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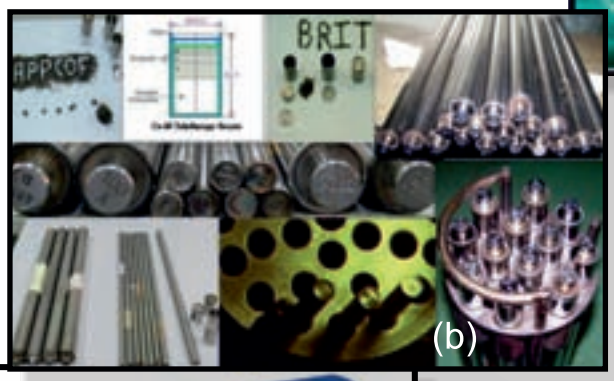
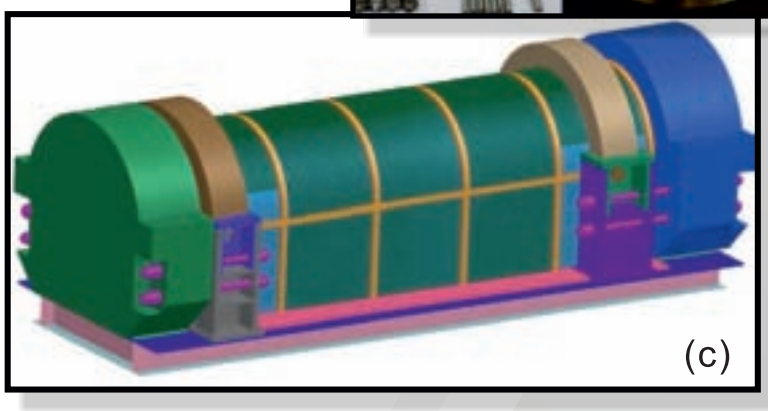
GOVERNMENT OF INDIA

BOARD OF RADIATION & ISOTOPE TECHNOLOGY (BRIT)

ANNUAL REPORT

2023-2024





DEPARTMENT OF ATOMIC ENERGY

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GOVERNMENT OF INDIA
DEPARTMENT OF ATOMIC ENERGY

BOARD OF RADIATION & ISOTOPE TECHNOLOGY

BRIT

ANNUAL REPORT
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Front Page:

(a) Indigenously developed delivery system for Y-90 microspheres 'Bhabhasphere' for liver cancer therapy, commercialized by BRIT.

(b) High intensity Cobalt-60 Teletherapy Sealed sources (CTS), & W-91 and BC-188 Irradiator sources fabricated at RAPPCOF, Kota.

(c) 3-D Model of Absorber Rod Transportation Package (ARTP).

Back Page: Prime Minister of India, Shri Narendra Modi, inaugurates programme marking National Technology Day 2023 on 11th May in New Delhi, and Digital India logo.

From the Desk of Chief Executive

I am pleased to present Annual Report 2023-24, which has highlighted another year of significant achievements of BRIT. It was a year marked by good financial performance, excellent results for regular production & supply of BRIT Products & services operations, valuable product additions, greater collaboration across our teams, not only amongst themselves, but also along with other units of DAE, and with our clients, growing excitement about our unified culture, and deeper commitments to the services to our customers.

This performance reinforces our belief in our vision to empower India through technology, creating more wealth (by catering to the global needs, as well), contributing to provision of sufficient, safe and nutritious food, services & products for industries and better healthcare to our people, through development and deployment of radiation technologies and their applications and while doing so, BRIT is continuing its role in providing better life to its citizens. We help our customers fulfil their requirements, be it scientific & academic communities, hospitals, industries etc., both within our country, as well as globally. This idea was proven not just in 2023-24, but we have witnessed the remarkable progress BRIT has made in 35 long years, since its inception as an independent arm of DAE.

The one common theme: our unwavering dedication to reach to the needs of our esteemed customers, it is clear that with self-discipline towards the regular production & supply of BRIT products & services, constant investment in innovation, good collaborations with other departments of DAE, along with the ongoing development of our people, have enabled us to achieve this consistency and commitment. In addition, across BRIT, we uphold certain steadfast tenets, that are worth repeating year after year which are clearly highlighted in our Annual Reports.

Expanding the infrastructure facilities of BRIT, Year 2023-24 witnessed the inaugurations of newly built I-131 Capsule facility and Low Temperature Irradiator (LTI) facility. LTI will be used for processing the meat and marine products, in addition to the usual radiation processing services provided to customers.

BRIT has started the commercialization of a new product, ^{90}Y (Yttrium-90) labeled Glass Microspheres named “Bhabhaspheres” for liver cancer therapy, that was developed in BARC. The product was supplied to nuclear medicine centers, along with an indigenously developed delivery system, by BRIT, for patient end use. Regular production and supply of Bhabhasphere was initiated from June 2023.

Best wishes for the coming years! Happy Reading!

Pradip Mukherjee
Chief Executive, BRIT

From the Editor's Desk

Season's Greetings!

BRIT has completed 35 years of its formation on March 01, 2024. In all these years, BRIT has served relentlessly to its customers, comprising of various cancer hospitals, diagnostic PET & SPECT centres, academic and research institutions, radiation processing plant operations, NDT centres, petroleum refineries etc., with its varied products and services.

Earlier BRIT used to give the respective progress inputs to DAE for preparing a consolidated DAE Annual Report. Subsequent to the formation of new Section, Scientific Information Resources & Publications (SIR&P) in 2014-15, under Corporate Planning Division, BRIT started witnessing the Annual Report publications. Since then every year we had its progress reports in the form of "Annual Report's", which are published on BRIT website.

As we present this Annual Report 2023-24, we are proud to showcase the remarkable achievements of our team over the past year, demonstrating our commitment to the Society, through innovative strategies, strong partnerships, and a relentless focus on the commercialization of broad portfolio of products in the form of Radiopharmaceuticals, Labelled Compound and Nucleotides, Sealed Radiation Sources, Gamma Chambers, Blood Irradiators and Radiography Exposure Devices. BRIT also offers Isotope Application services, Radioanalytical services, Calibration and Dosimetry services and Radiation Processing Services, besides Project Consultancy services, for setting up Radiation Processing Plants in the private sector. This report provides a transparent look at our progress, highlighting both our successes and areas for continued growth, as we navigate towards a future filled with even greater impact.

Apart from regular production and supply, our team is also involved in various R&D and HRD activities, either within their Groups or in collaborations with other research units of DAE, such as BARC, IGCAR, VECC etc., as per the interests of the organization. These are also highlighted as separate chapters in the Annual Reports. These compilations will endure encouraging the younger generations to continue the good work with increased vigour.

While I acknowledge the support and guidance provided by present Chief Executive (CE), BRIT, Shri Pradip Mukherjee, Dr. A.K. Kohli and Shri G. Ganesh, Ex-CE's of BRIT, Shri Piyush Srivastava, Ex-SGM, Engineering & Corporate Planning, BRIT, and Shri N. Jayachandran, GM, Labelled Compounds & Technical Services, BRIT, for carrying out this important assignment to me, I sincerely thank the 'Editorial Committee' (since 2021 onwards) for proving their valuable suggestions while compilation & bringing them out in a flawless manner.

I take this opportunity to thank Shri Satish Iyer, SO/F, along with past and present Head of Public Awareness Division (PAD/DAE), for their continuous support for the Publications of the past and present Annual Report's, by awarding through the printer appointed by DAE.

With Best Wishes to all!

Tarveen Karir
Sr. Manager,
Scientific Information Resources & Publications (SIR&P)

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CHAPTER 1

HIGHLIGHTS

2023-2024

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.

National Technology Day, in India, is celebrated annually on May 11, with great enthusiasm. On May 11, 2023, India has celebrated its 25th anniversary. Prime Minister, Shri Narendra Modi, marked the occasion by laying the foundation stone and inaugurating multiple projects aimed at advancing the country's scientific and technological capabilities.

Among the many projects dedicated to the nation, was, BRIT's Fission Molybdenum-99 Production Facility, located in BARC, Trombay, Mumbai. Shri Narendra Modi underlined the significance of nuclear technology in India's progress and development. The Prime Minister emphasized the need to create an inclusive ecosystem for growth, innovation and sustainable development goals, stressing the importance of technology at every step. He, also, clarified that India views technology as a tool for national progress and not a means to assert its dominance.

Celebration of 35th BRIT Day on Mar 01, 2024 at BRIT, Vashi Complex: The 35th BRIT day was celebrated on 1st March, 2024. The occasion was graced by the world-renowned nuclear scientist, Padma Vibhushan Dr. Anil Kakodkar, Member, AEC, and former Secretary, DAE as the chief guest and Shri. Vivek Bhasin, BRIT Board Chairman and Director, BARC.

The celebration commenced with a short presentation by Shri. Pradip Mukherjee, CE, BRIT on the journey of BRIT. The presentation covered the evolution of BRIT from its humble beginnings to what it is today. Various upcoming projects like the **Low temperature Marine irradiator, the Mobile Food Irradiator, etc.** were also touched upon.

This was followed by a talk by Shri. Vivek Bhasin, Director, BARC and Chairman BRIT Board, on the increasing relevance of BRIT in taking forward the ambitious vision of societal benefit of the department of Atomic Energy. A major thrust was given on BRIT taking active initiative in taking up and commercializing various products/technologies developed at BARC.

The highlight of the event was the inspiring talk by the chief guest, Dr. Anil Kakodkar. His talk was nothing short of a vision statement for BRIT in the coming years. From radiation processing to building Cyclotrons, Shri. Kakodkar harped upon many avenues for growth of BRIT in the future.

The event was concluded with a vote of thanks by GM, ESSA, followed by the National anthem.

The celebration continued off-stage, with the inauguration of the newly built I-131 capsule facility and the Low Temperature Irradiator facility by the Dignitaries.

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 2023-24, amounted to Rs. 56.44 Crores.**

(a) Radiopharmaceuticals Production (RPhP), Vashi

Radiopharmaceuticals based on ^{99m}Tc, ^{177}Lu, ^{153}Sm and ^{131}I radiopharmaceuticals are *in-vivo* products, used for diagnostic and therapeutic purposes in Nuclear Medicine (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 thyroid 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.

- **Three batches of Mo-99 were produced in Fission Molybdenum Production Facility (FMPF). 107-135 Ci of Mo-99 (six day calibration) could be produced and used for production and supply of COLTECH generators to nuclear medicine centers.**

- Production and supply of the user-friendly alumina column based Mo-99/Tc-99m radioisotope generator (COLTECH), Gel generators and solvent extraction generators (TCM-2), to avail Tc-99m at nuclear medicine centres for SPECT based diagnostic imaging of patients, continued in 2023-24 benefitting more than 2 lakh patients. A total of 214 Nos. of COLTECH generators, 527 Nos. of Gel generators and 118 consignments of solvent extraction generators (TCM-2), were produced and supplied during the period,.

- The supply of **28270 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 SPECT imaging of various organs and early disease diagnosis. **More than 2.25 Lakh diagnostic procedures were carried out using these kits.**

- **^{177}Lu and ^{153}Sm based radiopharmaceuticals**: A total supply of **866 & 867 consignments (~811.65 Ci)** of ^{177}Lu based **injectable radiopharmaceuticals,** namely, ^{177}Lu-DOTA-TATE for treatment of metastatic (somatostatin receptor positive) neuroendocrine tumors & ^{177}Lu-PSMA for the treatment of Prostate Cancer were produced and supplied to different Nuclear medicine centers, all over India. Around 80 patient doses of the injectable products for palliative care, ^{177}Lu-EDTMP and ^{153}Sm-EDTMP, were also produced and supplied on weekly basis to the hospitals.

- **A new product ^{90}Y (Yttrium-90) labeled Glass Microspheres named "Bhabhasphere" for liver cancer therapy developed in BARC was commercialized from BRIT. The product was supplied to nuclear medicine centers along with an indigenously developed delivery system for patient end use.** Regular production and supply of Bhabhasphere was initiated from June 2023. This therapeutic glass particle product requires a delivery system along with radioactive dose for patient use. The delivery system is a mechanical system which slowly infuses the product into cancerous liver under positive flow of saline. BRIT has indigenously developed a delivery system for its use with Bhabhasphere. The first patient dose using the delivery system was successfully tested in a liver cancer patient at Kasturba Hospital, Manipal. Till date 5 patient doses have been supplied to various Nuclear Medicine centres across the country.

Fig. 1: Delivery system for 'Bhabhasphere'

- Totally six consignments of ready-to-use ^{90}Y- Hydroxyapatite and ^{177}Lu- Hydroxyapatite injection doses were produced and supplied for treatment of rheumatoid arthritis of joints.

- **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 was also supplied to Nuclear Medicine 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 50,000 cancer patients, all over India, utilizing a total of ~1523 Ci of ^{131}I radioisotope supplied by BRIT**.

- **A new hot cell facility for production of the ^{131}I Capsules has been set-up in Radiopharmaceutical Laboratory at Vashi Complex. This facility was inaugurated by Padma Vibhushan, Dr. Anil Kakodkar,** Member, AEC, and former Secretary, DAE and **Shri. Vivek Bhasin,** BRIT Board Chairman and Director, BARC, **on March 01, 2024. The facility has remotely operated and semi-automatic "in-cell" gadgets, which can achieve production rate of 400-500 capsules per batch.**

Fig. 2: Newly installed production facility for ^{131}I Capsules

- About 1606 consignments of radioimmunoassay (RIA) and immunoradiometric assay (IRMA) kits were supplied to the various nuclear medicine centres, diagnostic laboratories and research institutes throughout India.

Fig. 3: ISO 9001:2015 Cerification and 13485: 2016 Cerifications for the Production of all the above Radiopharmaceutical Products

Fig. 4: Production Laboratories of Radiopharmacuticals & In-Vitro RIA and IRMA Kits awarded with Current Good Manufacturing Practices (cGMP) Certification

- cGMP and ISO 9001:2015 & ISO 13485:2016 certification of TCK and RIA laboratories were continued after successful completion of surveillance audits.

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

Quality Control, which includes Quality Assurance Section is responsible for the analyses of various ready-to-use radiopharmaceuticals, radiochemicals, TCK cold kits, certifying the product and the timely release of QC reports. During the year 2023-24, following are the QC reports:

- **Routine sample analyses:** Around 521 batches of radiopharmaceutical samples and 40 batches of ^{99}Mo-^{99m}Tc COLTECH Generators were routinely analysed and certified by QC during this period 2023-24. 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.

- Production and Quality Control Testing processes were routinely monitored and documented by QA Sub-section and appropriate QA certification for all batches of radiopharmaceuticals

were released from April 2023 to March 2024. 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 to ensure the respective devices for their precise & accurate validity.

- **ISO 9001:2015 Certification was awarded for Quality Control/Quality Assuarance Group:** Quality Control laboratory received ISO 9001:2015 continuation certificate, after third party audit by AJA authorized agency.

- **Quality Control Support to New Production activities:** Quality Control analyses of 3 Nos. of Trial Batches of Fission Molybdenum Generator was carried out.

- Reduction of Biodistribution testing of Radiopharmaceuticals: Based on past performance of TCK cold kits, a proposal was put up to Radiophramaceuticals committee (RPC) for reduction of biodistribution testing. Same has considered favorably by RPC. This will result in ~70% reduction of biodistribution testing consequently avoiding animal sacrifice.

- **Development activities carried out at RPhP-QC&QA:**

  - Pilot Biodistribution studies on bone pain palliative agent Strontium-89 chloride ($^{89}SrCl_2$). This work was carried out in collaboration with IGCAR.
  - Standardization of parameters for *in-vitro* labelling of RBC with Tc-99m.
  - Estimation of Stannous content in Technetium Cold Kits by Cyclic Voltammetry Method.

(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 460.66 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 2023-24. 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, (99.34 Ci) were made before their regular supply to cancer hospitals and PET centres, in and around the eastern part of the Country.

(e) Labelled Compounds (LC)

Labelled Compounds Programme of BRIT is involved in the synthesis & supply of a variety of ^{14}C, ^{3}H and ^{35}S-labelled products (387 Consignments) and various types of Tritium-Filled Self-Luminous sources.

During April 2023 to March 2024, Labelled Compounds Programme has supplied 21144 Nos. of Gaseous Tritium Filled Self-luminous (GTLS) sources of various sizes and shapes to defence establishments and used for illumination of various types of gadgets and instruments. During the period, EXIT sign board has been designed and fabricated using Gaseous Tritium Filled Light Sources. AERB type approval has been obtained for this product after successfully completing all prototype tests as per AERB SS-4 standard.

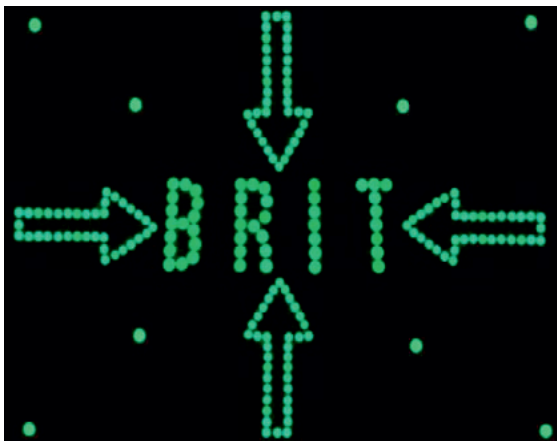


Fig. 5: Special illuminator sources (SpI)

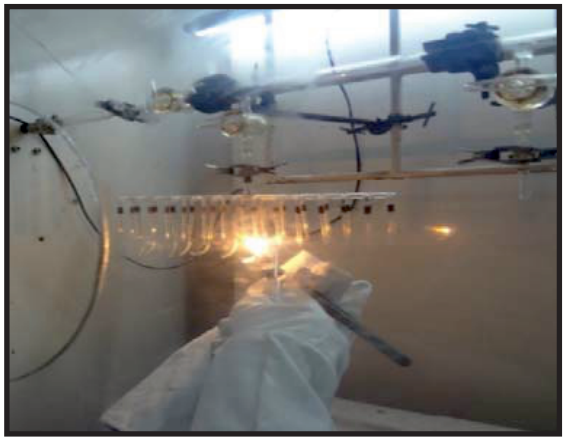


Fig. 6: Production of TFLS Sources

- Based on the MoU signed between BRIT and Heavy Water Board, deuterated NMR solvents were dispensed and supplied to various customers. All the solvents that were supplied had >98% Deuterium abundance. Supply of 90 consignments of deuterated solvents to various users, was made during the Financial Year 2023-24.

- Setting up of Special Illuminators Production Facility, CIRUS reactor building, BARC, Trombay has been completed. Cold trial experiments & hot trial experiments were completed successfully and the report has been submitted to the committees for final approval for regular production.

Fig. 7: Special illuminator sources (SpI)

Fig. 8: Glass blowing set-up of SpI sources

Fig. 9: Special illuminator production facility, CIRUS

Fig. 10: Optometer for Spl light measurement

- Custom synthesis and supply of radiolabelled compounds, mainly, C-14 based compounds, is provided to research institutes, including Zydus India Pvt. Ltd. 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. Another C-14 product, ^{14}C-Planchet source, used in environmental studies, was produced ad supplied by Labelled Compounds Section during the Annual Year 2023-24.

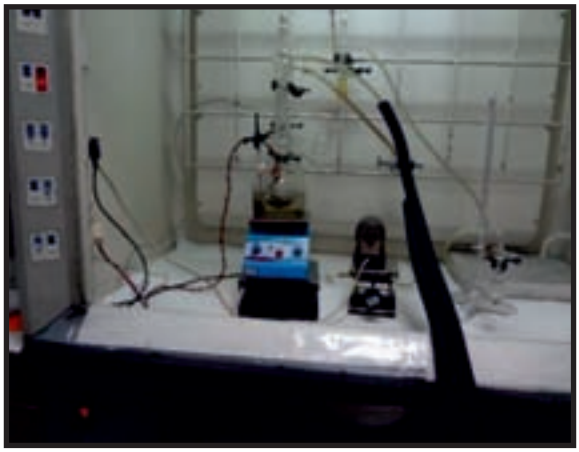


Fig. 11: Synthesis of C-14 labelled Methyl Iodide

Fig. 12: C-14 labelled Planchet for environmental studies

II. Engineering

The various engineering products offered by BRIT included the supply of more than 10913 kCi of Co-60 radioactivity in various forms and for varied uses. **The total revenue obtained by supplying Engineering Products, Equipment's & Devices, during the Financial Year 2023-24 is 142.11 Crores.**

(a) Sealed Radiation Sources

- **Twelve (12 Nos.) of high intensity Cobalt-60 Teletherapy Sealed Sources (CTS), with total activity of 105 kCi, in the range of 193 to 214 RMM,** were fabricated safely and supplied to fulfil domestic demands of various Cancer hospitals across the country.
- A total of **6619 KCi (77 Nos. of W-91 and 400 Nos. of BC-188 pencils) of High Intensity Multi-Gamma Irradiator Sealed Sources of Co-60 were supplied, both, for fulfilling the domestic needs of the country, as well as, exported to various countries, during the Financial Year 2023-24.**
- **BRIT exported Industrial Grade Irradiator Source (1000 kCi) to Nordion, Canada. Another Cobalt-60 industrial grade source (625 kCi) was exported to Research and Development Centre for Radiation Technology – VINAGAMA (Vietnam), and 300 kCi to Synergy Health, Thailand through M/s Steris.**
- **Co-60 CMR Sources: 45** Nos. of Co-60 Custom-Made Reference (CMR) Sealed Sources in 288 consignments, with total activity **94943 mCi,** were fabricated and supplied, upto **March 2024.**
- **Ir-192 & Co-60 Radiography Sources: 887 Nos. of ^{192}Ir & Co-60 radiography sealed sources,** with total activity **36495.24 Ci,** useful in NDT industries, were fabricated & supplied up to March 2024.
- 160 numbers of devices containing various types of radionuclides were handled at RSMS, BARC, for safe management of disused sources.
- 2 Nos. of dummy trial operations were made and performed radiometry of new HTC flasks for ISOMED, BARC.
- Identification and verification of 300 Nos. of disused nucleonic sources/devices were performed during 2023-24.

(b) Radiation Equipment Devices

- **Radiography Camera: A total of 86 Radiography Cameras,** which includes ROLI series, and COCAM-120 radiography devices, were supplied to various NDT users, within India during the Financial Year 2023-24. Inspection and services were provided for **818 numbers** of BRIT and imported radiography cameras.
- **Blood Irradiators/Low Dose Irradiators: Seven Blood Irradiators-2000 units** with Co-60 source have been supplied to hospitals in India during April 2023 to March 2024. Removal of decayed sources from 03 Nos. of BI-2000 was done.
- **Gamma Chamber 5000: Two units of GC-5000** with Co-60 source were supplied to various users. During the reported year 2023-24, decayed sources were removed from 04 Nos GC-900, 02 Nos from GC-5000, and one from GC-1200.

B. Services

Apart from Production & Supply of radioactive products related to Radiopharmaceuticals (from Vashi Complex, Medical Cyclotron Facility, both, from RMC, Parel and VECC, Kolkata locations), Labelled Compounds (from Vashi Complex and RCR, Hyderabad) and Engineering Products, Equipment's & Devices, BRIT offers Services in various fields, such as, Isotope Application Services (IAS), Radiography Camera Services, Calibration Services, Industrial 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 2023-24 amounted to 22.92 Crores.**

I. Consultancy and MoU for Radiation Processing Plants

Fig. 13: MoU signed between BRIT and M/s Poly Medicure Ltd.

- MoU was signed with M/s Poly Medicure Ltd for setting up a Gamma Radiation Processing Plant in Palwal, Haryana for sterilization applications as permitted by the relevant regulations.

Fig. 14: MoU signed between BRIT and M/s Hon. Balasaheb Thackaray Harida Research & Training Centre

- MoU was signed with M/s Hon. Balasaheb Thackeray Haridra Research & Training Center, for setting up a Gamma Radiation Processing Plant for treatment of agro products such as spices, herbal products etc. as permitted by the relevant regulations, in Hingoli, Maharashtra.

Fig. 15: MoU signed between BRIT and M/s RCC Nutra Fill Pvt. Ltd.

- MoU was signed with M/s RCC Nutra Fill Pvt. Ltd., for setting up a Gamma Radiation Processing Plant for treatment of agro products such as spices, herbal products etc. and sterilization applications as permitted by the relevant regulations, in Ernakulam, Kerala.

- **Gamma radiation processing plants of M/s Department of Agricultural Marketing & Agri Business (DAMAB), Krishnagiri, Tamil Nadu and M/s Lion Foods Pvt. Ltd., Gir Somnath, Gujarat, were both, commissioned during the Year 2023-24.**

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 2023-24.

- Project Safety System Upgradation and Refurbishment of ISOMED Facility with a sanctioned cost of Rs. 11.34 crore (Project commencement date: May 13,2021, Target Project Completion Date: May 13, 2024) accomplished approximately 49.03% physical progress till October 2023. It is estimated to achieve approximately 96.86% physical progress by end of Fiscal 2024.

- EPC contract for Safety System Up-gradation and Refurbishments, ISOMED facility is under active progress, as of now, out of total 6 stages 3 stages are under advanced stage of completion.

- ISOMED continued offering commercial gamma radiation processing services in GIC -5000 to the vendors of NPCIL, under equipment qualification programme.

- The novel custom-made training programme for ISO 11137 offered by ISOMED, BRIT accomplished another headway by expanding its training services to overseas clients, as well as to private Gamma Irradiators Industries, within the country, thus establishing its own niche in the field.

- Team ISOMED has been successfully managing the contract for the IT enabled pan India logistics for door delivery of radiopharmaceuticals and radiography cameras in full compliance to regulatory requirements for transportation of radioactive materials in public domain with encouraging customer feedbacks. As of now around 1000 customers are benefitted from door-to-door delivery pan India logistics service offered by BRIT.

(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. Nineteen 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 like electric cables, pressure switches, solenoid valves, electric motors etc were received from NPCIL vendors & exposed with desired doses of gamma radiation as per qualification test criterion.

- During the financial year, 2023-24, **3544 MT** of spices, Ayurvedic raw material, healthcare products and other products were processed.

- Surveillance/Recertification audits for ISO 9001:2015, 22000:2018 and ISO 13485:2016 were got 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 and Microbiology Laboratory Services of RPP, Vashi, continued to carry out the following work during the period April 2023 to March 2024.

- **Plant commissioning dosimetry for radiation processing plant of M/s Lion Foods, Gir, was completed** during the reported Year 2023-24. Plant recommissioning dosimetry services was provided for 08 Nos. of radiation processing plants, namely, M/s Ansell, M/s Himedia, M/s Innova, M/s. SARC, M/s Nippro, M/s Alligned, M/s. EMI, and M/s. Agrosurg, were completed.

- Production and supply of ~ 2.9 Lakh of Ceric-Cerous sulphate dosimeters was made to various gamma irradiators in the country, for absorbed dose measurement.

- Export of 2000 Nos. of Ceric-Cerous sulphate dosimeters were supplied to Atomic Energy Regulatory Board, Sri Lanka, during the reported year 2022-23.

- Dose rate certification services were provided for **Three No's of Blood irradiators (BI-2000), Three Gamma chamber - 5000 (GC-5000) and Two GC-1200,** were completed.

- Optimization of dose mapping studies for "Product box“ for Low Temperature Irradiator (LTI) was provided.

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 2023-24, following Services were provided by BRIT:

❖ Diagnosis of Crude Column (15-C-102) Using Gamma Scanning Technique at CPCL, Manali Refinery

Problem Statement:

In CPCL Refinery, CDU-II-unit processes both LS and HS+LS crude mix with a feed rate of 580 m3/hr to 620 m3/hr. respectively. There has been an abnormal increase in Stabilized naphtha endpoint up to 200ºC against the specified value of 130ºC (Max) and a subsequent reduction in throughput up to 430 m3/hr against 580 m3/hr during LS (Bombay High) crude processing. Based on the operating parameters it was suspected that flooding in the top zone may be the reason for abnormal stabilized naphtha endpoint and throughput reduction. BRIT was contacted to inspect the mechanical integrity and process condition of the column before shutdown through gamma scanning technique.

As per the offer submitted against **Tender No. CC 0103 23,** the Purchase Order **(WO No. 28881260 dt. 25-05-2023)** for **"Gamma Ray Scanning of CDU-II Atmospheric Distillation Column 15-C-102"** was issued to BRIT.

Fig. 16: General Assembly of Crude Distillation Column (15-C-102)

Fig. 17: Crude Column, Ground Setup and Scanning Data Collection

The gamma scanning work at CPCL was taken up using 80 mCi of Cobalt-60 as the gamma radiation source and BGO scintillation detector for radiation intensity measurement. The Cobalt-60 source was transported to Manali Refinery in AERB approved transport package. Marking on the column was done by CPCL as per the internal arrangement of trays. As per the requirement, scaffoldings, a temporary shed, and passage for the source and detector through platforms were provided by CPCL. Both the source and detector collimators have ~2.5" outer diameter which is required to pass through between platform and body of the column. Wherever necessary, at some locations specific gratings were removed from the platforms to facilitate the smooth passage of the collimators. Automatic gamma scanning system consisting of source operator and detector operator was kept at a suitable location. The source and detector operators were controlled through a control unit and data in the form of counts per unit time with respect to column elevation were obtained and recorded on the laptop.

Results & Analysis:

- The flooding zone was observed at the top section of the column i.e., above tray #40. CT#4, seal pan #41 and trays #42 to #44 were completely submerged in the liquid.

- Other internals in the column i.e. Two pass section trays and packed beds etc. seems intact and located at their respective positions in the column.

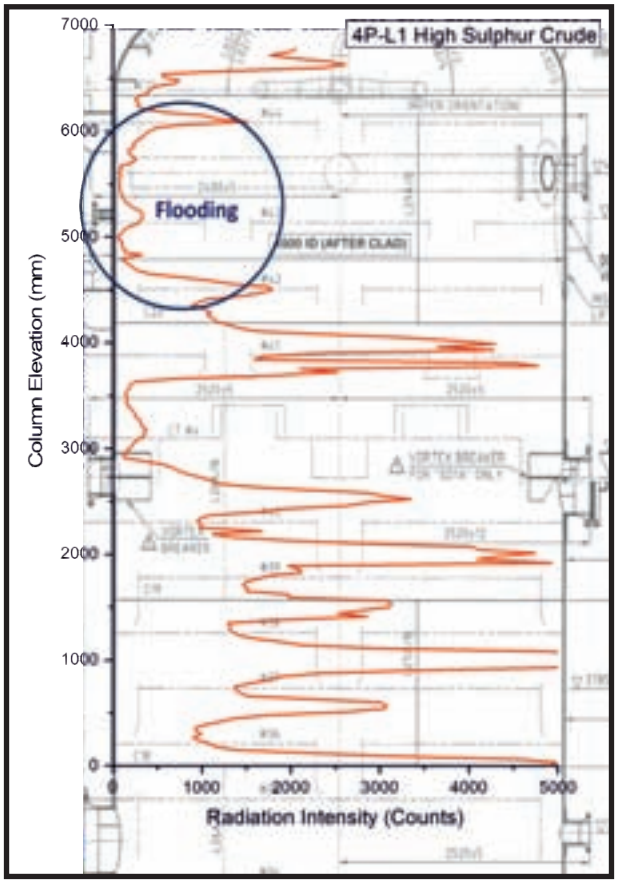


Fig. 18: Scan profile for four pass tray section-L1 in high sulphur crude

Conclusion & Recommendations:

- Gamma scanning was applied successfully to assess the mechanical health as well as hydraulic conditions of the fractionator column.
- As per the results obtained by gamma scanning of the crude column, it was recommended to inspect the top trays of the column for suspected solid deposits.
- The shutdown was preponed and sludge kind of material was found over the top trays.
- It was very helpful for the refinery engineers to identify the problematic zone and taking important decisions regarding column operation.

❖ Leakage Identification in a Series of Heat Exchangers Using Radiotracer Technique at IOCL, Paradip Refinery

Brief Process Description and Problem Statement:

In the DHDT unit of IOCL, Paradip refinery, off spec product was observed. As per the strict environmental norms, it is not permissible. It was suspected that feed-effluent heat exchangers (14-A to 14-F and 15-A to 15-F) may be leaky. Identification of leaky heat exchanger during operational condition is not possible through conventional techniques such as hydro testing, pressure drop or sampling etc. IOCL approached BRIT to apply radiotracer technique to identify the leaky heat exchanger, if any, as a possible cause of product contamination.

Order Details:

The job was awarded to BRIT as per the work order no. **29177427** dated: **02.09.20223.**

Experimental Details:

There were two trains i.e. 14 and 15 containing six heat exchangers in each train. Both the trains were connected in parallel combination. It was decided to carry out the radiotracer study by single injection of 5 Ci of Mo-99 in organic phase.

The injection device was fabricated and installed by IOCL. Radiotracer was injected into the shell side and the leak detectors were place at the tube outlets of remaining heat exchangers to record the leakage peak, if present.

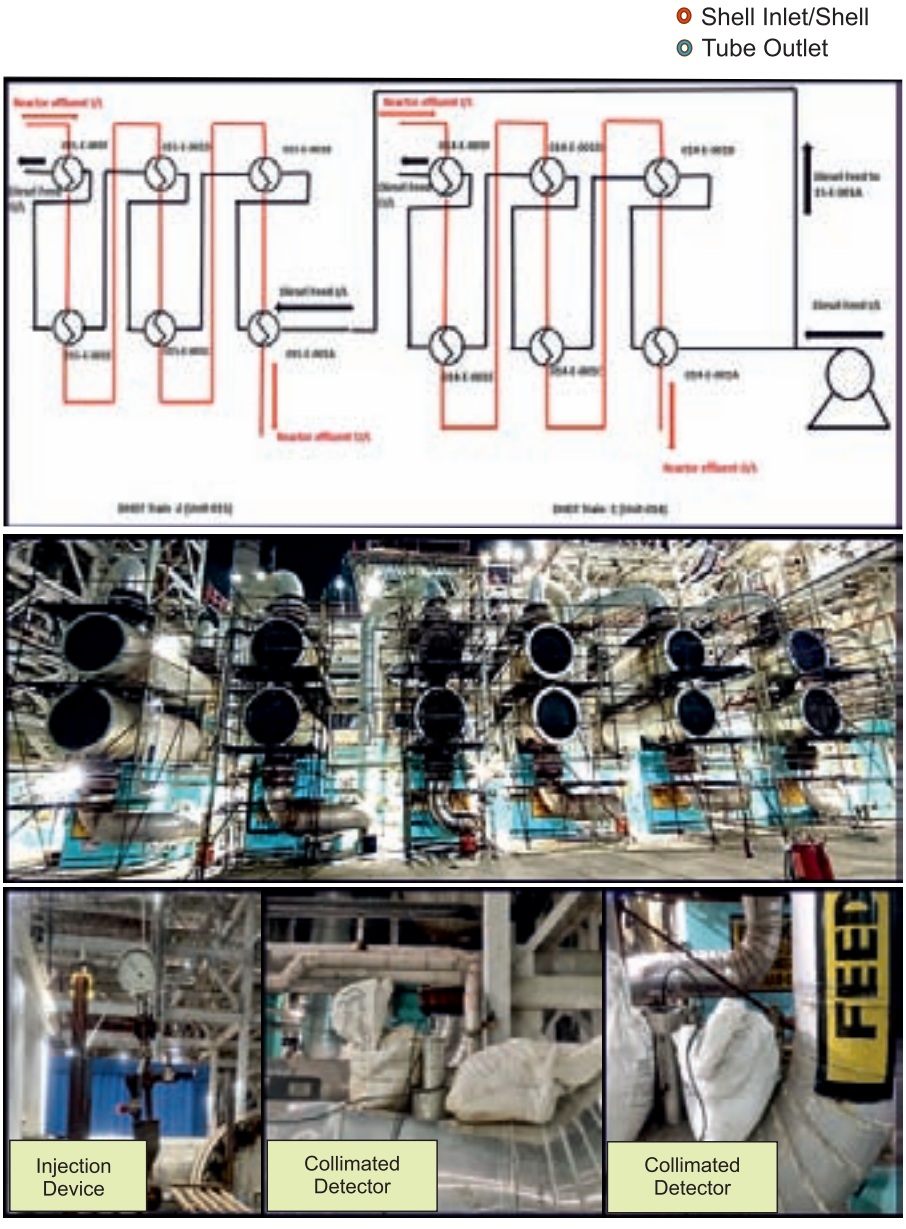


Fig. 19: Detector placement on the heat exchangers

Results & Analysis:

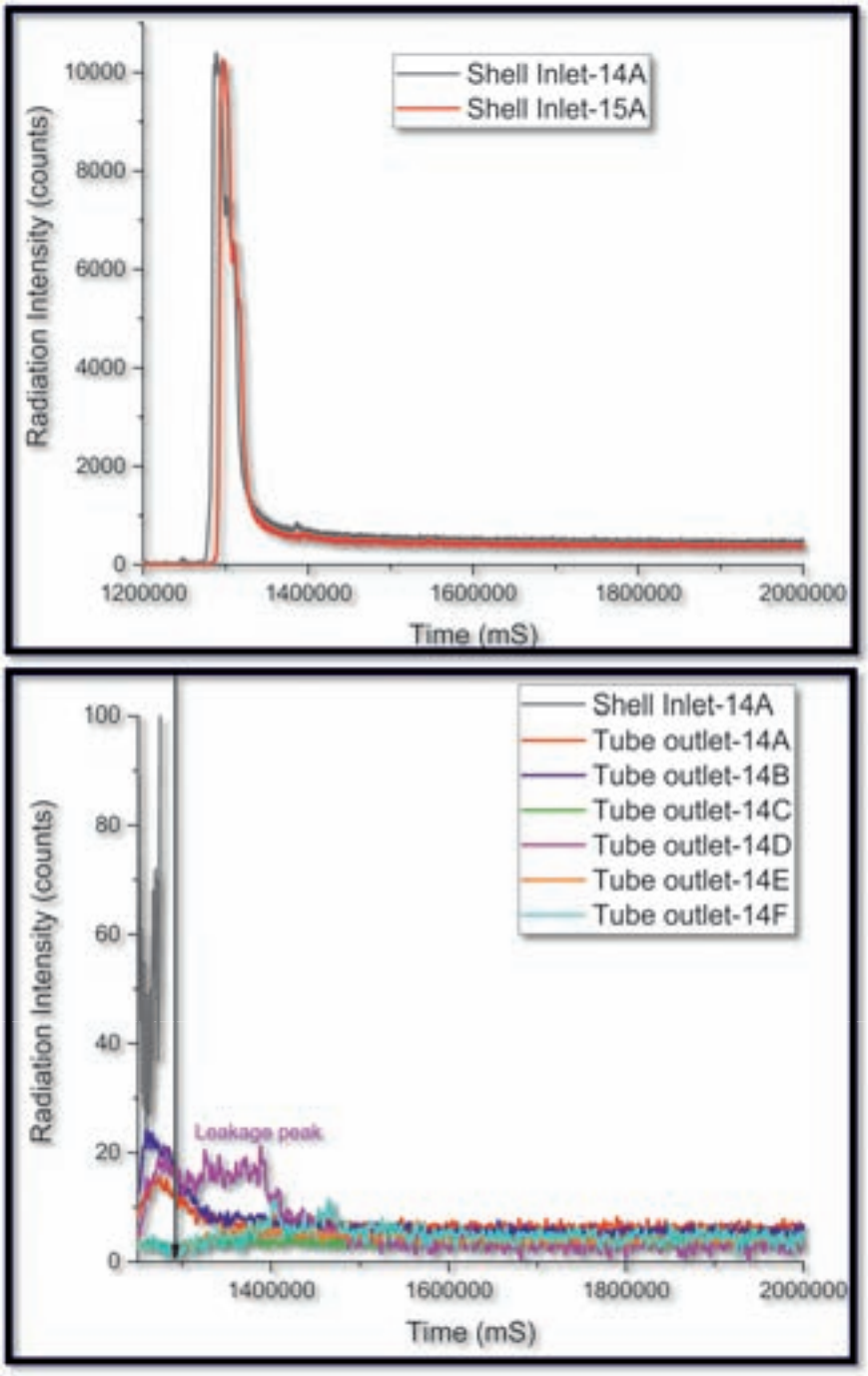


Fig. 20. Radiotracer detection of leakages in the heat exchanger

Conclusion:

- As per the radiotracer study, peak observed in the tube outlet of heat exchanger 14-D was due to leakage.
- The radiotracer study immensely contributed for the better productivity of the plant.

IV. Radiation Physics Services Group

- A theoretical investigation was conducted on BC-188 pencils to assess the viability of employing a mix of lower and higher source activity inner slugs, specifically non-uniform BC-188 pencils, in an industrial gamma irradiator. This study comprised of evaluating dose parameters for two RPPs (Radiation Processing Plants) - M/s. Solas Industries and M/s. Ansell Steriles. The objective was to compare the results obtained by these non-uniform BC-188 pencils with the currently utilized uniformly loaded BC-188 pencils.

- An assessment was conducted to explore the practicality of utilizing ^{137}Cs waste-canisters for product irradiation through theoretical analysis. Monte Carlo simulations were employed in this study to understand the feasibility by considering various source-product configurations.

- Shielding assessment calculations were performed for the following:

  - handling 500mCi Ge-68/Ga-68 target plate in either lead or tungsten pot for transportation within the facility.

  - Hot-cell walls, made up of high-density concrete, to safely handle 1 MCi ^{192}Ir source, under extension project of IFRT.

  - Transport cask for safely transporting 120 Ci ^{60}Co to industrial site for carrying out gamma scanning.

  - RC, Kolkata plans to supply F-18 to in LP 30 and LP 40 lead pots, the analysis is carried out to find the maximum amount of activity that can be safely transported.

  - ^{99}Mo Transportation Package (MTP-100) made up of tungsten alloy for transportation of 100 Ci of Mo-99 from FMP, BRIT to RPL, BRIT Vashi.

- A shielding assessment was conducted for the Hot-cell walls, using high-density concrete, to ensure safe handling of a 1 MCi ^{192}Ir source as part of the IFRT project extension. Additionally, ozone production and time delay requirement calculations were performed for the handling 1MCi of ^{192}Ir in the hot cell with the available air changes per hour for the hot-cell.

- Source (W-91/ BC-188) Loading configurations were designed for the following 15 gamma irradiators to achieve the desired Dose Uniformity Ratio for the concerned products which are to be radiation processed in respective plant:

  - M/s AKSHARGAMMA, AMBERNATH (530kCi in 22 pencils)
  - M/s ANSELL STERILE, CHENNAI (300kCi in 25 pencils)
  - M/s Hi Media (500kCi in 49 pencils)
  - M/s Microtrol Sterilization, Bawal, Haryana (400kCi in 18 pencils)
  - M/s SARC, DELHI (124kCi in 5 pencils)

- M/s SOLAS INDUSTRIES, MATHURA (200kCi in 18 pencils)
- M/s GAMMA AGRO, HYDERABAD (186kCi in 8 pencils)
- M/s EMI, VADODARA (300kCi in 33 pencils)
- M/s. Pinnacles Therapeutics, Ahmedabad (150kCi in 16 pencils)
- M/s. AIIPL, Vasai (125kCi, 6 pencils)
- M/s ALIGNED INDUSTRIES, REWARI (186kCi in 8 pencils)
- M/s GAICL, AHMEDABAD (400kCi in 19 pencils)
- M/s JAMNADAS INDUSTRIES, INDORE (300kCi in 28 pencils)
- M/s MICROTROL, BENGALURU (350kCi in 13 pencils)
- M/s NIPRO, SATARA (325kCi in 30 pencils)

➢ Theoretical dose simulations were attempted for two BI units and the results were compared with the dosimetry. The chemical dosimetry is performed for each Blood Irradiator unit for dose distribution certification before the supply. It is found that the maximum variation is approx. 12 % when compared to experimental dosimetry. The reasons of the deviations and the uncertainties are understood which will help in improving the theoretical results in future.

➢ Radiological Safety of Radiation Physics Group: The group uses number of check sources, ^{60}Co & ^{137}Cs for various purposes such as in-house radiometry, internal calibration of radiation monitoring instruments (RMIs), etc. Two Radiological Safety Status Reports (SSRs) are prepared and forwarded to AERB. The license of handling the radioactive sources is obtained through eLoRA and hence SSRs are uploaded on eLoRA. Maintaining the personnel monitoring records and maintenance of RMIs make the other important part of the radiological safety job for the Radiation Physics group.

V. Calibration Services for Portable Radiation Monitoring Instruments

BRIT is providing calibration services for gamma radiation monitoring instruments. A total of 152-Nos. of radiation monitoring instruments such as survey meters, dosimeters and portable area

Fig. 22: Test Set up for Radiation sensor by SAC/ISRO, at BRIT-Calibration Laboratory

monitors are calibrated during the period, from 1st Apr-2023 to 31st Mar-2024. So far, total of 1517 Nos of instruments, of various type/make, are calibrated in the calibration laboratory. Further, due to useful test results obtained by Space Application Centre (SAC)/ISRO, during first round of tests, the Agreement for testing Radiation Sensors, with BRIT is renewed by SAC. These sensors are to be used in satellite payloads and future manned missions of ISRO. So far total Ten test cycles are completed. Each test cycle lasts ~1.5 working day and involves dose rate of the order of 6-R/h, accurately calibrated. The data collected during testing of sensors at BRIT facility, has helped SAC/ISRO to finetune the electronic calibration of these sensors. More number of such tests are planned in near future.

VI. Radioanalytical Laboratory Services

Radioanalytical Laboratory (RAL), BRIT Vashi Complex is an NABL accredited laboratory engaged in 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, fly ash, soil, rock phosphate, phosphor-gypsum etc. The laboratory is also empanelled by BIS for the testing of gross alpha and gross beta content in water samples.

During the reported Financial Year, 2023-24, total number of radio analysis were 11668 performed by RAL. Out of this, RAL, Vashi Complex carried out more than 2079 tests on export (1260 Nos), domestic (718 Nos.) commodities and water samples (101 Nos.).

The desk top surveillance audit by NABL was also successfully completed during the period.

Fig. 22: NaI(Tl) detector for export import sample

Fig 23: Dual channel alpha beta counter for testing water samples

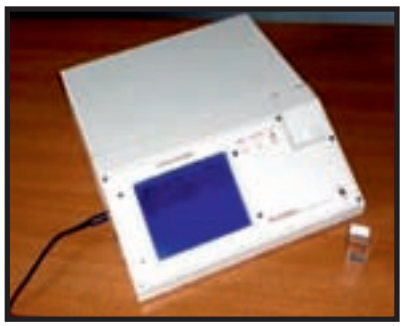


Fig. 24: Uranium analyzer for U in water samples

Fig. 25: HPGe detector for counting NORM radioactivity

VII. Services extended by Regional Centres (RC) of BRIT

Regional centres at Delhi, Dibrugarh & Kolkata, Hyderabad (also k/as Jonaki), Bengaluru, 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 Co-60 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. Regional Centre, Kota (RAPPCOF) facility continued the tasks related with the safe supply of Co-60 for various uses,

RCR, Kolkata & Dibrugarh

- **Services at RC, Dibrugarh:** The Regional Centre BRIT, Dibrugarh located at Assam Medical College & Hospital is rendering Radioimmunoassay and Immuno-radiometric diagnostic services for the benefit of patients of the entire North-Eastern region. The centre is rendering services to the referred patients of Assam Medical College, OIL Hospital, ONGC Hospital, Air force hospital Jorhat, RRL Hospital Jorhat, Rly Hospital Dibrugarh & Maligaon, Tea garden hospital & also patients from District Jail, BVFCL Namrup etc. The Radiopharmaceuticals products produced and supplied by BRIT Vashi Complex, are extensively used by the Regional Centre Dibrugarh, for diagnosis & investigation of various diseases. The centre is currently analysing the hormones like T_3, T_4, TSH, Free T4, Insulin etc. **In this period a total of 1856 Nos. of tests are done for almost 1805 Nos of patients.**

- **Sale of cold kits for Tc-radiopharmaceuticals from the retail outlet at RC, Kolkata:** During the year 2023-24, Technetium cold kits for formulation of ^{99m}Tc-radiopharmaceuticals were supplied to various Nuclear Medicine Hospitals in Kolkata, as per requirement.

- **Production, quality control and supply of ^{18}F-FDG to local hospitals:** Nearly 99.34 Ci of F-18 was produced from CYCLONE-30 at MCF, Kolkata, and RC, Kolkata, produced, duly analysed and supplied ~ 83 batches of ^{18}F-FDG & ^{18}F-NaF to Nuclear Medicine hospitals in North-Eastern region of India, during this period.

Regular Quality Assuarance (QA) was performed before the batch release of all the RPhs which were supplied through the Centre during the reported period.

RCR, Bengaluru

- During this period, Regional Centre, BRIT, Bengaluru supplied 106 Ci of ready-to-use ^{99m}Tc Pertechnetate to user hospitals and 1143 cold kits were sold through retail outlet for the preparation of ^{99m}Tc-radiopharmaceutical formulation.

- Gamma Irradiation facility for Blood and its component was extended to outside hospitals other than KMIO. Monthly around 2000 numbers of blood and platelets bags are irradiated at this Centre. We have irradiated around 21279 bags till Mar 2024.

- NABL accredited Radioactivity testing laboratory (RAL) has analysed 288 samples, from April 2023 to March 2024, for the measurement and certification of residual radioactivity in various commodities such as food items for human & animal consumption, medicine and other miscellaneous items.

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 (~6.01 Ci) (^{99}Mo Generator kit for Solvent Extraction) ($^{99m}TcO_4^-$) in 159 consignments, for the nuclear medicine centres in Delhi and NCR regions.

- Quality Control of ready-to-use Tc-99m & its labelled RPhs from 118 batches were analyzed during the said period. ~861 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 Tc-99m as Sodium Pertechnatate to local Nuclear Medicine Centres. It has supplied 787 Nos. of TCK Cold kits (produced at BRIT, Vashi Complex) from retail outlet of Regional Centre, BRIT, Hyderabad.

- RPC clearance has been obtained for the production of one of the TCK cold kit (TCK-5, which is cold kit of S,Colloid). Production scale of production of TCK-5 will commence shortly.

- RC, Hyderabad, has set up Radioanalytical testing facility for providing radioanalytical services to the users, for the measurement of Cs-137 in food commodities.

- RC, BRIT, Hyderabad, continued the synthesis and supply of ^{32}P-labelled nucleotides (135.5 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. It has completed the development of a new product, magnetic cellulose (MagCell) bead based genomic DNA extraction kit (MagCK-01/02) and distributed sample kits to potential users for evaluation.

RCR, Kota (RAPPCOF)

- BRIT handles several Million Curies of Cobalt-60 activity per annum in a safe manner at BRIT-Regional Centre- Kota, also called Rajasthan Atomic Power Plant Cobalt Facility (RAPPCOF), to supply Co-60 sealed sources to healthcare and industrial users in India and abroad.

- RAPPCOF facility continued the tasks related with the safe supply of Co-60 for various uses, right from receiving the adjuster rods (11 Nos. were received from RAPS-2 and 4 Nos. frpm

RAPS-6 this year) from various Indian PHWR power reactors (a by-product of neutron regulation), processing of the activity, fabrication of sealed sources, to supply of Co-60 sources (irradiator sources & teletherapy sources), are all carried out.

- During 2023-24, RC, Kota, processed 6000 Kilo Curie (kCi) of Cobalt-60 activity. This is mainly used for fabrication of indigenous Cobalt-60 Teletherapy Sources (CTS) and High intensity Multi-Purpose Gamma Irradiator Sources.

- 15 Nos. of adjuster rods were received and cut under water. 96 sub-assemblies were cut under water. Successful fabrication of 12 Nos. of Co-60 Teletherapy Sources with total activity of 105 kCi in the range of 193 to 214 RMM were supplied to various cancer hospitals across the country. 77 Nos. of W-91 Irradiator Source Pencils and 400 Nos. of BC-188 Pencils (Total activity 6000 kCi) were fabricated and 6619 kCi were supplied to various processing plants within the country and abroad, during the reported year, 2023-24.

- **BRIT exported Industrial Grade Irradiator Source (1000 kCi) to Nordion, Canada, 625 kCi to Research and Development Centre for Radiation Technology – VINAGAMA (Vietnam), and 300 kCi to Synergy Health, Thailand through M/s Steris.**

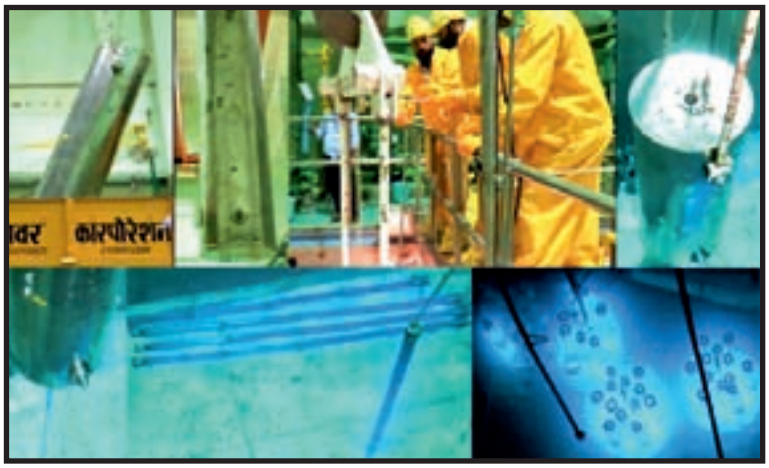


Fig. 24: Discharging operation of highly radioactive Cobalt-60 Adjuster rods received from RAPS Unit #4 in RAPPCOF Storage pool

Fig. 25: High intensity Cobalt-60 Sealed Teletherapy Sources (CTS), & W-91 and BC-188 irradiator sources fabricated at RAPPCOF Kota

C. Engineering Design & Development

1. Installation Commissioning & Inauguration of Low Temperature Irradiator

"Low Temperature Irradiator (LTI)" designed and developed to irradiate marine products such as fish, shrimps and meat. Fresh marine product can be irradiated with a dose of 3 - 5 kGy to increase the shelf life by reducing microbial load. Even frozen fish can be irradiated to eliminate pathogens and make it safe for consumption. Fish and meat are highly perishable products; they required cold chain to be maintained during the irradiation which is a major challenge.

The Low temperature Irradiator is designed in such a way that the cold chain can be maintained during irradiation. A dedicated Chilled air unit is integrated with the irradiator to provided blast air at + 10^{o}C to -20^{o}C. The plant is designed for a maximum of 400 kCi of Co-60 with a throughput of processing 5-8 Tons of fresh marine products. The plant consists of main components such as Transportation Cask, Upper Shield, Product Carrier, Electrical Hoisting Arrangement, Building with a pit and an overhead crane, Structures, Inlet & Outlet Conveyor, Chilled Air Supply Unit, Interlocks, and Control System. Longer shelf life and hygienic quality will enable exporters to meet the stringent international quality standards for export of marine product in international market.

Low Temperature Irradiator Plant

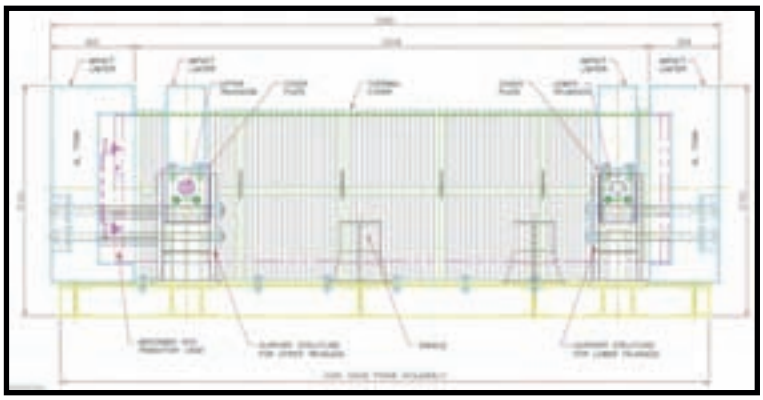
Chilled Air Plant of Low Temperature Irradiator

Shri Vivek Bhasin, Director BARC Inaugurating Low Temperature Irradiator Plant

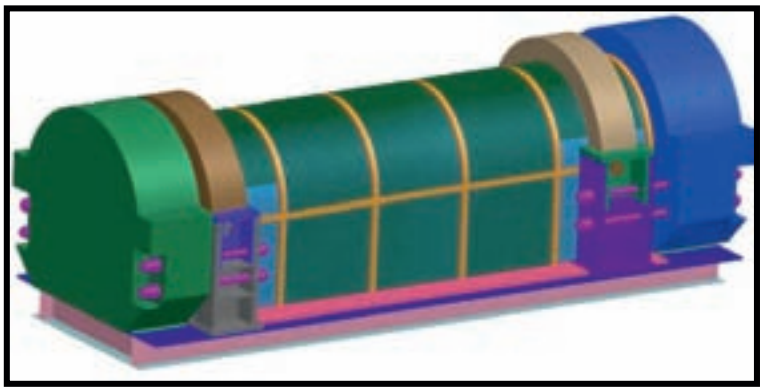
2. Development of Aluminium Foam based Impact limiter for Absorber Rod Transportation Cask.

Absorber Rod Transportation Package (ARTP) is designed to safely transport Cobalt-60 produced in power reactors to Rajasthan Power Project Cobalt facility (RAPPCOF) Kota. The package has capacity to carry a maximum of 400kCi of Cobalt-60. ARTP assembly consists of Cask, Bottom Saddle Support Base, Impact Limiters and Thermal Cover.

The Impact limiters are made of 0.62gm/cc bulk density aluminum foam encased in 8mm thick carbon steel cover. These aluminum foam are closed cell type with an average pore size of 5mm, produced by ALPORAS process they exhibits excellent shock absorbing characteristics with an energy absorption of 7000-9000 kJ/m^3 for a bulk density of 0.62gm/cc. Aluminum foam being light in weight results in an overall mass of the each impact limiter around 400kg to 500kg, making them easy to handle.



2-D Engineering Drawing of Absorber Rod Transportation Package



3-D Model of Absorber Rod Transportation Package

3. Development of Cocam-120 (W)

The Board of Radiation and Isotope Technology (BRIT) has successfully developed an advanced variant of its Co-60-based Industrial Gamma Radiography Exposure Device (IGRED), named COCAM-120(W). Designed as a dual-purpose device serving as both an exposure unit and a transport container, COCAM-120(W) accommodates a maximum capacity of 4.44 TBq (120 Ci) of Co-60 radiation source. The device incorporates a combination of tungsten heavy

alloy and lead as shielding materials, replacing the depleted uranium used in its predecessor, COCAM-120. The original COCAM-120 had been well-received in the NDT market, with numerous orders placed upon its introduction. However, further supplies were hindered due to the unavailability of depleted uranium.

Addressing this limitation, BRIT developed COCAM-120(W) to maintain high safety and operational standards while leveraging alternative shielding materials. The fabrication of the first operational prototypes has been completed, with rigorous testing validating the device's radiation safety, functionality, and performance. Recently approved by the Atomic Energy Regulatory Board (AERB) as a Type B(U) transportation package and industrial radiography equipment, the COCAM-120(W) stands ready to meet the needs of the NDT industry, marking a significant step forward in indigenous radiography device development.

COCAM-120 (W) Industrial Gamma Radiography Exposure Device (IGRED)

4. Integrated Radiography Facility

BRIT has developed an Integrated Facility for the Industrial Radiography Device (IFIR) at the REPF building within the BRIT-Vashi premises. This state-of-the-art facility incorporates advanced automation and streamlined workflows to enhance operational efficiency and safety. Key features of the facility will include the automation of critical Decayed Source Removal Operations, significantly reducing radiation exposure to personnel, and the implementation of an automated conveyor system with a hydraulic lifting arrangement to minimize manual handling of heavy lead/tungsten-shielded radiography devices, thereby eliminating potential safety hazards. By bringing together all operations related to industrial radiography devices—including inward registration, decayed source removal, mechanical maintenance, quality inspection, and dispatch—under one roof, IFIR ensures better coordination and shorter operational cycle time, even as new indigenous models are introduced. Additionally, the facility's advanced inventory management system facilitates the efficient handling of around 350 different spare parts required for device maintenance, further boosting operational efficiency and reliability.

With the completion of the layout, structural work, roofing, and electrical fitting, the facility has reached a significant milestone, and the commissioning of the automation of the conveyor system is currently underway.

During the Structural Work being carried out at Integrated Facility for the Industrial Radiography Device (IFIR)

Radiography Device Maintenance Shop-floor at Integrated Facility for the Industrial Radiography Device (IFIR)

Decayed Source Removal Area at Integrated Facility for the Industrial Radiography Device (IFIR)

5. Mobile Food Irradiator (MFI)

Food spoilage remains a pressing global challenge, contributing to food scarcity, rising prices, malnutrition, and starvation. Irradiation of food products has emerged as an effective solution to mitigate spoilage while preserving nutritional and sensory qualities. In this context, the Board of Radiation & Isotope Technology (BRIT) has developed the Mobile Food Irradiator (MFI), a Category-II, economical, batch-type irradiator designed for low-dose irradiation of fresh fruits, vegetables, cereals, and pulses, as well as medium-dose irradiation of fish and frozen meat. Unique in its mobility, the MFI is mounted on a 40-foot trailer bed, allowing it to reach remote districts across India. This innovative approach aims to empower local farmers and distributors at the lower levels of the supply chain by enabling them to extend the shelf life of their produce and facilitate export opportunities for perishable goods.

The MFI is designed to operate with a 100 kCi Co-60 radioactive source, providing a throughput of 14-15 tons per day for low- to medium-dose applications. To aid in its conceptualization and demonstration, a scaled-down functional model was developed. By addressing critical challenges in food preservation and supply chain efficiency, the Mobile Food Irradiator represents a groundbreaking step forward in the application of radiation technology for societal benefit.

Customer Support

- Sales and Marketing section continued its efforts to build a strong customer base by creating goodwill among the customers.
- The customer relation cell, Radio-Pharmaceutical Laboratory (RPL) increased its customer base for radiopharmaceutical products (medical products) by adding 30 new customers on the eportal during the period April, 2023-March, 2024. More than 14000 orders were processed in the said period for the radiopharmaceutical products.
- For the non-medical products 45 new customers in offline mode and 46 new customers in online mode were added during 01.04.2023 to 31.03.2024 (total 105 new customers).
- The revenue from sales of Radiopharmaceutical products, sealed sources, Radiochemicals & low level check sources has been steady during the period and the net revenue from sales of these products during April, 2023-March, 2024 is tabulated below:
- All relevant inputs with respect to adding important sales related messages/updates in the form of scroll in the eportal login page was given to the software development team. This has improved the communication with the grass root level users.
- **Y-90 based Glass microspheres (Product code YM-40) was launched during FY 23-24 and has been given wide publicity.**
- **Three export orders for Co-60 source (1925 kCi) with a total foreign revenue of USD 7560975 were carried out.**

S.No.	Product	No. of Cons	Activity	Revenue (cr.)
1	Radiopharmaceauticals	14000	------	45.61
2	Co-60 Teletherapy Source	12	2316 RMM (approx.. 118 kCi)	10.2
3	Irradiator Sources (domestic)	16	4694000 Ci	53
4	Irradiator Sources (Export)	3	1925 kCi	62.00
5	LU-2	96	226 Ci	5.67
6	Radiochemicals (Except LU-2 & I-131)	17	278.255 mCi	0.0107328
7	Reference sources	127	--	0.1531
8	Neutron Irradiation Services	33	--	0.0388
	TOTAL	**14281**	--	**176.68**

- Continuous coordination is done for providing inputs for smooth functioning of BRIT eportal for effective sales related services to the customers.
- 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.
- Prices of various BRIT Products were reviewed in Apex Pricing Committee meetings (2 meetings in this duration). New prices were implemented in BRIT eportal by updating the mastersheets.
- Customer relation cell was actively involved in giving technical support wrt continuing the "BRIT at doorstep" initiative. Door delivery of BRIT products has been well accepted and appreciated by BRIT customer base across the nation. The door delivery of RPL products have tremendously increased the customer satisfaction, especially the pick-up of spent generators.

Activities related to Official Language (OL) Implementation

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.
- As per the directions of Joint Secretary (Administration & Accounts), DAE, Mumbai, inspection questionnaire of the Hon'ble Parliamentary Committee on Official Language was filled and submitted to DAE, Mumbai.
- Two one-day Joint Computer Workshops were organized by BRIT during June 2023.
- A talk was presented in Hindi during the Independence Day celebrations on 15th August, 2023. Essay writing, slogan and poster competitions were organized in Hindi during Vigilance Week. Competitions are also organized in Hindi on the occasion of Safety Day etc.
- Under the aegis of Joint Official Language Coordination Committee, 05 Hindi competitions were jointly organized during August 2023 in which the personnel of BRIT participated enthusiastically.
- 08 Hindi competitions were organized by BRIT for its personnel during July - August 2023. The prizes were given to the respective winners through their salaries.
- Joint Controller (Finance & Accounts) and Assistant Director (Official Language) of the Board participated in the All India Official Language Conference organized by the Official Language Department in Pune on 14-15/09/2023.
- Apart from routine work, Joint Hindi Day celebration was organized on 27 September 2023 under the aegis of the Joint Official Language Coordination Committee. Heads of the five units delivered their talks on implementation of the Official Language in their respective offices. During the function, Hindi Drama based of the writings of Munshi Premchand ji were played.
- Hindi house magazine “BRIT Sampada” 2023 was prepared and distributed.
- On 14/10/2023, Hindi Rajbhasha Varta and Award Distribution Ceremony was organized on the occasion of Hindi Diwas under the aegis of Official Language Implementation Committee of BRIT.
- BRIT had active participation in various programs organized throughout the year under the aegis of Joint Official Language Coordination Committee. A three-days Hindi workshop was organized by BRIT during 21-23 February, 2024.
- BRIT personnel participate enthusiastically in the ATOLIS scheme.
- Official language inspection of 4 groups was done by the internal inspection team of the Board and the report was sent to the concerned groups.
- Rajbhasha Varta was organized on the occasion of Joint World Hindi Day on 10/01/2024.
- Apart from this, officers / employees of this office participate in Hindi programs organized from time to time by Navi Mumbai TOLIC.

TOLIC SCIENTIFIC SEMINAR IN HINDI-2023

HINDI FORTNIGHT 2023

JOINT COMPUTER WORKSHOP-2023

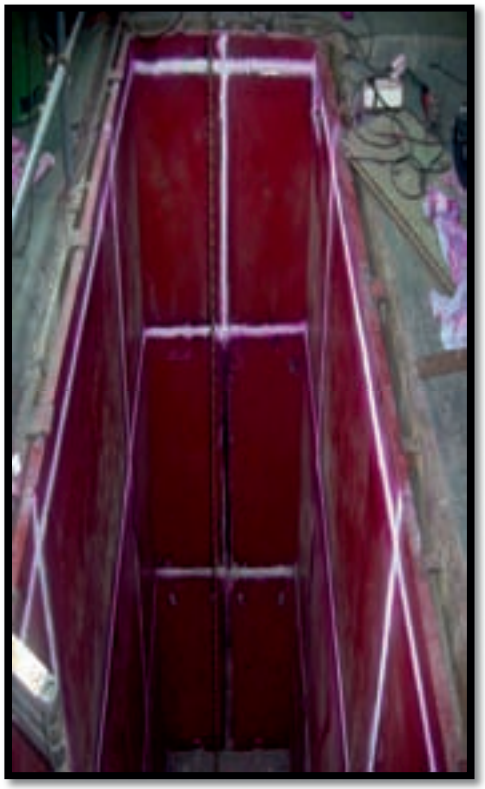
Status of New Projects

a. Safety System Upgradation and Refurbishment of ISOMED facility

This Project has been undertaken by BRIT with effect from November 2020. During the Year 2023-24, following progress was observed:

- The entire EPC work for upgradation of ISOMED facility has commenced in full swing with effect from November 2022. Under this project, one of the major milestones is achieved by successfully completing the fabrication of source frame and source cavity at fabricator's site. Source frame and source cavity integrated testing was conducted successfully at fabricator site and it is planned to be installed at ISOMED Site very soon. In addition to this, the source pit liner work has also get completed at site at ISOMED.

ISOMED Source frame and source cavity under testing at fabricator's site



ISOMED Source pit liner up-gradation (work in progress)

- ISO 11137 custom-made training programme, introduced by ISOMED facility in the year 2018, has been receiving encouraging response from the healthcare industry, and now, extending its training services need amongst the private gamma irradiators industries professionals, in addition to foreign professionals. In July 2023, professionals from M/s. Ansell Sterile Solutions Pvt. Ltd, India/Srilanka and M/s. Universal ISO-Med, Gujrat, India, have been trained by ISOMED facility.

ISO 11137 training for official from M/s. Ansell sterile Sol. (P) Ltd. from India/Srilanka and M/s. Universal ISO-Med, Gujrat, India (July 2023)

- Successful Installation and Commissioning of major M&E procurement i.e. Radiation Resistant remote Camera monitoring system under the project has been completed. Another major M&E procurement for handling, storage and transportation of Co-60 source i.e. 3 Nos. of Ten-ton Horizontal transportation Casks fabrication is currently at full swing; fabrication of one out of the three cask is to be completed very soon.

Under fabrication-New ISOMED Type Horizontal Transportation Cask (HTC) for Co-60 Source handling, transportation and storage

b. Expansion of RAPPCOF Facility (ERF) at Rawatbhata, Rajasthan

Cobalt adjuster rods, in the recently commissioned and other upcoming 700 MWe reactors of NPCIL, are larger in size and cannot be handled in the existing pool at RAPPCOF. A separate facility with water pool, hot cells its auxiliaries, need to be built for the same. Cobalt production in 700 MWe reactors will enhance the production in both quantity and quality (Specific activity). The increase in demand for Co-60 for its use in radiation processing of food and sterilization of healthcare products calls for capacity augmentation of the existing facility concurrently. The proposed expansion of the RAPPCOF facility will include a water pool for storage and handling of the adjuster rods, four hot cells for fabrication of sealed radiation sources, an enclosing High bay area and other related systems.

Present Status

The project has received sanction from DAE for 85 Cr in July 2021. The project has received excavation clearance from AERB and environment clearance from MoEFCC.

The excavation work at site has been initiated in July 2022 and ~60% of excavation work has been completed.

Design work of the facility is over and construction work is initiated by July 2023. Main Building NIT is released.

Fig. 8: ERF Excavation Site Photographs

c. Modernisation & Augmentation of Radiopharmaceuticals Production Facility (MARPF)

Few developments as part of MARPF Projects during the Financial Year 2023-24 are as given below.

1) Air Conditioning plant of Labelled Compounds Laboratory (LCL) was upgraded by installing the highly efficient screw chiller packages.

Fig. 9: Advance AC plant of LCL lab (screw chiller packages)

2) New facility for production of "Self Illuminators" in Cirus complex BARC: A new facility for production of Self-Illuminators in Cirus complex, BARC, has been **hot commissioned after obtaining approval from the regulators.**

Fig. 10: Hot commissioning of Self-illuminators production facility at the basement of Cirus complex, BARC

3) **A remotely operated PLC controlled facility for production of ^{131}I capsules was set-up. This facility was hot commissioned after obtaining approval from the regulators.**

Fig. 11: Hot commissioning of new advance facility for production of ^{131}I capsules in RPL

Status of Setting up of ^{68}Ga-RPhs and Radioanalytical Laboratory (RAL) at RC, Hyderabad: Indenting is in progress to procure equipment's for setting up of ^{68}Ga-radiopharmaceutical laboratory for supply of ^{68}Ga-radiopharmaceuticals to local nuclear medicine centres and expansion of Radioanalytical laboratory services for 'Measurement of Radionuclides in Commodities' at RC Hyderabad.

d. Augmentation and Revamping of Products and Services Facilities at BRIT Vashi Complex (ARPF)

The Project "Augmentation and Revamping of Products and Services Facilities at BRIT Vashi Complex (ARPF) is mainly towards developing and expanding the required infrastructure and facilities, which would be helpful in increasing the performance and production of indigenously developed radiopharmaceuticals, radiation technology equipment devices and other radioisotope-based services. This would reduce the dependency on the imports, while improving upon the safety & security of the premises.

Project Status during the Reporting Period

Few developments, as part of ARPF, are mentioned below:

- For augmentation of the production facility for TCK cold kits: Work on new GMP clean room facility for prodction of TCK Cold kits has started by site clearance, construction of the building for housing AHU of clean room. Fabrication of the facility components, is in progress.
- To upgrade old non-GMP compliant false ceiling in RPL, job of installation of the GMP compliant SS panel type false ceiling has been initiated.

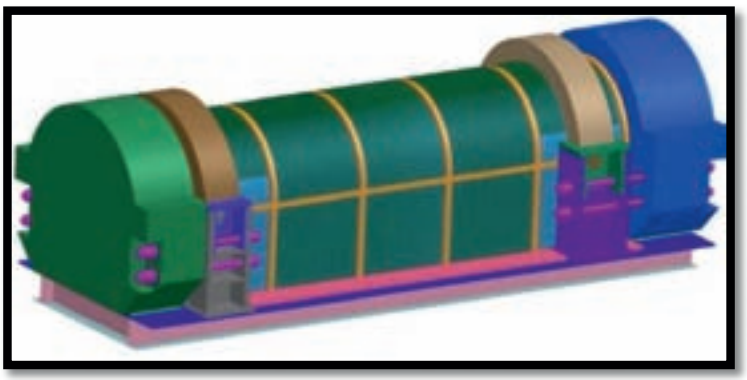
e. Radiation Equipment Development Project (EDP)

Few developments accomplished, during 2023-24, under this Project, are as follows:

- ✓ Hot Commissioning of Low Temperature Irradiator (LTI) is completed.
- ✓ Design & construction approval and Security Plan approval of Mobile Food Irradiator (MFI) is received from AERB and DAE respectively. The work contract for the irradiator is in the process of approval from the competent committee of BRIT.
- ✓ The Mo-99 Transportation Package (MTP-1200) received type B(U) transportation package approval from AERB.
- ✓ Delivery of Cobalt-60 based industrial radiography device, COCAM-A, is completed.
- ✓ Delivery of advance cranking unit for industrial radiography device is completed.
- ✓ Design and fabrication drawing of Cobalt Pin cask is completed. It is designed to carry a maximum of 50 kCi of Cobalt-60 produced from Co-NU fuel bundle of Indian PHWR to Cobalt handling facility of BRIT at Kota.
- ✓ The 9m drop and 1m punch test of ROTEX-I radiography device were successfully conducted at ARAI, Pune.
- ✓ Delivery, installation and commissioning of "Ansys Mechanical Enterprise Solver", a finite element analysis software, is completed.

Hot commissioning of Low Temperature irradiator

COCAM-120 (W)



Design of Co-60 Pin Cask

BRIT Website

Computer & Network Management (C&NM) Section is responsible for managing IT services including Network services, Web services and Application services in BRIT.

Various Network services such as Internet, Intranet, ANUNET services are managed by employing state-of-the-art security practices. The practices include design of network architecture with defence-in-depth policy, Access Controls at various network levels, Unified threat Management (includes Firewall, Intrusion Protection systems, antivirus protection) for network perimeter security and Security Auditing are continuously being pursued.

Applications such as BRIT Information System, User portal, Time and Attendance Management Software, Annual Performance Appraisal Report software services are managed and monitored for its performance and periodic database backup are maintained for data protection and disaster recovery. Application Services are also extended to Regional Centers (RC) of BRIT via VPN, ANUNET connectivity with minimum latency.

Video Conferencing Meetings are conducted with various DAE Units, organization. Around 250 Nos of meeting has been held through Video conferencing system/virtual meetings in year 2023-24.

In order to promote the paperless, transparent and efficient tendering process in BRIT, C&NM section is executing e publishing of BRIT tenders enquiry related to work contract through Central public procurement portal (CPPP).

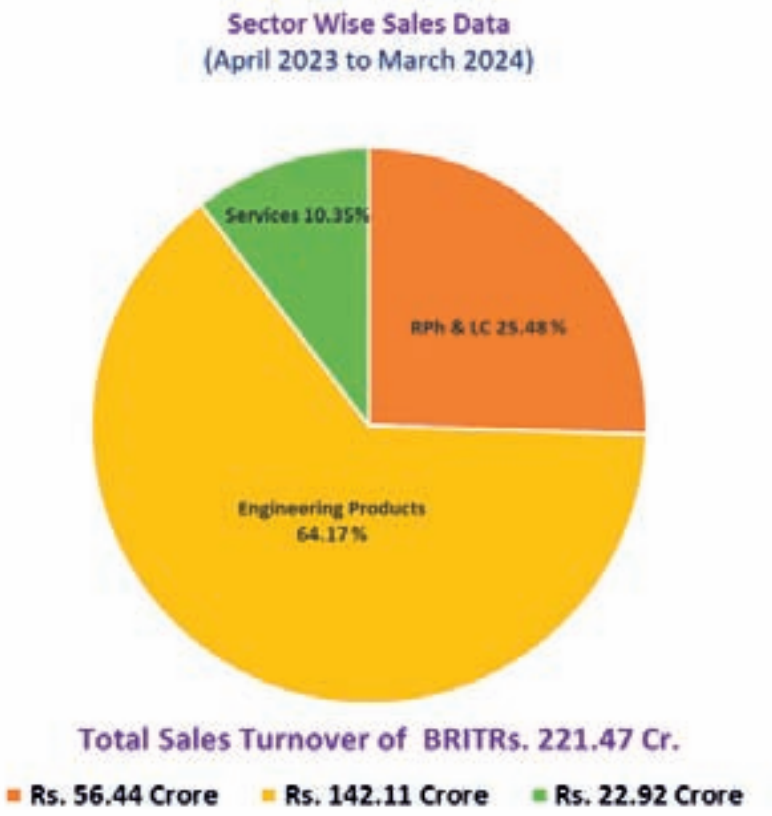
The various IT infrastructure development activities taken place at BRIT includes

- Implementation of Core switch with High Availability
- Upgration of Unified Threat Management System
- Upgrdation of Local Area Network connectivity at Renovated REPF Building
- Upgradation of Internet lease line connectivity
- Management of ePortal application to ensure smooth sales and business operation.
- In addition, Capacity planning and upgradation of Network at regular interval has been undertaken to provide smooth Internet/Intranet/ANUNET access to all BRIT users.

BRIT have its websites in bilingual form and it is updated regularly for content updation. BRIT website facilitates presentation of data for various key performance indicators, BRIT accomplishments, and publications. Total visitor 3298891 have visited BRIT website so far. Important information related to BRIT is published under NEWS Section. The respective new official orders, RTI information, BRIT KPI data, BRIT accomplishment and Tender information's, are all updated regularly on website.

Sales Turnover

Sales data of BRIT Products and Services (Revenue in Crores) during 2023-24



Total Sales Turnover in 2023-24 is
Rs. 221.47 Crores

CHAPTER 2

RESEARCH & DEVELOPMENT ACTIVITIES

A. Radiopharmaceuticals Production Programme (RPhP), Vashi Complex

- BRIT has designed and developed a semi-automated modular PLC based separation system for isolation of no-carrier-added (NCA) Lu-177 radiochemical from irradiated enriched Yb-176 target. The manual process for the separation of nca Lu-177 from Yb is cumbersome involving labour-intensive separation work of 3-4 d. The modular system designed is PLC based and is capable of delivering the required separation in 6-8 h. Using this modular set-up, NCA Lu-177 could be produced in high yield and purity. Two batches of Yb-Lu separation were processed on the developed modular set-up. The isolated NCA Lu-177 was subsequently used in the preparation of clinical doses of ^{177}Lu-DOTA-TATE and ^{177}Lu-PSMA which were evaluated in cancer patients at TMH Mumbai. The patient distribution profile showed desired distribution in cancerous metastatic lesions which is expected to have beneficial therapeutic effect.

- Bhabhasphere delivery system involves a tubing assembly through which radiolabeled Glass Microspheres is directly delivered into the liver cancer. The particles dispensed in ~100 mL saline are slowly and continuosly delivered under pressurized conditions via hepatic artery to the cancerous tissue. BRIT initially developed a delivery system, however its performance was sub-optimal during clinical usage stage, as around 50-70% of the radiolabeled particles were getting lodged to the cancerous tissue. Recently, with a lot of design iterations, BRIT has developed a newer version of Bhabhasphere Delivery system. This could resolve all the technical issues of the old design. The newer version is effective in delivering more than 95% of Bhabhasphere into patient's cancerous liver as tested at TMH.

- Biodistribution studies of a modified lyophilized kit formulation meant for the preparation of ^{99m}Tc-TRODAT injection at hospital end for SPECT imaging of Parkinson 's Disease was carried out in normal Wistar rats. Clinical trial of this kit was also conducted at the Jaslok Hospital, Mumbai during March 2024. The product dossier was submitted to RPC which accorded approval for its routine production and supply to nuclear medicine centres.

- Radiolabelled macrocyclic bisphosphonate ligands have demonstrated high efficiency in the clinical management of patients with painful skeletal metastases. In this regard, a lyophilized kit for the preparation of clinical doses of ^{177}Lu-BPAMD as a palliative agent for metastatic bone pain has been developed. Three batches of this kit have been prepared, thoroughly analysed for different quality control parameters and biologically evaluated in suitable *in vitro* and *in vivo* models. On preliminary clinical investigations, carried out in two patients diagnosed with prostate carcinoma with disseminated skeletal metastases, intense radiotracer uptake was observed in the metastatic skeletal lesions with insignificant uptake in any other major non-targeted organs. Further investigations are in progress to establish this radiotracer as a potent radiopharmaceutical.

- Peptide Receptor Radionuclide Therapy (PRRT) has attracted a lot of interest in recent times towards the treatment of various malignancies. Towards this, a lyophilized kit for the preparation of ^{177}Lu-DOTA-E-[c(RGDfK)]$_2$ radiotracer for targeting integrin $\alpha_v\beta_3$-receptors

known to be over-expressed on malignancies like glioblastoma, melanoma, osteosarcoma, neuroblastoma as well as types of breast cancer, lung cancer and thyroid cancer having limited treatment modalities is under development. This work was an extension of the earlier work where a lyophilized kit for the preparation of ^{68}Ga-DOTA-E-[c(RGDfK)]$_2$ was developed which exhibited excellent characteristics for PET imaging. Three batches of this new kit have been prepared followed by quality control, pre-clinical and limited clinical evaluation for theranostic application. More extensive clinical investigation is underway to establish the suitability of the formulation.

- Development of cold kit formulation for Tc-Pyp (Technetium pyrophosphate) towards use in bone imaging was taken up and completed. Batch product dossier to be submitted to Radiopharmaceuticals Committee towards approval for regular production.

- BRIT is currently supplying a three-component kit for the preparation of ^{99m}Tc- Ethylene di cysteine (EC) used for renal dynamic function studies. As part of continuous development, it is proposed to replace the current three-component kit with a user-friendly single-component kit. In this connection, a single component EC kit was formulated. The optimized kit formulation was labeled with Tc-99m. Radiochemical purity was found to be above 95% with good *in vitro* stability. Biodistribution studies are in progress to evaluate the biological efficacy of the product.

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 2023-24, the following R&D assignments were carried out:

I. Production and Radiochemical Separation of ^{68}Ge from irradiated Ga-Ni alloy target in 30 MeV Cyclotron

Gallium-68 [$t_{1/2}$: 67.7 min, decays β^+ (89%)] has application in PET imaging mainly for prostate cancer and neuroendocrine tumors. ^{68}Ga radiopharmaceutical can be produced directly from enriched ^{68}Zn solid/liquid targets, via ^{68}Zn(p, n)^{68}Ga reaction in a medical cyclotron and supplied to local hospitals. However, due to short half-life of ^{68}Ga, the supply of cyclotron produced ^{68}Ga-radiopharmaceutical is restricted to local regions only. Therefore, it is important to prepare ^{68}Ge ($t_{1/2}$ = 271 days) radiochemical for the manufacture of ^{68}Ge/^{68}Ga generator to cater to various nuclear medicine centers. ^{68}Ge has been produced in 30 MeV Medical Cyclotron from an indigenous electroplated Ga-Ni alloy target.

The Ga-Ni alloy target was prepared from sulphate bath (pH – 1.5) using constant current electrolysis technique on a gold-plated Cu-base material. Gamma Spectra of impure irradiated Ga-Ni alloy target is shown in Fig. 1. The target was irradiated with 28 MeV proton beam for 80 hours (total integral beam current: 4000 µAh) and chemically processed using Sephadex G-25 column after sufficient cooling in an indigenous automated module. The irradiated target (n=3) was dissolved in HNO_3 by repeated circulation of the hot acid solution in a closed loop. The dissolved solution was mixed with 1M Na-citrate (pH =12-13) and NaOH solution followed by loading on a preconditioned Sephadex G-25 column. Gamma Spectra of pure ^{68}Ge after radiochemical separation is shown in Fig. 2. The column was washed with 1M Na-citrate (pH = 12-13), dilute Na-citrate (pH = 12-13), dilute NaOH solution and deionized water successively. ^{68}Ge-chloride was eluted using 0.1M HCl solution. The chemical separation yield and radionuclidic purity of ^{68}Ge was about 70% (n=3) and >98% (n=3), respectively. Thus, pure ^{68}Ge-chloride may be used for the preparation of ^{68}Ge/^{68}Ga generator. Schematic diagram of module for purification of ^{68}Ge from Ga-Ni target & Schematic diagram for production and purification of ^{68}Ge are shown in Fig. 3 & Fig. 4.

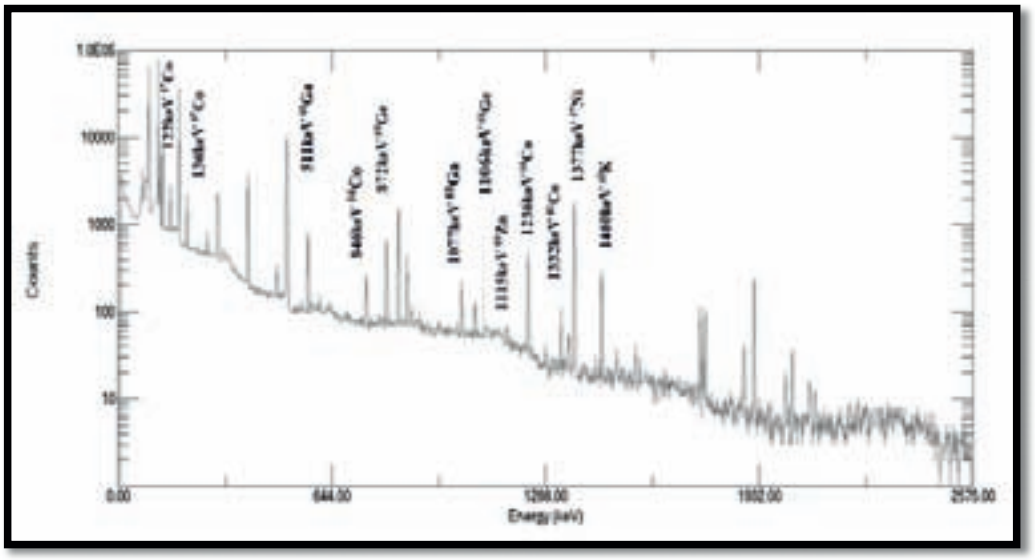


Fig. 1: Gamma Spectra of impure irradiated Ga-Ni alloy target

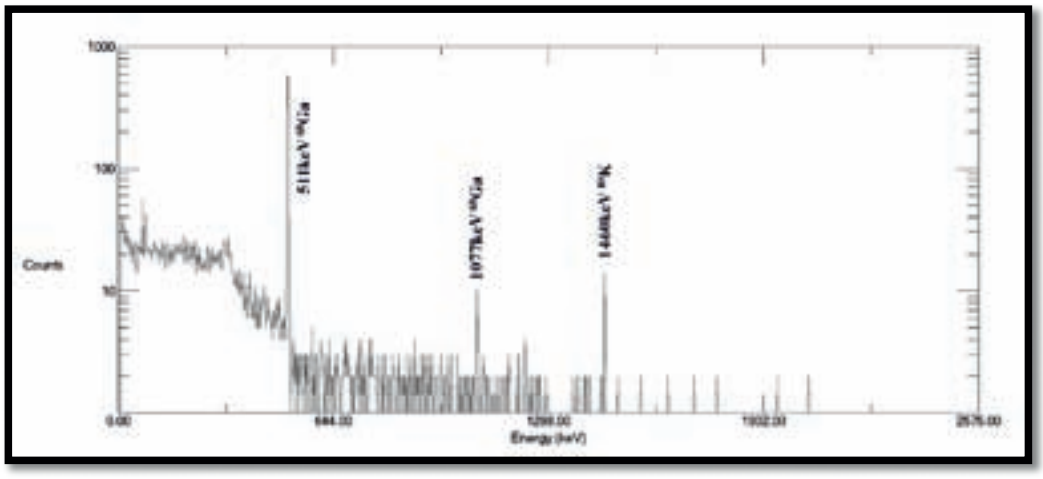


Fig. 2: Gamma Spectra of pure ^{68}Ge after radiochemical separation

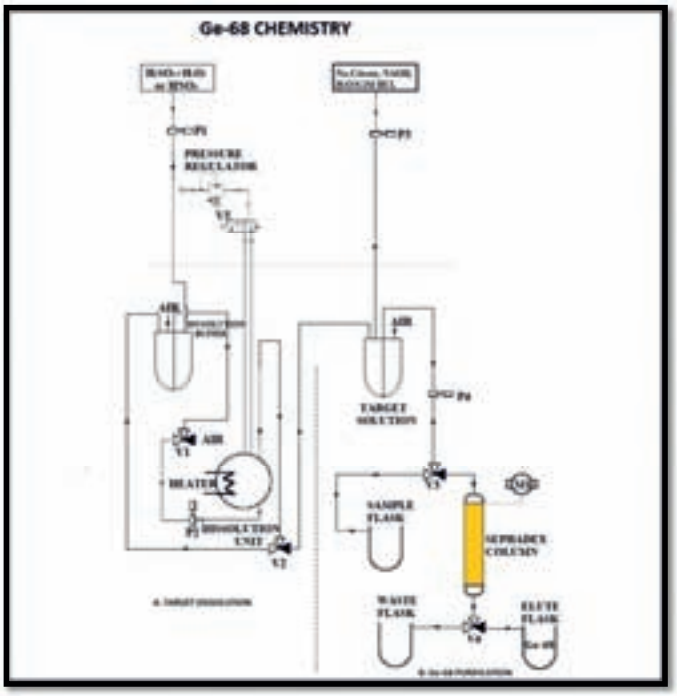


Fig. 3: Schematic diagram of module for purification of ^{68}Ge from Ga-Ni target

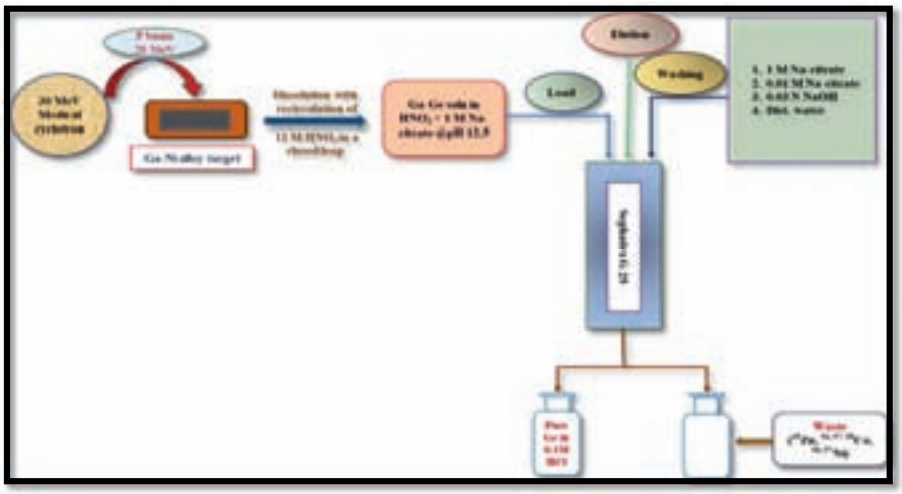


Fig. 4: Schematic diagram for production and purification of ^{68}Ge

II. Production and radiochemical separation of ^{64}Cu from enriched ^{68}Zn target in 30 MeV cyclotron

Copper-64 ($t_{1/2}$: 12.7 h, decays: 17.5% β^+, 38.5% β^-, 44.0% EC) is a multipurpose radionuclide with many potential applications in monitoring of cancer growth and its development (PET imaging) as well as for theranostic purposes. This isotope can be produced in reactor as well as in cyclotron. No-Carrier-Added ^{64}Cu is generally produced in a small cyclotron through ^{64}Ni(p, n)^{64}Cu nuclear reaction; however it can also be prepared via ^{68}Zn(p, αn)^{64}Cu nuclear route in a medium or high energy cyclotron. The utilization of exorbitantly priced enriched ^{64}Ni as a target compared to enriched ^{68}Zn makes the ^{68}Zn target a more economic route in target utilization.

The indigenously prepared electroplated enriched ^{68}Zn target (area: 11.69 cm^2) was irradiated for 5.3 hours (total integral beam current: 500 µAh) using 28 MeV proton beam in 30 MeV cyclotron. The irradiated target was transferred from the vault to the solid target processing hotcell via the pneumatic target transfer system. It was dissolved in acid and chemically processed in a semi-automated module using Dowex 50W-X8 (H^+ form), Dowex 1-X8 (Cl^- form) and solvent extraction to yield pure nca ^{64}Cu, (radionuclidic purity of >99.5% EOS, yield: 37 MBq/ µAh) in the form of $^{64}CuCl_2$ which may be further utilized for the preparation of other Cu-based radiopharmaceuticals. Therefore, it may be concluded that appreciable quantity of pure ^{64}Cu can be produced using ^{68}Zn(p, αn)^{64}Cu nuclear route.

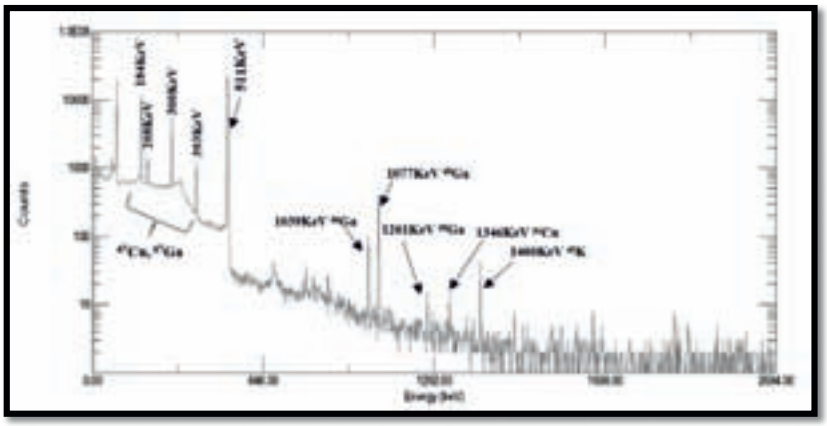


Fig. 1: Gamma Spectra of impure irradiated ^{68}Zn target

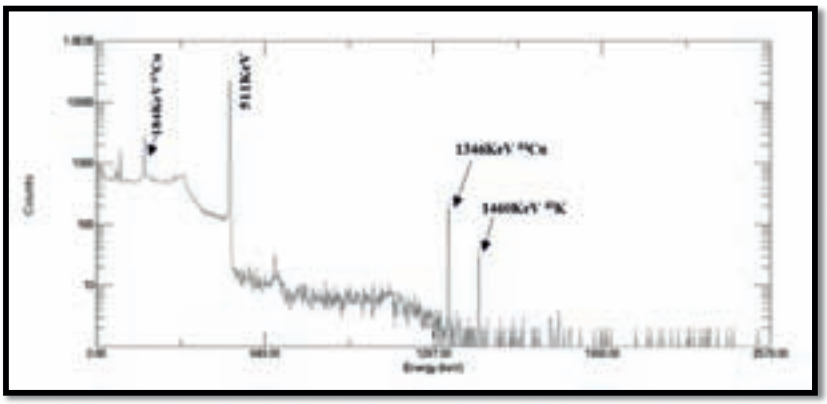


Fig. 2: Gamma Spectra of pure ^{64}Cu after radiochemical separation

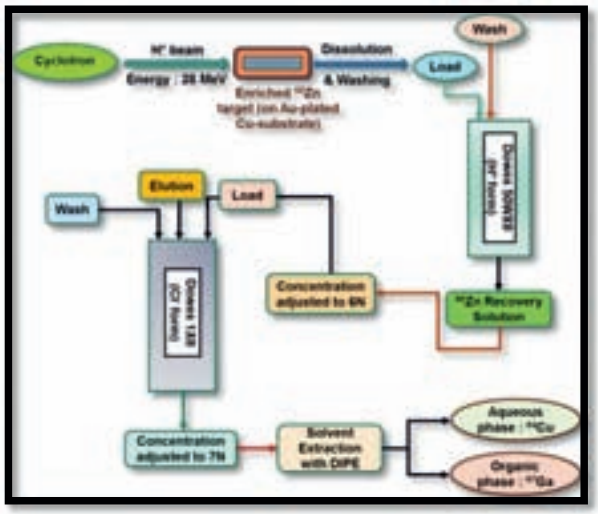


Fig. 3: Radiochemical separation and purification process of pure ^{64}Cu

III. Indigenous development of Pb-203 radioisotope from low cost natural thallium target using 30 MeV cyclotron

Pb-203 has drawn interest as a SPECT imaging isotope analogue to the therapeutic Pb-212, an alpha-emitter. This radioisotope has a half-life period of 52 hours and emits the γ energy at 279 keV with an intensity of 81%, it is adapting for the medical imagery SPECT. Furthermore, it can be used for theranostic with the same element but different isotopic: Pb-212. This radioisotope emits two β^- particles and one α particle during its decay.

NCA (no-carrier added) Pb-203 has been produced from an electroplated natural thallium target (thickness ≈ 100µm) prepared in-house after irradiation using 28MeV proton beam with total integrated beam current of 500 µAh. After chemical processing in an indigenous module resulted radionuclidically and chemically pure nca Pb-203 with a yield of approx. 0.50 mCi/ µAh.

Hence, it may be concluded that a large quantity in Curie level of pure Pb-203 could be produced using 28 MeV proton beam in 30 MeV Medical Cyclotron at Kolkata.

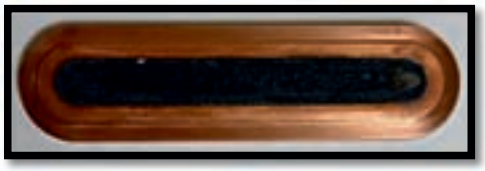


Fig. 1: Natural thallium (Tl)

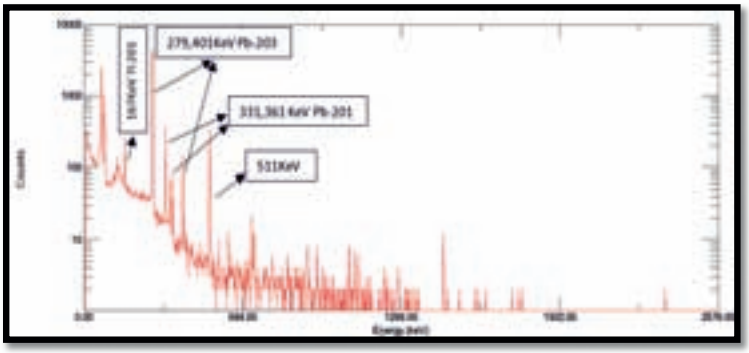


Fig. 2: Typical gamma spectrum of no- carrier-added Pb-203 with high radionuclidic purity (RCP)

Isotope	T 1/2(h)	R N Purity(%)
^{201}Pb	9.4	0.008
^{203}Pb	52.1	99.968
^{204m}Pb	1.15	0
^{202m}Pb	3.6	0
^{201}Tl	73.5	0.022

Fig. 3: Radionuclidic Purity (RNP) of Pb-203 @ 40h post irradiation

IV. Production and sample preparation for Indium-111 RIB using K130 cyclotron

An indigenously prepared thick natural silver target electroplated on a hemispherical copper base (Fig. 1a) was internally irradiated with 32 MeV, 30 µA alpha particle beam for 3 days in VECC K-130 cyclotron to produce ^{111}In via the ^{109}Ag(α, 2n)^{111}In nuclear reaction. Post irradiation the target was cooled for 48 hours to allow other short-lived isotopes produced via competing channels like ^{109}In (4.2 h) and ^{110}In (4.9 h) to decay. It was then removed from the cyclotron Dee, remotely dismantled from the target holder system (Fig. 1b) and transported to a lead shielded fume-hood in the BRIT-Laboratory in a 30 mm thick lead container. Chemical separation and sample preparation for ^{111}In RIB experiment was performed after 89 hours since end of bombardment (EOB).

The target was dissolved in 8M HNO_3 using a rotor system designed in-house. Curdy white precipitate was obtained on addition of concentrated HCl followed by dilution with distilled water. The precipitate was filtered and the filtrate was washed with 6N HCl multiple times. Post filtration, the filtrate was evaporated to dryness. The residue was reconstituted with conc. HCl and repeated evaporations to dryness ensured complete dissociation of nitric acid. The residue was finally taken up in 5 ml of water and passed through a 0.22 µm filter. The solution was further concentrated to ~500 µl and deposited on the sputter target of the RIB group of VECC. This activity was dried on a steel base diameter and used as the sample holder in the ECR chamber for further RIB experiments. The total activity deposited on the sputter target of RIB group at this time was 88 mCi.

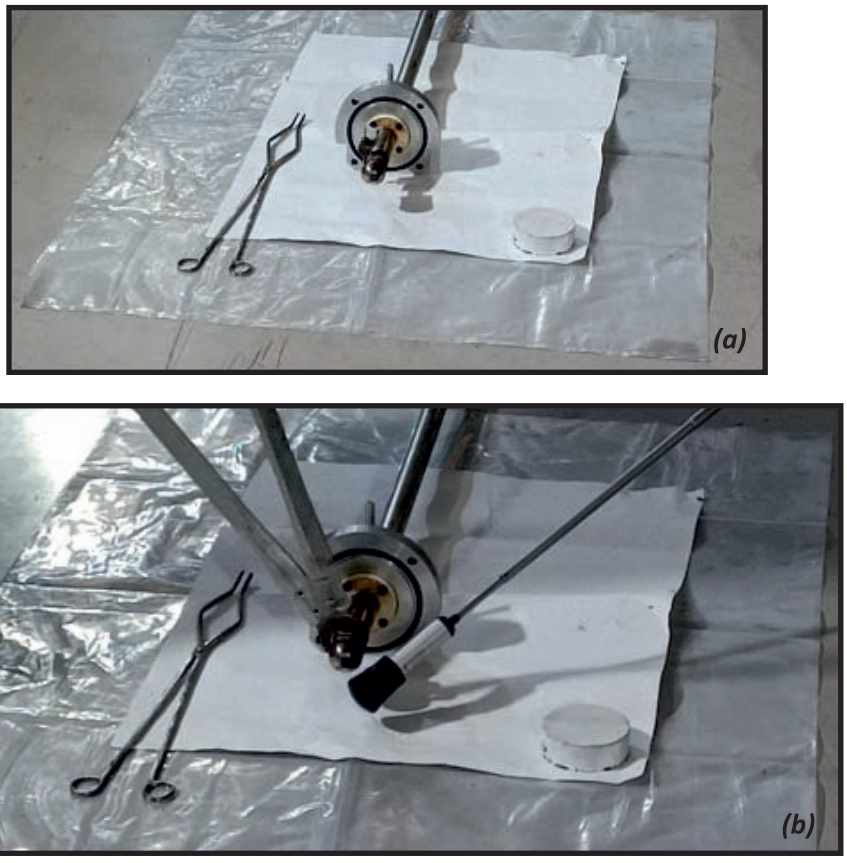


Fig. 1: Indigenously prepared natural silver target (a) before irradiation (b) after irradiation

V. First time production of nca Na[^{123}I]I in India using 30 MeV cyclotron

Iodine-123 with predominant energy of 159 keV is used in nuclear medicine imaging, including (SPECT) or SPECT/CT for diagnostic study of thyroid disease including diagnostic imaging thyroid tissue and thyroid cancer metastasis as iodine is taken up by the thyroid gland. Radioactive I-123 in particular is effective for this use as its half-life of approximately 13.13 hours is ideal for the 24-hour iodine uptake test and it has a reduced radiation burden as compared to I-131. The present methodology of production of I-123 from enriched Te-124 offers a convenient alternative to the costly enriched Xenon-124 gastarget system for the routine production of I-123. The electroplated enriched Te-124 target (Fig. 1) was prepared indigenously on a nickel coated copper base material. The I-123 radioisotope has been produced by irradiating the electroplated enriched Te-124 target with 28MeV proton beams using an average current of 20 µA. The irradiated target (Fig. 2) was transferred to the solid target processing hotcell (100 mm lead shield) from the irradiation vault by remote controlled rabbit transport system. After radiochemical processing approximately 50mCi of pure I-123 was produced. The radionuclidic purity of sodium iodide (Na^{123}I) was greater than 99%. The co-produced I-124 content was less than 1%. Hence, a highly pure sodium iodide (Na^{123}I) has been produced successfully.

Fig. 1: Enriched ^{124}Te target

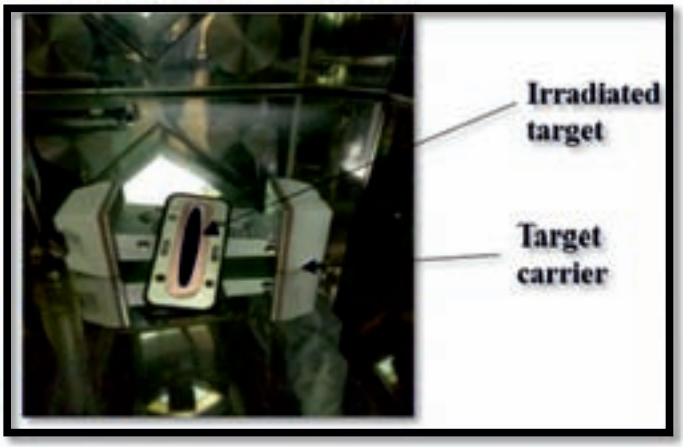


Fig. 2: Irradiated target carrier

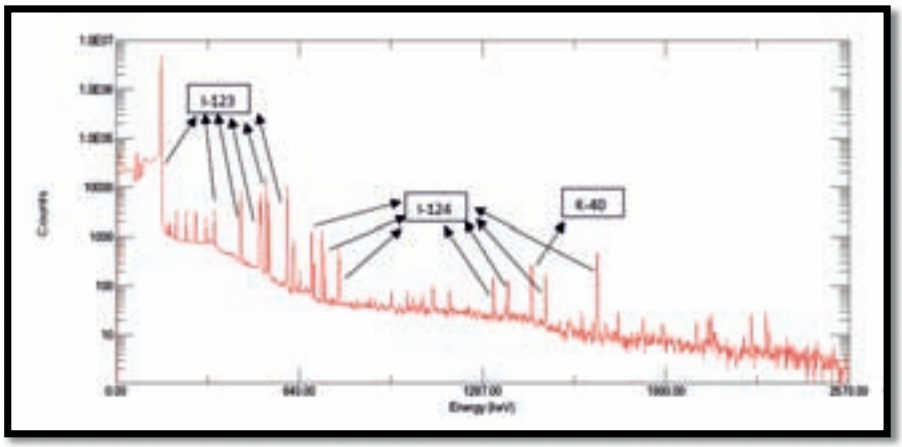


Fig. 3. Gamma Spectra of pure Iodine-123

VI. Indigenous Development of BVSynth

[^{18}F]-Fluorodeoxyglucose ([^{18}F]-FDG) is the most widely used positron-emission tomography tracer, used for imaging in clinical studies. The liquid target is transferred to either of the hot cell for the synthesis. There are two IBA Synthera unit in two hot cells. M/S IBA make Synthera is a multipurpose synthesis system which automates the synthesis of radiopharmaceuticals (^{18}F-FDG, ^{18}F-NaF). The system includes processing unit, control unit, laptop PC and power supply and a software programme.

The Synthera system includes a graphical user interface (GUI) and development environment for programming and monitoring the automated multipurpose module (Fig-1). Essentially consisting of electromechanical and electro-pneumatic assemblies that includes valve actuations, temperature-controlled heater, pressure regulators, the system utilizes IFP cartridges to synthesize [^{18}F]FDG from irradiated F-18. The system is operated by an electronic controller and controlled by a GUI. The Synthera is operated automatically as per the process sequence (Extraction, Striping, Evaporation, Drying, Labelling, Hydrolysis, Water mixing, Purification) required according to the process parameters.

The IBA Synthera at PET hot cell 2 had stopped working after the synthesis of batch FDG -309 dated 26/11/2021 due to breakdown of the controller.

To counter this problem that was affecting the production reliability, a replacement electronic control unit, BVSynth, with a compatible GUI was indigenously developed that interfaced with the mechanical module to cater to the required functionality. The design attempted to follow the functioning of the IBA make Synthera specifics, as closely as possible. Several cold runs and hot runs were conducted in BVSynth for checking yield and quality of product.

It was handed over for the production in the last week of February 2023 and after performing the quality control Tests as per RPC recommended procedure, the products are being supplied to the hospitals on regular basis.

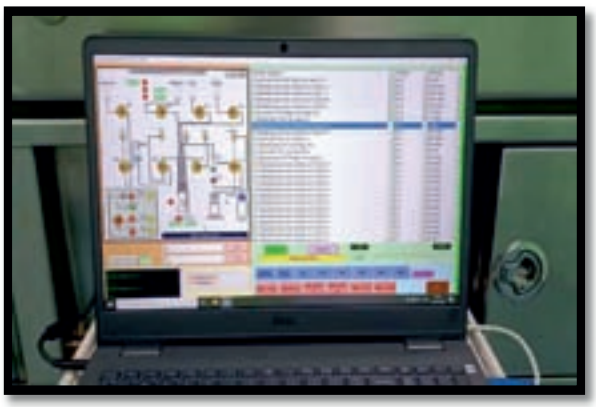


Fig. 1: Laptop communicating with BVSynth via GUI

Fig. 2.: Synthera device wired with BVSynth

Fig. 3.: Control unit

C. Microbiology Laboratory, (RPP), Vashi Complex

- Radiation sensitivity studies of a bacterium, *Methylorubrum thiocyanatum* isolated from irradiated chilli powder

The microbiological data on variety of spices processed at the facility showed frequent occurrence of radiation resistant, pink coloured, Gram-negative, rod shaped bacterium in most of the irradiated chilli powder. 16S rRNA sequencing data (~1200 bp) of the bacterium showed 99.93% similarity with the bacterium *Methylorubrum thiocyanatum.* The said bacterium when studied for its radiation sensitivity showed a D_{10} value (decimal reduction value) of 1.94 kGy in phosphate buffered normal saline. The same studies when repeated in chilli powder showed D_{10} value of 2.47 kGy with 27% increase in its resistance to radiation which might be due to radio-protective effect of the carotenoids present in chilli powder. Similar studies when carried out with *S. aureus* there observed 50% increase in its D_{10} value.

D. Regional Centre (RC), Hyderabad (Jonaki)

Development of a new product 'Magnetic cellulose (MagCell) bead based genomic DNA extraction kit (MAGCK-01/02)' was completed and demonstrated its improved performance over the catalogued spin column-based DNA isolation kits. The developed MagCell kits is being evaluated in clinical samples using indigenous FRET real time PCR method to demonstrate its potential in molecular diagnostics.

E. Regional Centre (RC), Bengaluru

RCB is on the process of setting up a water testing laboratory for measurement of gross alpha and gross beta. Instrument procurment and its calibration process is over. Initial trail testing and participation in Inter-Laboratory activities is in progress.

CHAPTER 3

HUMAN RESOURCES DEVELOPMENT

Training Courses/ Lectures/ Workshops/ Seminars/Conferences

1. Dr. Usha Pandey delivered an invited talk on “Societal Applications of Radioisotopes” in the 106th workshop on "Radiochemistry and Application of Radioisotopes” at SVNIT, SURAT, Gujarat during 8-12 Jan. 2024.

2. Dr. Usha Pandey delivered an invited talk entitled “Analytical Chemistry : An Essential Tool in the Field of Radiopharmaceuticals” in the 3rd DAE-BRNS Symposium on Current Trends in Analytical Chemistry (CTAC-2023) held during 6-9 March 2024 at DAE Convention Centre, Anushakti Nagar.

3. Dr. Usha Pandey reviewed manuscripts for journals such as Journal of Radioanalytical & Nuclear Chemistry and Cancer Biotherapy and Radiopharmaceuticals.

4. Shri Aaditya Shah and Ms. Amala Mathai imparted training of Bhabhasphere (^{90}Y-Glass Microsphere) new delivery system to users of TMH, Mumbai. This training was imparted to orient the user for safe delivery of Bhabhasphere directly into the patient liver using BRIT's developed delivery system.

5. Dr. Anupam Mathur delivered an invited lecture on “SPECT Radioisotope and Radiolabeling of a New Drug” in 13th Annual Workshop on “In Vivo Preclinical Imaging & Drug Discovery” held between 16-18th Dec 2024 at ACTREC, Navi Mumbai.

6. As part of their curriculum, MSc (NMMIT&HRP) students of HBNI from RMC, Parel underwent practical orientation course at the production facilities of Radiopharmacetical Programme, BRIT during July and Aug. 2024. The visit was co-ordinated by Smt. Uma Sherikumar.

7. 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.

8. Dr. Soumen Das presented the “Vision 2047 for BRIT in Healthcare” at DAE Chintan Shivir held in Central Complex Auditorium, BARC during 22-24th January 2024.

9. Shri Manohar Bhatia, Smt. Pooja M. Kale and Dr. Soumen Das were the resource persons from BRIT in the National Science Day 2024 on the Theme “Atoms for Society: Water, Food and Health” held during February 28 to March 1, 2024 at Central Complex, BARC.

10. Dr. Usha Pandey was invited as Chief Guest for the National Science Day celebration at Apeejay School Nerul on 29th February 2024. She inaugurated the Science Exhibition as part of the celebrations.

11. Smt. Prasanna Rao, Dr. Soumen Das, Shri. Navin Sakhare and Shri. Sudhir Singh exhibited BRIT products and posters at the 3rd DAE-BRNS Symposium on Current Trends In Analytical Chemistry (BARC-CTAC 2023) held at the DAE Convention Centre, Anushaktinagar during 06th-09th March 2024.

12. Smt. Shalaka N. Paradkar delivered a lecture on 'Overview of DAE Activities' specific to the role of BRIT in the department, at the JPA/JSK 3rdInduction Training programme conducted by DPS.

13. Dr. Sankha Chattopadhyay has delivered three lectures on “Basics Of Radiopharmaceutical Chemistry For Nuclear Medicine” at School of Medical Science and Technology (SMST), Indian Institute of Technology, Kharagpur, August, 2023.

14. One B.E. (Biomedical Engineering, 1st Year) student from Schaefer School of Engineering, Stevens Institute of Technology, New Jersy, USA has completed the project titled “A Perspective on Production and Quality Control of Iodine-123 Radiopharmaceutical Produced in Cyclone-30 for Applications in Nuclear Medicine” during July-August, 2023.

15. One B.Tech. (Biotechnology & Biochemical Engineering, 2nd Year) student from Indian Institute of Technology, Kharagpur, has completed the project titled “A Perspective on Production and Quality Control of F-18 FDG Produced in Cyclone-30 for Applications in Nuclear Medicine” during December, 2023.

16. Dr. Luna Barua delivered an invited talk on 'Feasibility of Unconventional Radioisotope Production for Clinical Application in India – Our experience at BRIT, Kolkata, using 30 MeV Cyclotron' in PRACTICUM on Cyclotron Operations, handling of theranostic radio-nuclides and safety of radiation workers in nuclear medicine and research” (21st-23rd Feb 2024) at INMAS, DRDO, Delhi.

17. Presention about the “Activities of Isotope Application Services (IAS)” was given by Shri Gaurav Agrahari, to the Director, Refinery, RHQ-Delhi.

18. BRIT sponsored the event, 'Distillation Experts Conclave-2023' to showcase the activities of IAS Group through the 'Table top' exhibition to the refinery experts, manufacturers and technology providers. **During this event, Chief Executive, BRIT, had delivered a keynote talk regarding current market scenario and future aspects of industrial applications of radioisotopes and Shri Vinay Bhave presented a case study on gamma scanning.**

19. Officers of ISOMED were involved in providing ISO 11137 training for the staff from M/s Ansel, Sri Lanka, and RPP Plant owners in India, during October 2023.

20. Officers of Microbiology Laboratory, RPP, Vashi, conducted internal quality audits/surveillance for Quality Management Systems (QMS/FSMS/MDQMS) of RPP Facility. They also have successfully carried out recertification of food safety management systems (FSMS) and ISO 22000:2018 of RPP, Vashi Complex.

21. Two Post graduate students of Mumbai University, were trained for their project work, as part of their M.Sc. curriculum, in the field of Biotechnology/Microbiology, under Shri Milind Kumbhare, in the Microbiology Laboratory of Radiation Processing Plant.

22. Dr. Rahul Kumar of MIG, ESSA, is one of the four authors of “Proceedings of the International Conference on Information Control, Electrical Engineering and Rail Transit (ICEERT 2022), Springer Publication **(2023)**. This book houses 'Lecture Notes in Electrical Engineering 1024'.

23. Dr. Ashok Chandak was involved in guiding M.Sc and M.D. Students at RMC, Parel for the following Projects: (a) ^{68}Ga-NODAGA-RGD PET-CT imaging in patients of thyroglobulin elevated negative ^{131}I scintigraphy (TENIS) carcinoma thyroid and anaplastic thyroid carcinoma (ATC), project with Dr. Abhay Gondhane (June 2023); (b) To evaluate angiogenesis expression

(^{68}Ga-NODAGA-RGD PET/CT imaging) in patients of thyrotoxicosis to predict the response of given treatment, with Dr. Bhaskar Parasram Lakhule (June 2023); (c) Labeling and evaluation of ^{177}Lu-RGD dimer; and, (d) Radiolabeling of PSMA-617 with ^{89}Zr and physicochemical evaluation.

24. Smt. Raksha Rajput delivered a lecture on "Radiation Sources (Gold seeds, Tantalum wires, ^{125}I-seeds, beta-ray applicatiors)" to the students of 61st batch of Diploma Radiological Physics, RPAD, BARC.

25. Obtained RPC Clearance for "^{68}Ga-NODAGA-RGD dimer for its use in the diagnosis of Cancer", (Dr. Ashok Chandak) during Jan 2023. Dr. Ashok Chandak is also involved in Collaborative work with IIT, Indore, for the "Labelling & Evaluation of ^{99m}Tc- and ^{177}Lu-based Radiopharmaceuticals for diagnostic & Therapy of Prostate Cancer".

26. Shri. Deepak B. Kalgutkar delivered a lecture on "Preparation of Tracers and Labelled Compounds" to the Students of Diploma in Radiation Protection (DRP-61), Conducted by RPAD, BARC, (2023).

27. Dr. T.K. Sankaranarayana of RC, Kolkata, presented and participitated in the discussion on the topic, "Emergency preparedness for nuclear and radiological exigencies" at the Regional Security Strategies Cenference – 2023 held at Hyderahad, on 24th August 2023, Conducted by Intelligence Bureau, Government of India.

28. Smt. Srishti Srivastava of RC, Delhi, coauthored a Chapter on "Energy Sector and Renewables", in a Book entitiled, "Sustainable Development of Purvanchal", Released by Planning Department, Government of Uttar Pradesh.

29. Smt. Teena Goel delivered a lecture on "Radiation Safety Aspects of Research, Radiotracer and Column Scanning Applications of Ionizing Radiation" for students of RSO Certification Course, and another lecture on "Production of Radioisotopes & Labelled Compounds" at Amity Institute of Nuclear Science and Technology, Amity University, Uttar Pradesh, Noida, during June, 2023.

30. Smt Manjusha Ranjit attended RSO training course on Radiation Safety aspects of Gamma Irradiation chamber (Cat-I Irradiator) conducted by IARP & RP & AD, BARC.

Publications in Peer Reviewed Journals

1. **Preparation of [^{68}Ga]Ga-Chloride from ^{68}Zn solid target for the synthesis of pharmaceutical grade [^{68}Ga]Ga-PSMA-11 and [^{68}Ga]Ga-DOTA-TATE.**

   Sankha Chattopadhyay, Shayantani Ash, D.G. Mahesh, Luna Barua, Arpit Mitra, Sujata Saha Das, Samarjit Singha, Md Alam Nayer, Madhusmita, Umesh Kumar, Samarendu Sinha

   Applied Radiation and Isotopes 195 (2023) 110744.

2. **Production and radiochemical separation of ^{68}Ge from irradiated Ga–Ni alloy target in 30 MeV cyclotron.**

   Sankha Chattopadhyay, Samarjit Singha, Shayantani Ash, Luna Barua, D. G. Mahesh, Sujata Saha Das, Madhusmita, Md. Nayer Alam, Umesh Kumar, Suprakash Roy, Prosenjit Dhang and Santu Dey

   Radiochim. Acta 112 (2024) 7-8.

3. **Production of Pharmaceutical Grade [^{201}Tl]Thallous Chloride using 30 MeV Cyclotron.**

   Sankha Chattopadhyay, Luna Barua, D.G. Mahesh, Shayantani Ash, Arpit Mitra, Sujata Saha Das, Samarjit Singha, Md. Neyar Alam, Madhusmita, Suprakash Roy, Prosenjit Dhang, Mukesh Jain

   App. Rad. & Isotop. 204 (2024) 111128.

4. **Imaging of Bacterial Infection: Harnessing Positron Emission Tomography and Cerenkov Luminescence Imaging with UBI-Derived Octapeptide.**

   Jyotsna B Mitra, A Mukherjee, Anuj Kumar, ***Ashok Chandak,*** *S Rakshit, Hansa D. Yadav, Badri Narain Pandey, Haladhar Dev Sarma*

   Drug Dev. Res. 84 (2023) 1513-1521. https://doi.org/10.1002/ddr.22103.

5. **^{68}Ga-PSMA-HBED-CC PET/CT imaging in brain gliomas and its correlation with clinicopathological prognostic parameters.**

   Verma Priyanka, Singh Braj Kishore Sudhan, Manoharan Dwark, Singh Rupesh Kumar, Bagul Swati, ***Chandak Ashok,*** *Basu, Sandip*

   Clin. Nucl. Med., 48/12 (2023) e559-e563.

6. **Exploring the Potential of Radiolabeled Duramycin as an Infection Imaging Probe.**

   Anuj Kumar, Jyotsna B Mitra, ***Ashok Chandak,*** *S Rakshit, A Mukherjee*

   Drug Dev. Res. 85/1 (2024) e 22138. https://doi.org/10.1002/ddr.22138.

7. **Prospective Evaluation of ^{68}Ga-NODAGA-RGD PET-CT in patients of Carcinoma Thyroid with Thyroglobulin Elevated Negative Radioiodine Scintigraphy (TENIS) with a Head-to-Head comparison with FDG-PET/CT.**

   Gondhane Abhay, Verma Priyanka, ***Chandak Ashok,*** *Basu, Sandip*

   Nucl. Med. Comm. 45/5 (2024) 412-419.

8. **Angiogenesis Imaging of Adrenocortical Carcinoma with ^{68}Ga-NODAGA-RGD PET: Opening New Horizons in Multimodality Imaging from Theranostic Perspective.**

   Verma Priyanka, ***Chandak Ashok,*** *Shetye Suyog Sharad, Nazar Aamir K., Bagul Swati D., Malhotra Gaurav*

   Ind. J. Nucl. Med. 38/2 (2023) 183-184.

9. **Design, Characterization and Evaluation of a New ^{99m}Tc-Labeled Folate Derivative with Affinity towards Folate Receptor Evaluation.**

   Soumen Das, Navin Sakhare, Dheeraj Kumar, Anupam Mathur, Shubhangi Mirapurkar, Sheela Muralidharan, Bhabani Mohanty, Pradip Chaudhari, Sudipta Chakraborty

   Bioorganic and Medicinal Chemistry Letters, 86, (2023) 129240.

10. **^{68}Ga-Labeled Trastuzumab Fragments for ImmunoPET Imaging of Human Epidermal Growth Factor Receptor 2 Expression in Solid Cancers.**

    Shishu Kant Suman, Archana Mukherjee, ***Usha Pandey,*** *Avik Chakraborty, Sutapa Rakshit, Megha Tawate, Haladhar Dev Sarma*

    Cancer Biother. Radiopharm. 38 (2023) 38-50.

11. **Development of a Magnetizable Cellulose Particle-based Immunoradiometric Assay for Quantification of C-peptide in Rat Serum.**

    B. R. Manupriya, ***Shalaka Paradkar,*** *Tanhaji Sandu Ghodke,* ***Vijay Kadwad,*** *N. Karunakara & K. Bhasker Shenoy*

    Journal of Radioanalytical and Nuclear Chemistry, 332 (2023) 517–525.

12. **Freeze-dried Technetium Cold Kits for Facile Formulations of ^{99m}Tc-Radiopharmaceuticals at Nuclear Medicine Centres.**

    Archana Ghodke, Vijay B. Kadwad and Usha Pandey

    In "IANCAS Bulletin: Design Development and Applications of Radiopharmaceuticals – Part 1, Volume XIX No.2, September (2023) Pages 41-45.

13. **Industrial Applications of Radiation Technology and Radioisotopes.**

    Pradip Mukherjee, Vinay Bhave and Tarveen Karir

    In "Atomic Energy in India: Achievements since Independence". Edited by Dr. A.K. Tyagi and Dr. P.R. Vasudeva Rao, Published by HBNI & BARC (2023) Pages 180 - 201.

14. **I-125 labelling of C-Reactive Protein for the Development of Radioimmunoassay (RIA).**

    T.S. Ghodke, B.R. Manupriya, V.B. Kadwad, S. Paradkar, N. Karunakara, K.B. Shenoy

    Journal of Radioanalytical and Nuclear Chemistry, 333 (2024) 3007–3013.

Conference Proceedings and Abstract Publication

1. **Design, Development and Deployment of Packages for Economic Transport of Radiopharmaceuticals.**

   Rohit Kamble, Chetan Kothalkar, Niteesh Kumar, Tukuna Muni

   Paper Presentation and Abstract Published in Book of Abstracts of 2nd International Conference on Mechanical Engineering (INCOME-2023), September 01-02, 2023, at Netaji Subhash University of Technology (NSUT), New Delhi.

2. **Shielded Tong-box Facilities for the Production of Radiopharmaceuticals at BRIT.**

   Chetan Kothalkar, A.C. Dey

   Paper Presentation and Full-length Paper Published in Book of Abstracts of DAE-BRNS Symposium on "Advances and Innovations in Technologies for Hot Cell Engineering Systems of Nuclear Facilities (HOTCELLTECH-2023)", May 25-27, 2023, at DAE Convention Centre, Anushaktinagar, Mumbai.

3. **Separation of Ge-68 from Ga-Ni alloy target for ^{68}Ge/ ^{68}Ga generator production.**

   Sankha Chattopadhyay, Shayantani Ash, Samarjit Singha, Sujata Saha Das, D. G. Mahesh, Luna Barua, Umesh Kumar, Madhusmita, Md. Nayer Alam

   Paper Presentation (Virtually) and Article Published in the Souvenir of International Symposium on Trends in Radiopharmaceuticals (ISTR 2023), 17 – 21 April 2023, organized by International Atomic Energy Agency (IAEA). Published in ISTR 2023 - Abstract ID: 66.

4. **Production and Radiochemical Separation of ^{64}Cu from Enriched ^{68}Zn Target in 30 MeV Cyclotron.**

   S. Chattopadhyay, S. Ash, S. Singha, L. Barua, D.G. Mahesh, S. Saha Das, Madhusmita, Md. N. Alam, U. Kumar, S. Roy and P. Dhang

   Poster Presentation and abstract published in Book of Abstracts of DAE-BRNS Symposium on Nuclear and Radiochemistry (NUCAR-2023), 01-05 May, 2023, held at Mumbai, India. NUCAR-2023, Abstract ID: F-10, Page number: 266.

5. **Direct production of Ga-68 in 30 MeV DAE Medical Cyclotron and subsequent synthesis of ^{68}Ga-PSMA-11 radiopharmaceutical using indigenously developed semi-automated module.**

   Sankha Chattopadhyay, Luna Barua, Shayantani Ash, D.G. Mahesh, Sujata Saha Das, Samarjit Singha, Madhusmita, Md Alam Neyar, Umesh Kumar

   Paper Presentation and Abstract Published in the Souvenir of International Symposium on Trends in Radiopharmaceuticals (ISTR 2023), 17 – 21 April 2023, Vienna, Austria, organized by International Atomic Energy Agency (IAEA). Published in ISTR 2023 - Abstract ID: 236.

6. **Production and Radiochemical Separation of ^{68}Ge from irradiated Ga-Ni Alloy Target in 30 MeV Cyclotron.**

   S. Chattopadhyay, S. Singha, S. Ash, L. Barua, D.G. Mahesh, S. Saha Das, Madhusmita, Md. N. Alam, U. Kumar, S. Roy and P. Dhang

   Oral Paper Presentation and Abstract Published in Book of Abstracts NUCAR-2023 in Proceedings of DAE-BRNS Symposium on Nuclear and Radiochemistry (NUCAR-2023), 01-05 May, 2023, held at Mumbai, India. Abstract ID: F-11, pp 267.

7. **Advanced Facility for Production of ^{177}Lu-PSMA-617 At BRIT, Vashi.**

   Chetan Kothalkar, Babloo Kumar, Varun Nair, Tukuna Muni, Niteesh Kumar, Seema, Rohit Kamble, Navin Sakhare, Barkha Karkhanis, Anupam Mathur, Arun Chandra Dey, Vrinda C., Usha Pandey, Pradip Mukherjee

   Poster Presentation and Abstract Published in Book of Abstracts of National Seminar on "Recent Trends on Applications of Radio Isotopes & Radiation Technologies (ARIRT-2023)", organized by Andhra University, Vizagapatam, in association with National Association for Application of Radioisotopes and Radiation in Industry (NAARRI), Mumbai, during September 28-29, 2023 (PRI-5) pp 91.

8. **GMP Facility for Production of ^{131}I mIBG Doses at BRIT, Vashi.**

   Chetan Kothalkar, Anupam Mathur, Bikas Tiwari, N.C. Joseph, Babloo Kumar, Tukuna Muni, Niteesh Kumar, Rohit Kamble, Sanjeev Kumar, Shubhangi Mirapurkar, Arun Chandra Dey, Usha Pandey, Pradip Mukherjee

   Poster Presentation and Abstract Published in Book of Abstracts of National Seminar on "Recent Trends on Applications of Radio Isotopes & Radiation Technologies (ARIRT-2023)", organized by Andhra University, Vizagapatam, in association with National Association for Application of Radioisotopes and Radiation in Industry (NAARRI), Mumbai, during September 28-29, 2023 (PRI-7) pp 93.

9. **Comparative Evaluation of Renal Functions Using ^{68}Ga-DOTATATE and Conventional Nuclear Imaging Modalities in Patients Being Planned for Peptide Receptor Radionuclide Therapy (PRRT).**

   ***Ashok Chandak,** Muktikanta Ray, Gaurav Malhotra, Sutapa Rakshit, Priyanka Verma*

   Book of Abstracts of the International Symposium on Trends in Radiopharmaceuticals, IAEA-CN-310/222, Page No. 166 (17-21 April 2023).

10. **Formulation optimization, physicochemical evaluation and *in-vitro* stability of ^{99m}Tc labelled with solubilized glibenclamide.**

    *Sajid Husain, **Ashok Chandak,** M. K. Ray*

    Paper Presentation and Abstract Publication in Book of Abstracts of SNMI-CON 2023, Jodhpur, Nov. 2023 Hepato 2 (S-31).

11. **Radiolabeling methods in the preparation of ^{89}Zr-PSMA-617 and its physicochemical evaluation.**

    M. K. Ray, ***Ashok Chandak,*** *Ankita Jadhav, Monica Dubey, K. Kushwaha, M. K. Ray, Sandip Basu*

    Paper Presentation and Abstract Publication in Book of Abstracts of SNMI-CON 2023, Jodhpur, Nov. 2023 Onco 13 (S-55).

12. **^{68}Ga-NODAGA-RGD PET-CT imaging in patients of thyroglobulin elevated negative ^{131}I scintigraphy carcinoma thyroid and anaplastic thyroid carcinoma.**

    Abhay Gondhane, Priyanka Verma, ***Ashok R. Chandak,*** *Sandip Basu*

    Paper Presentation and Abstract Publication in Book of Abstracts of SNMI-CON 2023, Jodhpur, Nov. 2023 Thyroidology 4 (S-109).

13. **Evaluation of the effect of uricosuric agent (probenecid) on the pharmacokinetics of ^{68}Ga-peptide based radiopharmaceuticals.**

    Vikash Kumar Sahu, ***Ashok Chandak,*** *Sutapa Rakshit, Yogita Shete, M. K. Ray, Sandip Basu*

    Paper Presentation and Abstract Publication in Book of Abstracts of SNMI-CON 2023, Jodhpur, Nov. 2023 Onco 48 (S-72).

14. **Detecting Leaky Heat Exchanger using Radioactive Tracer Technique in a Petroleum Refinery.**

    Gaurav Agrahari, Vikrant Dhakar, C.B. Tiwari, Vinay Bhave, Ramakant Sahu, Pradip Mukherjee

    Poster Presentation and Abstract Published in Book of Abstracts of National Seminar on "Recent Trends on Applications of Radio Isotopes & Radiation Technologies (ARIRT-2023)", organized by Andhra University, Vizagapatam, in association with National Association for Application of Radioisotopes and Radiation in Industry (NAARRI), Mumbai, during September 28-29, 2023 (IAR-2) pp 102.

15. **Dosimetric Evaluations and Shielding Assessment of Low-Temperature Irradiator.**

    R. Rajput, J. Garg, K. Khedkar, D.K. Sahoo, N. Jayachandran, P. Mukherjee

    Full-length Paper Published in the Proceedings of the DAE-BRNS National Conference on Industrial Safety & Hygiene – Zero Incident Vision (IndSHV – 2024) pp-118-121 (Jan 2024).

16. **Cationic Modification of C-18 Reverse Phase HPLC Column for Quality Control Analysis of ^{131}I-Sodium Iodide Solution.**

    Sanjeev Kumar B., Pramod B. Dodke, V.V. Murhekar

    Abstract Published in Book of Abstracts of the International Symposium on Trends in Radiopharmaceuticals (ISTR-2023), IAEA, Vienna, Austria, held from 17-21 April 2023.

17. **Targeting Pancreatic Ductal Adenocarcinomas (PDAC) with Neuroendocrine Differentiation (NED) Subgroup of Tumours with Combination of ^{177}Lu-DOTA-TATE and Dihydroxy Stilbene (DHS) Combination: Mechanistic Insights.**

    Krishna Mohan Repakka, Ganesh B. Pai, Anupam Mathur and Birija Sankar Patro

    Abstract Published in Book of Abstracts of the International Symposium on Trends in Radiopharmaceuticals (ISTR-2023), IAEA, Vienna, Austria, held from 17-21 April 2023.

18. **Applying the "Reduce, Reuse and Recycle Principle" in the User-friendly Sterility Testing Method for Injectable Radiopharmaceuticals.**

    Chanda Arjun, Sabreen Modak, Nida Khan, Vishwas Murhekar, N. Jayachandran

    Abstract Published in Book of Abstracts of the International Symposium on Trends in Radiopharmaceuticals (ISTR-2023), IAEA, Vienna, Austria, held from 17-21 April 2023, Page No. 155.

19. **Bacterial Endotoxin Testing of Injectable Radiopharmaceuticals: Vendor Qualification.**

    Chanda Arjun, Barakha Karkhanis, Seema Asif, Vishwas Murhekar, Jaychandran N.

    Abstract Published in Book of Abstracts of the International Symposium on Trends in Radiopharmaceuticals (ISTR-2023), IAEA, Vienna, Austria, held from 17-21 April 2023, Page No. 156.

20. **^{68}Ga-NODAGA-RGD PET-CT Imaging in Patients of Thyroglobulin Elevated Negative ^{131}I-Scintigraphy Carcinoma of Thyroid and Anaplastic Thyroid Carcinoma.**

    Abhay Gondhane, Priyanka Verma, Ashok Chandak, Sandip Basu

    Paper Presentation and Abstract Publication in Book of Abstracts of SNMI-CON 2023, Jodhpur, Nov. 2023 Thyroidology 4 (S-109).

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    Vinay Bhave, Gaurav Agrahari, C.B. Tiwari, Ramakant Sahu, Pradip Mukherjee

    Paper Presentation and Full-Length Paper Publication in Book of Abstracts of Distillation Expert Conclave, 2023.

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

    Poster Presentation and Abstract Published in Book of Abstracts of the 92nd Annual Meet of the Society of Biological Chemists, held from 18-20 December 2023, at BITS Campus, Goa, India.

23. **Advanced Semi-Automated Facility for Production of ^{131}I Therapeutic Capsules at BRIT, Vashi.**

Chetan Kothalkar, Navin Sakhare, Pooja Kale, Tukuna Muni, Niteesh Kumar, Rohit Kamble, Pramod Dodke, Ravi Seshan, Arun Chandra Dey, Pradip Mukherjee

Poster Presentation and Abstract Published in Book of Abstracts of National Seminar on "Recent Trends on Applications of Radio Isotopes & Radiation Technologies (ARIRT-2023)", organized by Andhra University, Vizagapatam, in association with National Association for Application of Radioisotopes and Radiation in Industry (NAARRI), Mumbai, during September 28-29, 2023 (PRI-6) pp 92.

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Mukhar Sharma, Dhiren Sahoo, Pradip Mukherjee

Poster Presentation and Abstract Published in Book of Abstracts of National Seminar on "Recent Trends on Applications of Radio Isotopes & Radiation Technologies (ARIRT-2023)", organized by Andhra University, Vizagapatam, in association with National Association for Application of Radioisotopes and Radiation in Industry (NAARRI), Mumbai, during September 28-29, 2023 (IAR-3) pp 103.

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Saquib, Dhiren Sahoo, Pradip Mukherjee

Poster Presentation and Abstract Published in Book of Abstracts of National Seminar on "Recent Trends on Applications of Radio Isotopes & Radiation Technologies (ARIRT-2023)", organized by Andhra University, Vizagapatam, in association with National Association for Application of Radioisotopes and Radiation in Industry (NAARRI), Mumbai, during September 28-29, 2023 (RPM-1) pp 112.

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Chindarkar A. S., Sawant D. K., Chavan S. V., Sharma Ranjit, Sharma, ***Abhishek K., Singh Balender, Thamke Ajay, Jaychandran N.***

Poster Presentation and Abstract Published in Book of Abstracts of the 16th Biennial DAE-BRNS Symposium on NUCLEAR AND RADIOCHEMISTRY (NUCAR-2023), May 01-05, 2023 at DAE Convention Centre, Anushaktinagar, Mumbai (E-81) pp 238.

27. **Dual mode automated module for radiolabelling of ^{68}Ga produced from both generator and medical cyclotron.**

Nitin Yuva Raj, Nayak Shrinibas, ***Kumar Amit, Sharma B. K.,*** *Kulkarni Savita*

Poster Presentation and Abstract Published in Book of Abstracts of the 16th Biennial DAE-BRNS Symposium on NUCLEAR AND RADIOCHEMISTRY (NUCAR-2023), May 01-05, 2023 at DAE Convention Centre, Anushaktinagar, Mumbai (F-6) pp 262.

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    Kumar K. S. Ajish, ***Mathur Anupam***

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    Menon Sreeja Raj, ***Mitra Arpit****, Sahu Sudeep, Chakraborty Avik, Ray Mukti Kanta, Banerjee Sharmila*

    Poster Presentation and Abstract Published in Book of Abstracts of the 16th Biennial DAE-BRNS Symposium on NUCLEAR AND RADIOCHEMISTRY (NUCAR-2023), May 01-05, 2023 at DAE Convention Centre, Anushaktinagar, Mumbai (F-45) pp 301.

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    Suman Shishu Kant, Mukherjee Archana, ***Pandey Usha,*** *Chakraborty Avik, Rakshit Sutapa, Tawate Megha, Sarma Haladhar Dev*

    Poster Presentation and Abstract Published in Book of Abstracts of the 16th Biennial DAE-BRNS Symposium on NUCLEAR AND RADIOCHEMISTRY (NUCAR-2023), May 01-05, 2023 at DAE Convention Centre, Anushaktinagar, Mumbai (F-46) pp 302.

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    Prabhala Anupama, ***Kumar Dheeraj, Mitra Arpit, Mathur Anupam,*** *V. Manisha,* ***Pandey Usha,*** *Sethi Sanjay*

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    Sahu R. K., Patil S. P., Kalgutkar D. B., Mathew K. M., Jayachandran N.

    Poster Presentation and Abstract Published in Book of Abstracts of the 16th Biennial DAE-BRNS Symposium on NUCLEAR AND RADIOCHEMISTRY (NUCAR-2023), May 01-05, 2023 at DAE Convention Centre, Anushaktinagar, Mumbai (F-39) pp 295.

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34. **Application of the magnetizable cellulose particle in development of CRP radioimmunoassay.**

Ghodke T. S., ***Kadwad V., Paradkar S. N.,*** *Karunakara N., Shenoy K. B.*

Paper Presentation and Abstract Published in Book of Abstracts of the 16th Biennial DAE-BRNS Symposium on NUCLEAR AND RADIOCHEMISTRY (NUCAR-2023), May 01-05, 2023 at DAE Convention Centre, Anushaktinagar, Mumbai (F-25) pp 281.

This Paper won the "Best Oral Presentation" Award.

35. **Design and development of an indigenous delivery system for direct delivery of 90Y-Glass microspheres (Bhabhasphere) in liver cancer patients**

B. K. Tiwary, Aaditya Shah, Amala Mathai, Arpit Mitra, N. C. Joseph, K. V. V. Nair, Anupam Mathur, *Madhumita Goswami, Sudipta Chakraborty,* ***Usha Pandey, Pradip Mukherjee***

Presented in the 55th Annual Conference of Society of Nuclear Medicine, India (SNMICON 2023), held during 16-19 Nov. 2023. Abstract ID: (Topic 04: Hepatology) Published in IJNM | Volume 38 | Abstract Supplement Issue 1 | November 2023.

36. **^{99m}Tc-glucoheptonic acid as a tracer for clinical use in brain tumour imaging.**

M. K. Ray, N. T. Bivinjith, ***Ashok R. Chandak,*** *Nikhil Mohan, T. H. Asalah*

Presented in the 55th Annual Conference of Society of Nuclear Medicine, India (SNMICON 2023), held during 16-19 Nov. 2023. Abstract ID: 43 (Topic 01: Neurology): Published in IJNM | Volume 38 | Abstract Supplement Issue 1 | November 2023.

37. **Development and standardisation of lyophilised single component kit for the preparation ^{99m}Tc-ethylene dicysteine for renal dynamic function studies.**

G. Shunmugam, M. Sheela, B. Sanjeev Kumar, R. Krishna Mohan, Vijay Kadwad, Usha Pandey

Presented in the 55th Annual Conference of Society of Nuclear Medicine, India (SNMICON 2023), held during 16-19 Nov. 2023. Abstract ID: 101 (Topic 06: Renal): Published in IJNM | Volume 38 | Abstract Supplement Issue 1 | November 2023.

38. **Design of ^{99m}Tc analogue of DUPA PSMA inhibitor for its potential use in prostate cancer imaging.**

Navin Sakhare, Anupam Mathur, Shubhangi Mirapurkar,G. Rani, M. Sheela, Shalaka Paradkar, Arpit Mitra, Usha Pandey

Presented in the 55th Annual Conference of Society of Nuclear Medicine, India (SNMICON 2023), held during 16-19 Nov. 2023. Abstract ID: 38 (Topic 10: Prostate Imaging): Published in IJNM | Volume 38 | Abstract Supplement Issue 1 | November 2023.

39. **Multi-Curie ^{177}Lu-PSMA clinical dose formulation using semi-automated production system for prostate cancer therapy**

Navin V. Sakhare, N. C. Joseph, B. K. Tiwary, Arpit Mitra, Pooja Kale, Chetan Kothalkar, *K. S. Ajish Kumar,* ***Anupam Mathur,*** *Sudipta Chakraborty,* ***Usha Pandey, V. V. Murhekar***

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40. **Ready-to-Use [^{177}Lu]Lu-FAPI-46: Multiple Patient Dose Formulation and its Pre-Clinical Evaluation.**

A. Mitra, L. Ram, N. Sakhare, *A. Chakrabotry,* ***B. Sanjeev kumar, Seema, S. Mirapurkar, A. Mathur, U. Pandey***

Presented in the 55th Annual Conference of Society of Nuclear Medicine, India (SNMICON 2023), held during 16-19 Nov. 2023. Abstract ID: Therapy 7. Published in IJNM | Volume 38 | Abstract Supplement Issue 1 | November 2023, pp S102.

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