in the 50% ^{203}Tl depleted bath containing a complexing agent (EDTA), an anodic depolarizer and a wetting agent. From this bath, four targets were prepared by constant current electrolysis (current efficiency > 99%) involving the application of a bipolar chopped saw-tooth voltage between a central grounded Pt anode wire and four cathodes, i.e. four copper carriers, mounted vertically in appropriate windows of the electrodeposition vessel. Thereby after one electrodeposition cycle a 50% ^{203}Tl depletion is obtained, i.e.: one half of the ^{203}Tl-EDTA- is reduced to $^{203}Tl^0$ and deposited on the Cu backings. The control electronics involves a single generator, 4 voltage controlled current sources, and the stirrer-control.

^{68}Zn Electrodeposition for ^{68}Ga and ^{67}Ga production

The electrodeposition bath was prepared by dissolving an amount of Zn or ZnO (corresponding to the ^{68}Zn weight of 8 targets) in the 50% ^{68}Zn depleted bath containing an anodic depolarizer. The required amount of enriched Zn for 1 plating bath is 5g. Reuse of the plating bath up to 10 times is possible after addition of 2.5 g. From this bath, four targets were prepared by constant current electrolysis (current efficiency > 99%) involving the application of a chopped sine wave voltage between a central Pt anode wire and four grounded cathodes, i.e. four grounded

copper carriers, mounted vertically in appropriate windows of the electrodeposition vessel. Thereby a 50% ^{68}Zn depletion is obtained i.e. half of the $^{68}Zn^{++}$ is reduced to $^{68}Zn^{0}$ and deposited on the Cu backings.

Results:

- ^{203}Tl electrodeposition obtained: approx. 100 microns obtained in 5 hrs. 50 minutes time.
- ^{68}Zn electrodeposition obtained: approx. 120 microns obtained in 1 hr. 50 minutes time

(b) Production of ^{68}Ga Radioisotope from solid ^{68}Zn target in Cyclone-30 and Preparation of $^{68}GaCl_3$, ^{68}Ga-PSMA & ^{68}Ga-DOTA-TATE Radiopharmaceuticals

The irradiated target was dissolved in 20 mL of 10N HCl (containing 100 µL H_2O_2). Ion Exchange Chromatography using Dowex 50W-X8 resin (100-200 mesh, H^+ form) was carried out to remove Cu and ^{68}Zn from ^{68}Ga. Solvent extraction of ^{68}Ga from aqueous phase (HCl) to organic phase Di-Isopropyl Ether (DIPE) was carried out utilizing 15 mL DIPE (DIPE saturated with 7N HCl). Back extraction was performed by combining DIPE after adding 20 mL of 0.005N HCl. After successful removal of DIPE from aqueous phase, finally $^{68}GaCl_3$ (in 0.005N HCl) was collected and filtered with sterile pyrogen free 0.20 µm PES membrane syringe filter.

$^{68}GaCl_3$ solution obtained was assayed for radioactive concentration and suitable activity dispensed into sterile pyrogen free glass vials for supply. The entire operation was carried out in aseptic environment using ultrapure grade chemicals and sterile and pyrogen-free glassware to ensure the purity (radionuclide, radiochemical and chemical), sterility and apyrogenicity of the product. The physicochemical quality control and BET assay was completed prior to release of the product. Sterility was initiated within the same day of production.

All the operations were carried out remotely using the computer operated chemistry modules installed inside the processing hotcell. The ^{68}Ga-chloride was labelled with PSMA-11 & DOTA-TATE ligands. RPC Clearance has been received for the Production and Supply of Cyclotron-produced clinical grade [^{68}Ga]$GaCl_3$ as a radiochemical precursor for labelling of PSMA-11 and DOTATATE.

Quality Control Specifications of $^{68}GaCl_3$ is shown in Table 1.

Table 1: Specifications of $^{68}GaCl_3$

Test	Acceptance Criteria	Procedures	Testing Schedule
Appearance	Clear, Colorless solution, free from particulate matters.	Visual observation under adequate light behind Lead glass	Test to be completed prior to release.
pH	≤ 2	Narrow range pH paper strips to be used. *Details given in QC monograph*	Test to be completed prior to release.
Radioactive Concentration (RAC)	0.37 to 29.6 GBq / mL	Activity and volume are measured in pre-calibrated dose calibrator *Details given in QC monograph*	Test to be completed prior to release.
Radiochemical Purity (RCP)	The radioactivity as $^{68}GaCl_3$ (Ga^{3+} form) > 95% of total activity.	Method-I: TLC using BGO(V) coupled radio-chromatogram scanner.	Test to be completed prior to release.
		Method-II: Reversed phase HPLC using NaI(Tl) and UV detector *Details given in QC monograph*	Test to be initiated immediately after production but not completed prior to release of product
Radionuclide Purity (RNP)	^{67}Ga & ^{66}Ga (both together) < 2 % Other long lived γ rays emitting radionuclides < 0.1 % (^{65}Zn)	HPGe detector coupled to 4k channel MCA.. *Details given in QC monograph*	Test to be completed prior to release.
Radionuclide Identity (RNI)	The measured half-life should be within the range 67.71 ± 0.1 minutes	$T_{1/2}$ Method. *Details given in QC monograph*	Test to be performed once in every 10 batches.
Sterility Test	As per IP 2007 (Chapter 2.2.11.)	Direct Inoculation Method. *Details given in QC monograph*	Test to be initiated immediately after production but not completed prior to release of product (Post-facto).
Test for Apyrogenicity	As per IP 2007 (Chapter 2.2.3.)	Gel Clot Method. *Details given in QC monograph*	Test to be completed prior to release of product.
Shelf life	5h from the reference date and time	Stability to be assured by testing RCP (TLC)	Test to be performed once in every 10 batches.
Metal content analysis	Fe: < 10µg / GBq Zn: < 10 µg / GBq Cu: < 10 µg/ GBq	Colorimetric Method (Radioactive samples) and ICP-AES (Decayed samples) *Details as given in QC monograph*	Test to be performed once in every 10 batches
Residual Solvent Levels	DIPE < 98 ppm	Gas Chromatography *Details as given in QC monograph*	Test to be performed once in every 10 batches

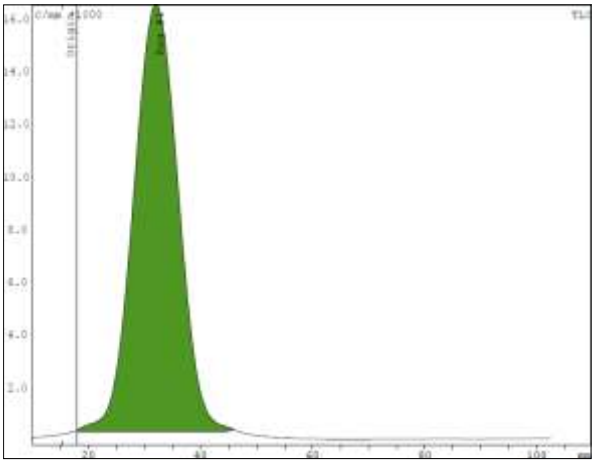


Fig. 1: TLC Spectra of $^{68}GaCl_3$ (R_f: 0.24, RCP: 100%)

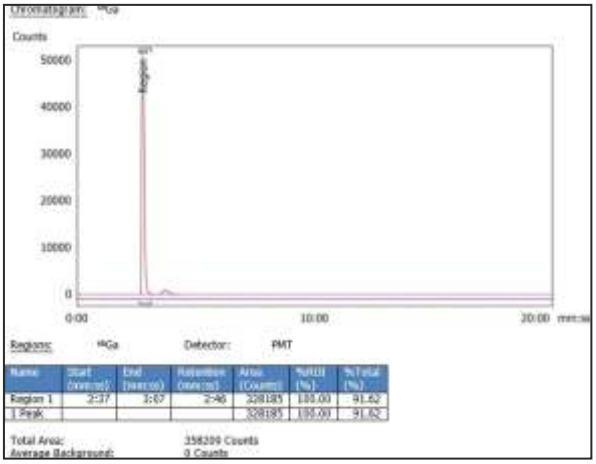


Fig. 2: HPLC of $^{68}GaCl_3$ (R_t: 2.46 min.; RCP: 100%)

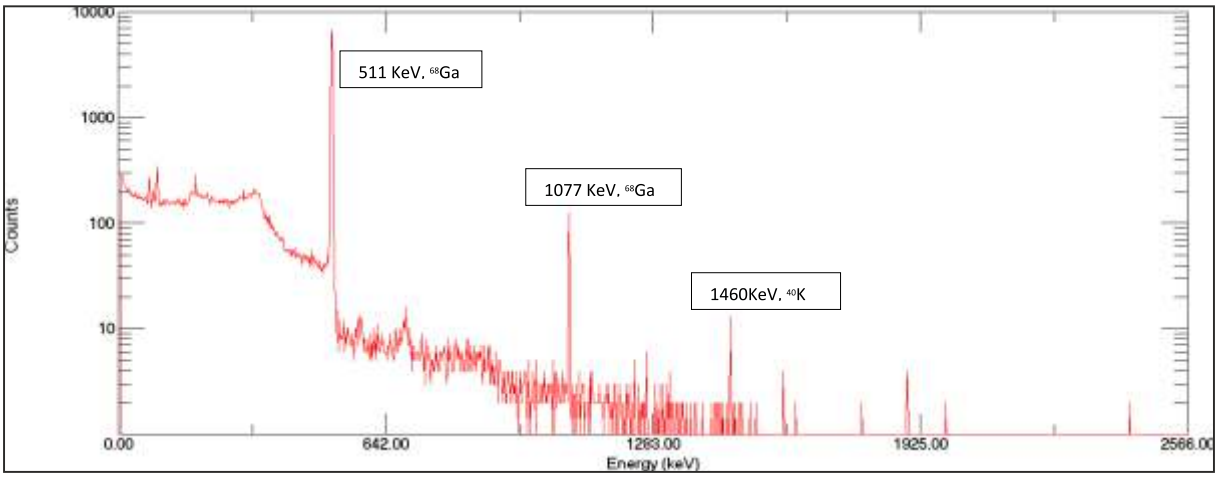


Fig. 3: HPGe Spectra of $^{68}GaCl_3$ (Activity: 122 nCi/20µL; Counting Time: 300 Sec; Radionuclidic Purity (RNP): 99.89%; Prominent Characteristic γ-ray peak (511 and 1077 KeV) of Pure ^{68}Ga is detected

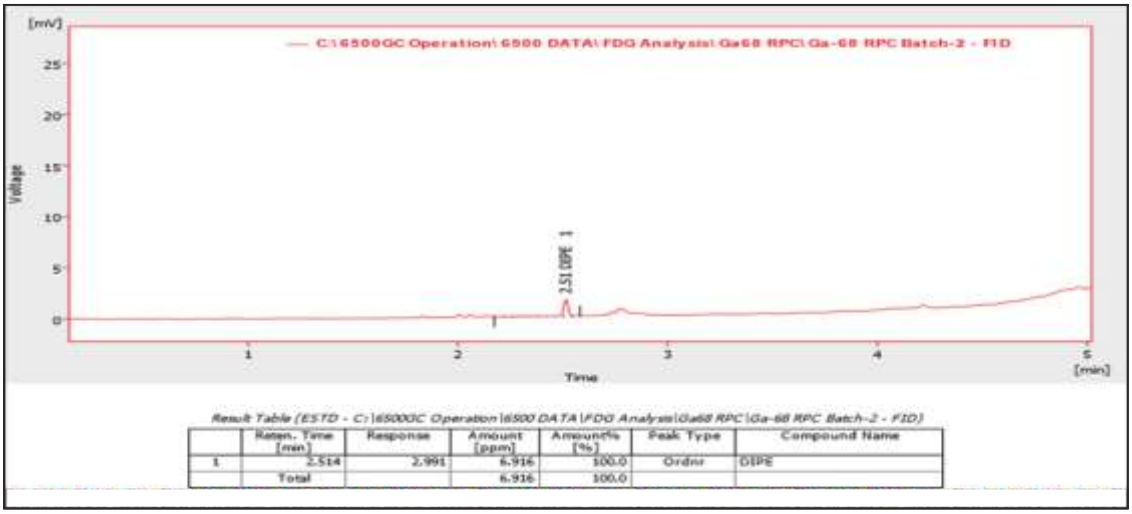


Fig. 4: HPGe Spectra of $^{68}GaCl_3$ (Batch No. 2: R_t of DIPE: 2.51 min., 6.91 ppm)

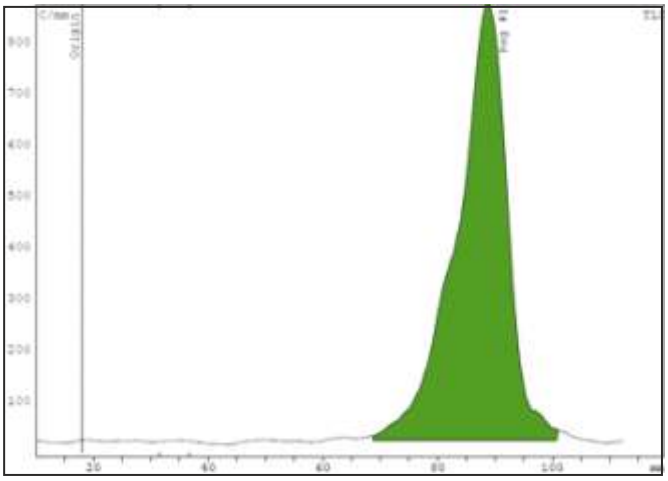


Fig. 5: TLC Spectra of [^{68}Ga]Ga-PSMA-11 (R_f: 0.79; RCP: 100%)

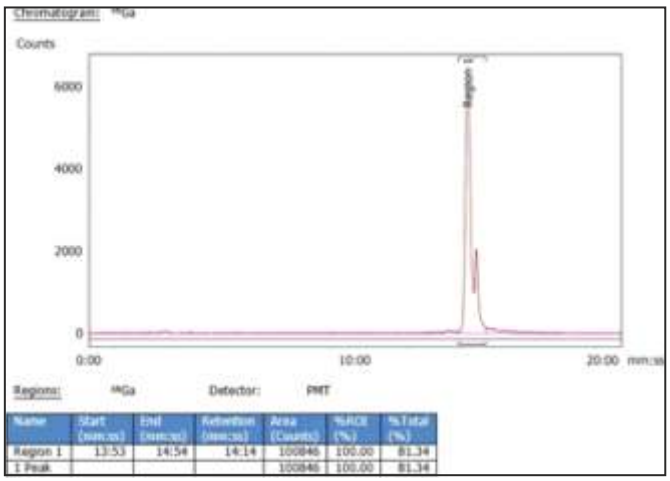


Fig. 6: HPLC of [^{68}Ga]Ga-PSMA-11 (R_t: 14.14 in.; RCP: 100%)

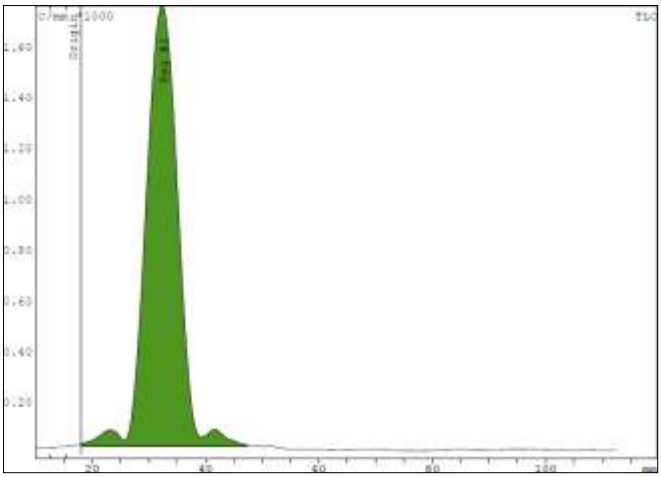


Fig. 7: TLC Spectra of [^{68}Ga]Ga-DOTA-TATE [R_f: 0.79; Radiochemical Purity (RCP): 100%]

(C) Production and Supply of Sterile, Pyrogen Free, Isotonic Aqueous solution of Radioactive Thallium-201 (^{201}Tl) in the form of Thallous Chloride suitable for diagnostic uses in Patients

Thallium-201 (^{201}Tl, $t_{1/2}$ = 73.06 hours) in the form of Thallous Chloride is a potential myocardial flow tracer to detect coronary artery disease as regional disparities in scintigraphy studies. It is also used to assess myocardial viability, with an accuracy comparable to that of positron emission tomography.

^{201}Tl was produced via reaction ^{203}Tl(p,3n)^{201}Pb → ^{201}Tl utilizing a proton (28 MeV) beam current of 25-50µA for up to 8h. At first chemical separation of ^{201}Pb from ^{203}Tl was done within 1h after end of bombardment (EOB). Then after 32-34 hrs of decay of ^{201}Pb to ^{201}Tl, second separation was

carried out to get [^{201}Tl] TlCl radiopharmaceutical. The production of ^{201}TlCl, has been carried out in GMP certified hot cell and automated radiochemistry module under aseptic environment. Physico-chemical and biological quality control of ^{201}TlCl were optimized and carried out at MCF, BRIT, Kolkata. RPC Clearance has been obtained for the Production and Supply of Sterile, Pyrogen Free, Isotonic Aqueous solution of Radioactive (^{201}Tl) in the form of Thallous Chloride suitable for diagnostic uses in patients.

Chemistry-I: The irradiated target was dissolved in 25 mL of 0.7N HNO_3 (containing 100 mg $Pb(NO_3)_2$). ^{201}Pb was precipitated as $^{201}PbSO_4$ by using 10 mL of 3.6N H_2SO_4. The first dissolution of $^{201}PbSO_4$ was carried out with 10 mL of 0.1M Na_2EDTA (pH ~ 9.0), while second dissolution was carried out with 10 mL of 0.1M Na_2EDTA (pH ~ 5.4). $^{203}Tl^{3+}$ was reduced to $^{203}Tl^{+}$ by bubbling SO_2 gas. Ion Exchange Chromatography using Dowex 50W-X8 resin (100-200 mesh, H^+ form) was employed to remove co-precipitated $^{203}Tl^{+}$. Cation exchange chromatography was employed to adsorb $^{203}Tl^{+}$ in the column while the ^{201}PbEDTA complex was collected in column eluate. $^{201}PbEDTA^{2-}$ complex was stored for 32h for decay of $^{201}Pb^{2+}$ either to $^{201}Tl^{3+}$ or $^{201}Tl^{+}$.

Chemistry-II: Post 32h decay, $^{201}Pb^{2}$+ (in the form of ^{201}PbEDTA mother solution) was converted to either $^{201}Tl^{3+}$ or $^{201}Tl^{+}$. The reduction of $^{201}Tl^{3+}$ to $^{201}Tl^{+}$ was carried out by bubbling SO_2 gas through the mother PbEDTA solution until a pH ~3 is attained. Post reduction, the pH of reduced $^{201}Tl^{+}$ in mother PbEDTA solution was adjusted to ~ 5.4 by using 1N NaOH. The mother PbEDTA solution containing $^{201}Tl^{+}$ was passed through Dowex 50W-X8 resin (100-200 mesh, H^+ form) chromatographic column. $^{201}Tl^{+}$ was adsorbed in the column while PbEDTA was collected as eluate in waste flask. The adsorbed $^{201}Tl^{+}$ was eluted from cation exchange chromatographic column using 15 mL of 6N HCl. Further $^{201}Tl^{+}$ was oxidized to $^{201}Tl^{3+}$ using ozone. Solvent extraction of $^{201}Tl^{3+}$ from aqueous phase (HCl) to organic phase (DIPE) was carried out utilizing 15 mL DIPE (DIPE saturated with 7N HCl). Back extraction was performed with DIPE after adding 15 mL of 0.005N HCl. Reduction of $^{201}Tl^{3+}$ to $^{201}Tl^{+}$ was carried out by SO_2 gas in aqueous phase (0.005N HCl). Post reduction, $^{201}Tl^{+}$ was back extracted into 15 mL of 0.005N HCl. After successful removal of DIPE from aqueous phase, finally ^{201}TlCl ($^{201}Tl^{+}$ form, in 0.005N HCl) was collected. pH of ^{201}TlCl was adjusted to 6 - 7 using 1N NaOH and was diluted with 0.9% NaCl. ^{201}TlCl (in 0.9% NaCl) was filtered with sterile pyrogen free 0.20 µm PES membrane syringe filter.

^{201}TlCl ($^{201}Tl^{+}$ form) solution obtained was assayed for radioactive concentration and suitable activity dispensed into sterile pyrogen free glass vials for supply. The entire operation was carried out in aseptic environment using ultrapure grade chemicals and sterile and pyrogen-free glassware to ensure the purity (radionuclide, radiochemical and chemical), sterility and apyrogenicity of the product. The physicochemical quality control and BET assay was completed prior to supply of the product. Sterility was initiated within the same day of production.

Quality Control Specifications of ^{201}TlCl is shown in Table 2.

Table 1: Specifications of ^{201}TlCl

Test	Acceptance Criteria	Procedures	Testing Schedule
Appearance	Clear, Colorless solution, free from particulate matters.	Visual observation under adequate light behind Lead glass	Test to be completed prior to release.
pH	4.5 – 7.5	Narrow range pH paper strips to be used. *Details given in QC monograph*	Test to be completed prior to release.
Radioactive Concentration (RAC)	74 to 555 MBq / mL	Activity and volume are measured in pre-calibrated γ dose calibrator *Details given in QC monograph*	Test to be completed prior to release.
Radiochemical Purity (RCP)	The radioactivity as ^{201}TlCl(Tl^+ form) > 95% of total activity.	TLC using BGO(V) or NaI(Tl) coupled radio-chromatogram scanner.	Test to be completed prior to release.
Radionuclide Purity (RNP)	^{200}Tl ≤ 0.6% ^{202}Tl ≤ 1.2% ^{203}Pb ≤ 0.2%	γ-Spectrometry (HPGe detector coupled to 4k channel MCA.) *Details given in QC monograph*	Test to be completed prior to release.
Radionuclide Identity (RNI)	The measured half-life should be within the range 70- 75 hours	$T_{1/2}$ Method. *Details given in QC monograph*	Test to be performed once in every 10 batches.
Sterility Test	As per IP 2007 (Chapter 2.2.11.)	Direct Inoculation Method. *Details given in QC monograph*	Test to be initiated immediately after production but not completed prior to release of product (Post-facto).
Test for Apyrogenicity	As per IP 2007 (Chapter 2.2.3.)	Gel Clot Method. *Details given in QC monograph*	Test to be completed prior to release of product.
Shelf life	Seven days from the reference date and time	Stability to be assured by testing RCP (TLC)	Test to be performed once in every 10 batches.
Metal Content	Fe: < 5.0 µg / mL Cu: < 5.0 µg/ mL Tl: < 2.0 µg/ mL	Colorimetric Method *Details as given in QC monograph*	Test to be performed once in every 10 batches
Residual Solvent Levels	DIPE < 98 ppm	Gas Chromatography *Details as given in QC monograph*	Test to be performed once in every 10 batches

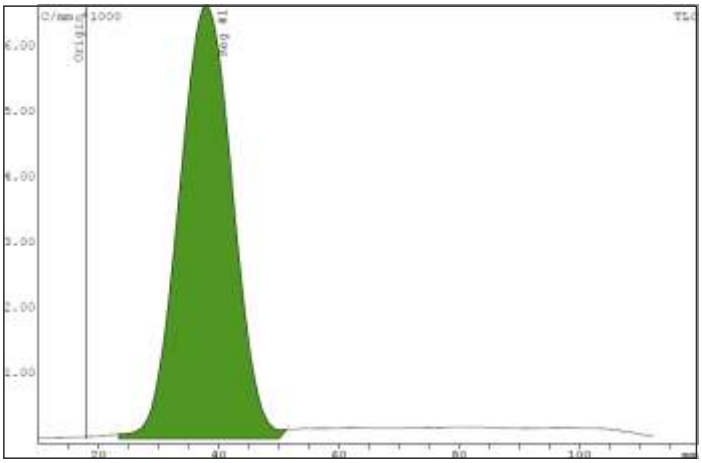


Fig. 1: TLC Spectra of ^{201}TlCl
(R_f: 0.28, Radiochemical Purity (RCP): 100 %)

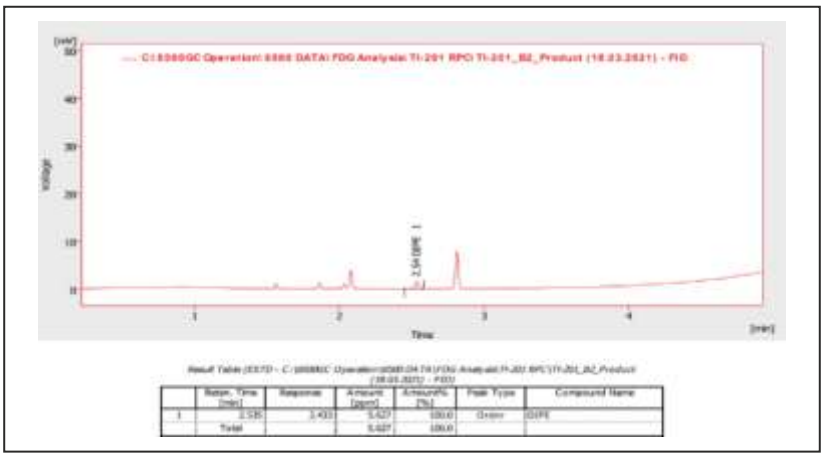


Fig.2: HPGe Spectra of ^{201}TlCl *(R_t of DIPE (solvent): 2.53 min, 5.63 ppm)*

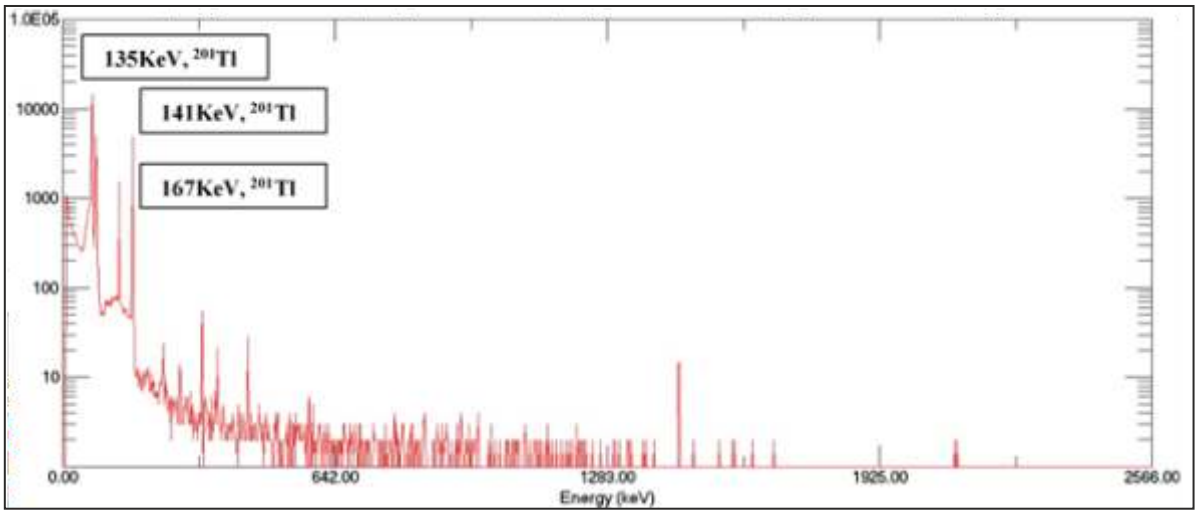


Fig. 3: HPGe Spectra of ^{201}TlCl

[Counting time: 300s, Radionuclidic Purity (RNP): 99.98% Prominent characteristic γ-ray peak (135 KeV, 141 KeV and 167 KeV) of pure ^{201}Tl is detected]

Patient Study using ^{201}TlCl

Thallium-201 chloride (^{201}Tl) for cardiac imaging studies towards early diagnosis of heart ailments. BRIT Regional Centre at Kolkata jointly with VECC, Kolkata, produced ^{201}Tl for the first time from the 30 MeV cyclotron [CYCLONE-30]. ^{201}Tl-chloride was recently approved for use in cardiac imaging by Radiopharmaceutical Committee, DAE. The ^{201}Tl patient doses were supplied to NH Rabindranath Tagore International Institute of Cardiac Sciences, Kolkata. Excellent feedback has been received from the hospital on the SPECT imaging performed in two patients for ischemia evaluation and viability assessment respectively. The ^{201}Tl produced by BRIT RC Kolkata reportedly showed good bio distribution as shown in Fig. 4 with good cardiac uptake due to which excellent quality images could be obtained. Uptake of ^{201}Tl in the liver and soft tissues was low as compared to that of ^{99m}Tc-MIBI in the same patients.

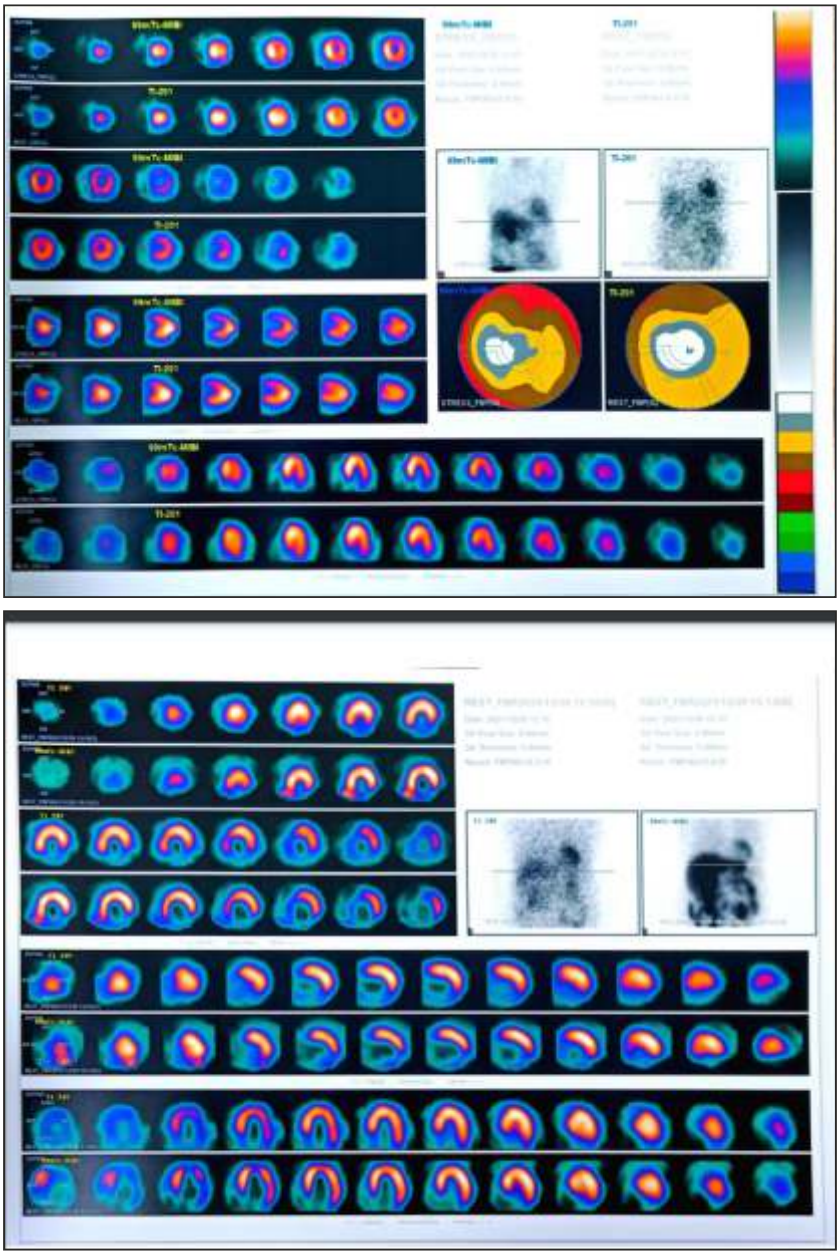


Fig 4: SPECT Imaging for cardiac studies for two patients: A comparison between ^{201}TlCl and ^{99m}Tc-MIBI

C. MIG Section, Control & Instrumentation (C&I)

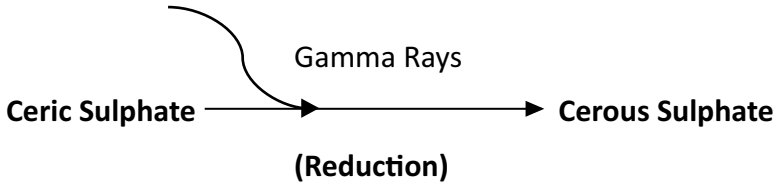
a) Design and Development of prototype milliVoltmeter for Ceric Cerous Dosimetry System

Radiation Processing Plant, Vashi (RPP) is the first commercial-scale Gamma Irradiator for food processing in India. The facility was commissioned on January 1, 2000, with the mandate of showcasing commercial viability of Gamma Irradiators for food processing. The facility is providing radiation processing services to more than 300 customers from all over the country for irradiation of spices, Ayurvedic raw materials, pet feed, animal feed and packaging material etc.

BRIT offers Ceric Cerous Sulphate Dosimetry system which is used for measurement of absorbed dose in Gamma radiation processing plants. Dosimeters are used for routine dosimetry, dose-mapping and plant validation of Industrial Gamma Irradiators. Evaluation of absorbed dose in radiation processed product with dosimeters play a vital role in the Quality Assurance programme of industrial Gamma Irradiators. BRIT offers Ceric-Cerous dosimeters prepared as per ISO/ASTM 51205:2009(E) specifications for use across a wide dose range (1 to 45 kGy). These dosimeters are traceable to National Standard Laboratory, BARC and offer a simple read-out system.

The Ceric Cerous Dosimetry system consists of an electrochemical cell (Fig. 1) and an precision electronic digital milli-voltmeter apparatus (Fig. 2 and Fig. 3) for the potentiometric method of measurement of total radiation dose from the difference in electrochemical potential between an un-irradiated solution containing known concentrations of Ceric and Cerous ions and a gamma irradiated solution initially containing the same known concentrations of Ceric and Cerous ions. The apparatus comprises a cell which is divided into two sections, which are separated by a porous frit.

The gamma irradiation reduces Ceric Sulphate solution to Cerous Sulphate



The solution separated by the porous frit develops electric potential in milli-Volts range that can be measured using a precise milli-Voltmeter to map the total dose. The potential is developed between nodes marked F and G in Fig. 1 which is measured using a high precision digital milli-voltmeter of range 0-100mV with an accuracy better than 1%.

An electrochemical cell, similar to that described above, should be used (Fig. 1). The electro potential across the cell should be measured with a high-precision digital voltmeter that is capable of measuring dc potentials in the range from 0 to 100 mV within an accuracy of 1 %. The electrochemical cell has two compartments separated by a porous junction, such as a glass frit, a ceramic or kaolin junction, or a fibreglass wick. The inner compartment is always filled with unirradiated solution. The lower compartment is filled with solution whose response is to be measured (transferred from an irradiated or unirradiated ampoule). The electro potential, E, generated between the platinum electrodes in the two compartments is measured by a digital voltmeter.

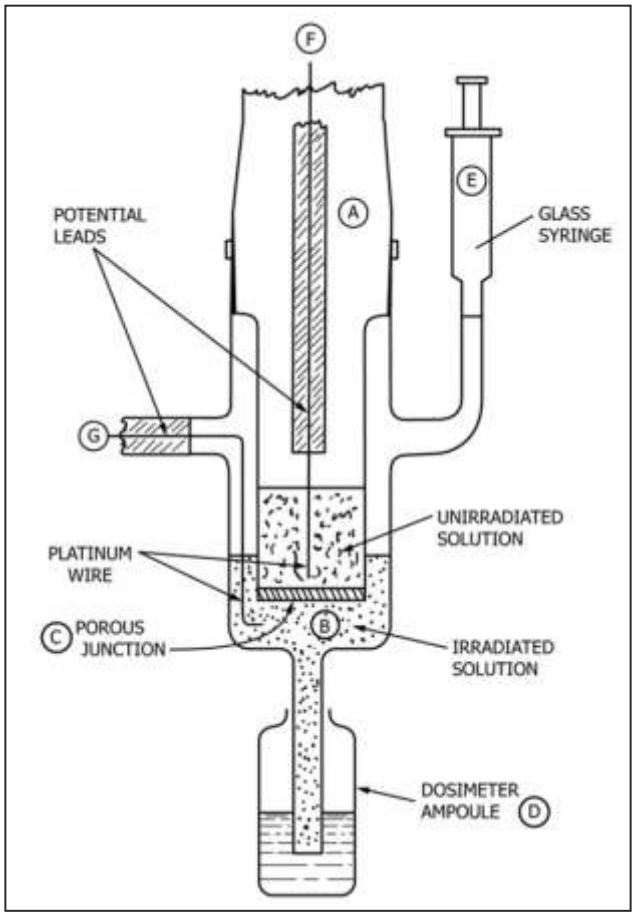


Fig. 1 Ceric-Cerous Electrochemical cell. (Ref: ISO/ASTM 51205:2017(E) Standard Practice for use of Ceric-Cerous Sulfate Dosimetry System)

There has been a recent requirement of a revamped milli-Voltmeter to replace the older model and incorporate new features. The Ceric-Cerous electrochemical cell is a very feeble voltage and current source that a needs very precision voltage measurement instrument to measure the potential difference without loading the cell and therefore getting erroneous measurement. Like any chemical cell it also tends to discharge when electric load is applied at the cell terminals. Keeping this in mind an electronic design (Fig. 2) containing a very high input impedance precision operational amplifier (OPAMP) with extremely low offset and temperature drift has been incorporated at the input stage. It is followed by a Schottky diode-based protection clamp for Analog to Digital (ADC) converter input protection. The Analog to Digital converter converts the input analog voltage amplified by the input amplifier to binary digital form which is read by a microcontroller based embedded system and is processed accordingly for a digital read out on a good quality and legible Graphics LCD. An additional feature of ambient temperature measurement and its digital readout on the same display has been provided in accordance with point 10.5.8 of ASTM/ISO 51205-2017 for readout of temperature in the near vicinity of the electrochemical cell and then to apply correction for this temperature by the staff carrying out measurement. The temperature is measured using an extended temperature sensor probe attached near the electrochemical cell mount on the experiment table.

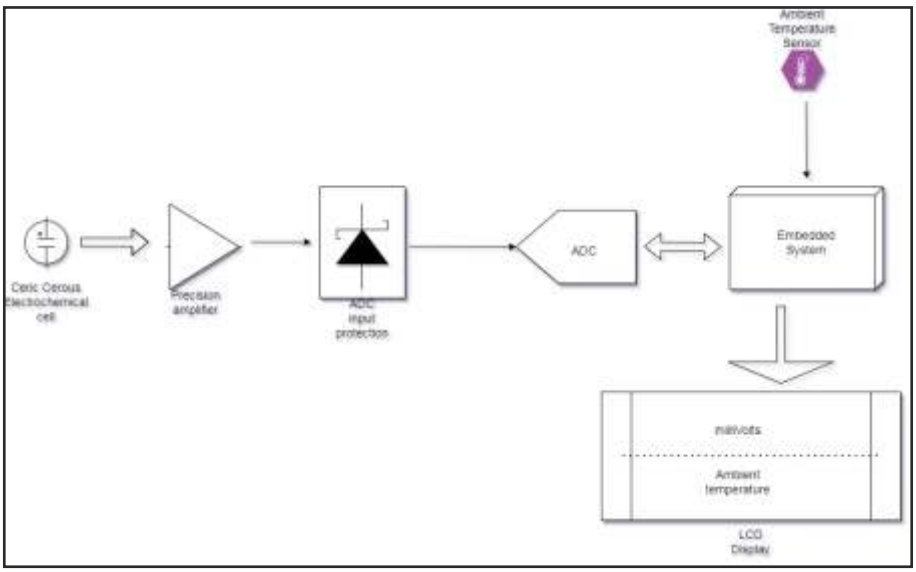


Fig. 2: Block diagram of the designed system

When Ceric-Cerous Sulphate dosimeters are exposed to gamma radiation. Ceric ions are reduced to Cerous ions. The electrochemical potential difference, ΔE, between an unirradiated dosimeter solution and an irradiated solution, is used in the following expression to calculate the absorbed dose in kGy.

(radiochemical yield of the Cerous ion, mol /J)
ΔE = Electrochemical potential difference (mV) at 25° C
solution(mol/L)
solution(mol/L)

Fig. 3: Instrument with Graphics LCD with milli Volt readout and Ambient temperature readout.

D. Medical Cyclotron Facility (MCF), Parel, Mumbai

(a) Radiochemical Studies of ^{68}Ga Radiopharmaceuticals via Production of ^{68}Ga from a Liquid Target

^{68}Ga was produced in Medical Cyclotron using $^{68}Zn(NO_3)_2$ target via $^{68}Zn(p,n)^{68}Ga$ reaction. ^{68}Ga was separated from $^{68}Zn(NO_3)_2$ target using solid phase extraction method. In order to standardize the process, $^{68}GaCl_3$ from ^{68}Ge-^{68}Ga generator was spiked with different concentration of $^{68}Zn(NO_3)_2$ solution. Separation was carried out in the indigenously developed synthesis module. The separation of $^{68}GaCl_3$ process was optimised.

E. Quality Control - Radiopharmaceutical Production, Vashi Complex

(a) Designing of Microbiological Sterility Testing Module

Automatic sterility testing module has been designed and delivered. The equipment will be thoroughly validated and approval would be sought from competent authority. This is an important step in automation of Quality Control of Radiopharmaceutical procedures, which would reduce operator fatigue/error and boost productivity.

CHAPTER 3

HUMAN RESOURCES DEVELOPMENT ACTIVITIES

Training Courses/ Lectures/ Workshops/ Seminars/Conferences

1. One M.Sc. student of Nuclear Medicine from School of Medical Science & Technology (SMST), IIT, Kharagpur, West Bengal, successfully completed his research project internship under Dr. Sankha Chattopadhyay, OIC, RC, Kolkata.

2. Dr. Sankha Chattopadhyay delivered three lectures on 'Radiopharmaceuticals' for M.Sc. Nuclear Medicine students, School of Medical Science & Technlogy (SMST), IIT Kharagpur, West Bengal.

3. Dr. Sujata Saha Das delivered lecture on 'An Overview of Radioisotopes/ Radiopharmaceuticals' produced in Cyclone-30: Production and Quality Control'. This lecture was arranged through Webinar, mainly for BRIT employees, which was conducted by SIR&P Section of BRIT, under Continuous Education Program (CEP).

4. Dr. Arjun Gopalakrishna, along with Dr. S. P. Kulkarni and Dr. P. Pujari of BARC, were involved in the submission of Technical Specification Report and Renewal of Operating Licence of 16.5 MeV Medical Cyclotron.

5. **Dr. Anupam Mathur received the Scientific & Technical Excellence Award of DAE for the year 2020, for his immense contributions to the ^{177}Lu radiopharmaceutical programme.**

6. **BRIT team (Shri. Manohar Bhatia & Shri. Dheeraj Kumar) was part of the DAE Contingent which won the 'Best Technology Pavilion' at the India-International Science Festival at Goa held during 10-13 Dec. 2021.**

7. **Radiopharmaceutical production team won the Best oral presentation award for the abstract entitled "Production of medical-grade no carrier added $^{177}LuCl_3$ via neutron activation of enriched ^{176}Yb target" at the 53rd Annual Conference of the Society of Nuclear Medicine (India) held in virtual mode during 16th to 18th Dec. 2021.**

8. Dr. Usha Pandey delivered an invited lecture on "^{99m}Tc chemistry and Evolution of ^{99m}Tc Radiopharmaceuticals" in a web-based thematic symposium on Radiopharmacy organized by Indian College of Nuclear Medicine on 17th October 2021.

9. A one week orientation visit to Radiopharmaceutical production laboratories at BRIT Vashi Complex was organized for the M.Sc. Hospital Radiopharmacy students of RMC, BARC. The schedule comprised of series of lectures on the various aspects of radiopharmaceutical production along with the visits to the production laboratories. This was co-ordinated by Dr. Chanda Arjun, Manager, QC.

10. **Dr. (Smt) Yojana Singh, Sr. Manager, Customer Relations & Publicity, BRIT, had conducted a total of ten lectures under the lecture series to celebrate "Azadi ka Amrit Mahotsav", between August 2021 to August 2022 through virtual mode. The theme of these lectures was "Radiation & Radioisotope based Technologies for Medical and Industrial applications" and lectures were given by Dr. Anupam Mathur, who delivered two lectures, entitled "Advances in Radioisotope based technologies for Healthcare Management and**

"Radioisotope based imaging modalities for early screening of human diseases". Shri. N. Jayachandran delivered lecture on 'Measurement of Radionuclide Content in Commodities', Dr. Dhiren Sahoo delivered a lecture on "New Developments in Exposure Devices for Industrial Radiography", Shri. R. Krishnamohan delivered his talk on "Ensuring the Safety of Radiopharmaceuticals for Human Use", Shri. Amit Shrivastava talked on "Gamma Radiation Sterilisation Technology – An indefatigable workhorse for Healthcare Industry", Shri. Vinay Bhave delivered his talk on "Applications of Radioisotopes in refineries", and Dr. Sankha Chattopadhyay delivered a talk on "Production and supply of pharmaceutical grade Na[^{18}F]F injection using Cyclone-30".

Two invited talks were also arranged, one on, "Gamma Radiation Technology for Municipal Sewage Sludge Hygienisation", which was delivered by Dr. Lalit Varshney, Former Head, RTDD, BARC, and another one, "Radiation processing Technology in PPP mode – How the nation has benefitted?" by Shri. Vikram Kalia, Managing Director, Microtrol Sterilization Services Pvt. Ltd.

11. Shri. Dheeraj Kumar participated in and completed the KAERI-WCI-IAEA E-Learning Course on 'Diagnostic and Therapeutic Radioisotopes and Radiopharmaceuticals Application' held on August 2-20, 2021, and completed the training course as an excellent grader by securing 94 % marks in the training course.

12. Shri. Soumen Das attended and presented work titled 'Design and characterization of a new Technetium-99m labeled folate derivative towards targeting of folate receptor positive malignancies' in the IAEA 'Technical Meeting on State of the Art Research Reactor Based Radioisotope and Radiopharmaceutical Production' as a virtual event from March 22-26, 2021.

13. Post graduate students of various Universities were trained in various aspects of radiopharmaceutical development for their project work as part of their M.Sc. curriculam. 5 graduate and postgraduate students were imparted training in the field of radiopharmaceuticals while 4 postgraduate students were trained in the field of RIA and allied sciences.

14. Dr. Anupam Mathur, Dr. Vrinda PC, Dr. Shubhangi Mirapurkar, Dr. S.K. Sarkar, Smt. Archana Ghodke and Smt. Uma Sheri Kumar delivered lectures on Radiopharmaceuticals to M.Sc, HRP Trainees from RMC, BARC on 30/10/2021.

15. Dr. Anupam Mathur, Shri. G. Shunmugam, Shri. Navin Sakhare, Smt. Uma Sheri Kumar and Smt. Richa Tiwary represented BRIT in Indian Nuclear Society (INS) exhibition held at Atomic Energy Junior College during 18-20 Dec 2021.

16. Shri. Abhisheik Sharma was awarded Doctor of Philosophy degree in Chemistry discipline from Homi Bhabha National Institute (HBNI) in Nov. 2021. The title of PhD thesis is "Radiochemical Separation and Purification of Molybdenum-99 for Medical and Industrial applications".

17. Officers of RPL, RPh-QC, LC&TS, ESSA, MIG, ES and ILU-EB Section of BARC, successfully conducted Basic course (3 month duration) and Advance course (3 months duration) for imparting training to newly recruited batch of Cat I/II Trainees in BRIT. A special mention about the ^{99}Mo Generator group Officers of RPL in this aspect is a must as this group has taken a lead role in taking up the responsibilities which involved designing of course structure, syllabus, compilation of lecture notes, arranging of lectures, practical, demonstrations and site visit (DHRUVA, APSARA etc.).

18. ^{99}Mo Generator group along with other officers of RPL, RPh-QC, LC&TS, ESSA, ES, MIG and ILU-EB Section of BARC were involved in conducting and assessment of theoretical exams and viva-voce examination of CAT-I/ II trainees.

19. RPhP-QC laboratory, Vashi Complex, received ISO 9001:2015 certification after their party audit by AJA authorized agency. The Quality Manual and required documentation including SOP's were prepared by the Officers of RPhP-QC Section, and were duly approved.

20. One Post graduate student of Mumbai University was trained for his project work, as part of his M.Sc. curriculam, in the field of Microbiology Laboratory of Radiation Processing Plant (RPP), Vashi.

21. Officers of Microbiology Laboratory, RPP, Vashi, conducted internal quality audits/surveillance for Quality Management Systems (QMS/FSMS/MDQMS) of RPP Facility. They could successfully obtain licences from CDSCO for radiation sterilization of Class C & D Medical Devices.

22. Shri. Ashraf, RSO, RAPPCOF, Kota, delivered 6 lectures during the Training & Awareness Programmes conducted by Nuclear Training Centre of NPCIL, DAE, R. R. Site, regarding the "Commercial Production of High-Intensity Cobalt-60 Sealed Sources, their Applications & the Role of Board of Radiation & Isotope Technology (BRIT) in the Use of Atomic Energy for Societal Benefit”.

23. Officers of Regional Centre, Delhi, prepared a Radiological Practical Manual, viz., 'Trainer's Manual and Log book' for the course material of Post Graduate Certificate for MMCBRNE Programme of IGNOU University.

24. Dr. Teena Goel delivered a lecture and training on "Management of Nuclear and Radiological Emergencies", at Research and Innovation in CBRN Medical Emergencies, held at IITD, New Delhi, on Nov. 23, 2021.

25. Shri. Deepak B. Kalgutkar delivered lecture on "Production of radioisotopes and labelled compounds" in Training cum RSO Certification Course on Radiation Safety Aspects in Research Application of Ionizing Radiation (Twice during the Year 2021, May & Dec.) and to the students of Diploma in Radiation Protection (DRP) conducted by RPAD, BARC.

26. Dr. Chanda Arjun participated (in virtual mode) in the IAEA Technical Meeting on 'Radiolabelled Molecules for Diagnosis and Treatment of Infections and Inflammation' held at IAEA, Vienna from 14 -18, March, 2022, and contributed to the Manuscript task assigned to all participants.

Publications in Peer Reviewed Journals

1. **Clinical Doses Production of Pharmaceutical Grade Sodium [^{18}F] Fluoride using Modified Integrated Fluidic Processor in a SYNTHERA Module.**

   S. Chattopahyay, A. De, U. Kumar, A. Mitra, L. Barua, S. Saha Das, Md. N. Alam, S. Ash, Madhusmita, D.G. Mahesh

   Applied Radiation & Isotopes 179 (2022) 110035.

2. **Regular production and supply of ready-to-use gallium-68 radiopharmaceuticals: centralized radiopharmacy concept with supply experience of 300 doses.**

   Dheeraj Kumar, Anupam Mathur, Vrinda Prashant, Shubhangi Mirapurkar, Soumen Das, Sanjeev Kumar, Vishwas Murhekar

   Jour. Radioanal. & Nucl. Chem 330/3 (2021) 83-90.

3. **Development of Technetium-99m labelled ultrafine gold nano bioconjugates for targeted imaging of folate receptor positive cancers.**

   Dheeraj Kumar, Navin Sakhare, Soumen Das, Pooja Kale, Anupam Mathur, Shubhangi Mirapurkar, Sheela Muralidharan, *Pradip Chaudhari, Bhabhani Mohanty, Anand Ballal, Pankaj Patro*

   Nucl. Med. & Biol. 93 (2021) 1-10.

4. **Camptothecin enhances ^{131}I-rituximab-induced G1-arrest and apoptosis in Burkitt lymphoma cells.**

   Chandan Kumar, Rohit Sharma, ***Krishna Mohan Repaka,*** *Aanchal Udaynath Pareri, Ashutosh Dash*

   Journal of Cancer Res. Ther. 17/4 (2021) 943-950.

5. **Revision of discharge limit of gross beta activity to the aquatic environment based on public dose estimation: An Operational Study.**

   Singh, H., Goel, T., Kadwad, V. B., Mukherjee, P.

   Radiat. Protect. Environ. 44 (2021) 42-46.

6. **Prostate-Specific Membrane Antigen Expression in Patients with Differentiated Thyroid Cancer with Thyroglobulin Elevation and Negative Iodine Scintigraphy Using ^{68}Ga-PSMA-HBED-CC PET/CT.**

   Verma, Priyanka; Malhotra, Gaurav; Meshram, Vilas; ***Chandak, Ashok;*** *Sonavane, Sunita; Lila, Anurag R.; Bandgar, Tushar R.; Asopa, Ramesh V.*

   Clin. Nucl. Med. 46/8 (2021) pp. E 406–E 409.

7. **Pulmonary Embolism as Post COVID 19 Sequelae: Role of Lung Perfusion Scintigraphy**

   Keerti Sitani, Priyanka Verma, Ramesh D. Rao, ***Ashok Chandak****, Ramesh V. Asopa*

   Ind. J. Nucl. Med. 36/4 (2021) pp. 455–456.

8. **A successful virtual technical exchange between India, The United Kingdom, and The United States on security by design for devices and facilities that use radioactive materials**

   Michal Kuca, Kaitlin Oujo, Vijendra Sinha, ***Dhiren Sahoo****, Probal Chaudhury*

   Full Length Paper Published in the Souvenir released by International Atomic Energy Agency (IAEA), Vienna, June 20-24, 2022.

Conference Proceedings and Abstract Publication

1. **Development Work on Economic Production of High and Low Specific Activity, ^{64}Cu, Suitable for Preclinical Studies using Accelerator Neutrons.**

   A. Gopalakrishna, Amit Kumar, P. Maletha, Kamaldeep, S. V. Suryanarayana, H. Naik, B. K. Nayak, S. P. Kulkarni, P. Mukherjee

   Book of Abstracts of 1st IAEA International Conference on Accelerators for Research and Sustainable Development: From Good Practices Towards Socioeconomic Impact, Vienna, May 23-27, 2021.

2. **Mobile Irradiator: A concept towards food security in India.**

   Pradip Mukherjee, Dhiren Sahoo, Mukhar Sharma

   Paper Presentation and Article Published in the Souvenir released by International Conference on Applications of Radiation Science and Technology (ICARST-2022), International Atomic Energy Agency, Vienna (IAEA) Vienna, Aug 22-26, 2022.

3. **A successful virtual technical exchange between India, The United Kingdom, and The United States on security by design for devices and facilities that use radioactive materials**

   Michal Kuca, Kaitlin Oujo, Vijendra Sinha, Dhiren Sahoo, Probal Chaudhury

   Presentation at International Atomic Energy Agency (IAEA), Vienna, June 20-24, 2022.

4. **Production of medical grade no carrier added (nca) Lu-177 via neutron activation of enriched Yb-176 target.**

   Dheeraj Kumar, Bikash K. Tiwary, Vimalnath Nair, Abhishek K. Sharma, Aaditya Shah, Varun Nair, Anupam Mathur, Usha Pandey, Sudipta Chakraborty

   Book of Abstracts of 53rd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # SNMP108.

   [This work was conferred with the award of best oral presentation at SNMICON 2021.]

5. **Comparative study of labeling characteristics of ^{68}Ga-PSMA 11 cold kit with direct ^{68}Ga-PSMA 11 radiosynthesis method using E-Z module at RMC.**

   Ashok R. Chandak, S. Sadavarte, Sindhu K., Sutapa Rakshit, S Kar, M. K. Ray.

   Book of Abstracts of 53rd Annual Conference of Society of Nuclear Medicine, India, (Virtual)

   [Best Poster Award in Non-Clinical Category].

6. **Development of Alternate Radiochemical Purity (RCP) Analysis methods for ^{99m}Tc-Macro Aggregated Albumin (MAA).**

   Akshita Deo, Archana S.Ghodke, V.V.Murhekar and Krishna Mohan Repaka

   Book of abstracts of Theme Meeting on "Nuclear Probes for Materials, Medicine and Industry-2022" (NPMMI-2022), March 04-05, BARC, Mumbai P23 (2022).

7. **Development of ready to use no carrier added ^{177}Lu labelled DOTA-TATE and PSMA-617 peptide radiopharmaceuticals for clinical end use.**

   Dheeraj Kumar, N C Joseph, Vimalnath Nair, Vrinda PC, Shubhangi Mirapurkar, Navin Sakhare, Rani G, H D Sarma, Anupam Mathur, Usha Pandey, Sudipta Chakraborty

   Book of Abstracts of 53rd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # SNMP109, 2021.

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