सत्यमेव जयते

GOVERNMENT OF INDIA

ANNUAL REPORT
2020-2021

BOARD OF RADIATION & ISOTOPE TECHNOLOGY (BRIT)

DEPARTMENT OF ATOMIC ENERGY

GOVERNMENT OF INDIA

DEPARTMENT OF ATOMIC ENERGY (DAE)

BOARD OF RADIATION & ISOTOPE TECHNOLOGY (BRIT)

ANNUAL REPORT 2020-2021

Front Page : Illustrations indicating various on-going activities of BRIT depicted under different Sections, within the Annual Report 2020-21.

Back Page : Indigenously designed & developed Radiography Camera, “COCAM-120" & “Cranking Device”, being inaugurated by Director, BARC at BRIT, during the Annual Year 2020-21

From the Desk of Chief Executive

Greetings!

BRIT has made steady progress over the years, since its inception. The overall growth of BRIT is not restricted to just core verticals like Nuclear Medicine, Radiography and Radiation Processing, but has extended to new businesses, like Isotope Application Services, Radioanalytical Services and Radiation Instrument Calibration Facilities, over past decade. Our services have been continuously used for societal benefits, and it has become a reality by the effective utilization of our products by our prestigious customers, not only within India, but also customers from abroad.

Areas which are yet to be explored, could be realigned in the future to address the concerns of customers.

All sections of BRIT contributed immensely towards achieving the intended objectives of BRIT, which in turn, translated into improvement in the quality of human life. I congratulate all the staff members for your efforts, and it is, in fact, a matter of pride to BRIT that all essential services continued to be available throughout the COVID pandemic period during this year.

I take this opportunity to thank our valued customers, whose continued patronage and confidence in our products inspires us to extend the best of our services.

I am extremely happy on the release of Annual Report 2020-21. It indicates valuable contribution services from BRIT. I wish all my colleagues, from BRIT and other Units of DAE, linked with BRIT, for better performances in all endeavours. I am sure future progress in all relevant fields would be revealed in the Annual Reports of the coming years.

With Best Wishes.

Pradip Mukherjee
Chief Executive, BRIT

CONTENTS

CHAPTER 1

HIGHLIGHTS

2020-2021

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. It is a matter of special pride to BRIT that all essential services continued to be available throughout the COVID pandemic period during this year.

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, except during the stringent nationwide lockdown due to COVID-19 (March 2020 to April 2020), during which, Radiopharmaceutical Program, BRIT, was declared as 'Essential Services'. 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 2020-21, amounted to Rs. 31.34 Crores.

(a) Radiopharmaceuticals Production (RPhP), Vashi

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

- BRIT continued the regular supply of TCM-1 (COLTECH), TCG (GELTECH) ^{99}Mo/^{99m}Tc generators and TCM-2 (^{99}Mo supplied as sodium molybdate solution for solvent extraction generators) to NM centres, in 774 consignments, across the country.

- The supply of 9697 consignments of ^{99m}Tc-cold kits, used for the preparation of radiopharmaceuticals at hospital radiopharmacy, was continued during the reported period. A major part of the supply comprised 19 cold kits for ^{99m}Tc- labelling (TCK Kits), towards preparation of ^{99m}Tc- radiopharmaceuticals, for the functional imaging of various organs. ^{188}Re and ^{177}Lu based cold kits were also supplied for preparation of ^{188}Re and ^{177}Lutherapeutic radiopharmaceuticals.

- ^{131}I-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 also produced and supplied for treatment of neuroendocrine tumors and ^{131}I-Lipiodol (used for the treatment of Hepatocellular Carcinoma) were also supplied to NM hospitals. During the period under report, these ^{131}I-based products, benefitted more than 20000 cancer patients all over India.

- BRIT resumed the supply of 25 mCi and 50 mCi of ^{131}I-capsules, while 100 mCi capsules were introduced for supply due to the advantages associated with capsules in comparison to oral solution (minimum chance of contamination, ease of usage, more accurate dose delivery, less radiation dose to the buccal cavity of patient etc.).

- ^{177}Lu radiopharmaceuticals (^{177}Lu-DOTATATE and ^{177}Lu-PSMA) comprised the bulk of the other therapeutic products supplied by BRIT. In spite of the lockdown conditions, demand for these ^{177}Lu radiopharmaceuticals saw an increasing trend.

- A new production facility for ^{177}Lu radiopharmaceuticals was installed under the 12th Plan Project, "Advanced Facilities for Radiopharmaceuticals Production (AFRP)" during this period. Cold commissioning, trial cold runs for pharmaceutical validation followed by regular production of ^{177}Lu-PSMA could be successfully carried out.

- A GMP-compliant ^{131}I-mIBG (Diagnostic) production facility (procured from ITD, Germany) which was installed in 2019-20 under the 12th Plan Project, "Advanced Facilities for Radiopharmaceuticals Production (AFRP)" is being routinely used for the production and supply of ^{131}I-mIBG (diagnostic) doses during this year.

- ^{106}Ru plaque brachytherapy is an effective and vision-sparing treatment modality for ocular cancers. Waste Management Group, BARC has developed ^{106}Ru notch plaque sources for ocular cancer therapy which were given regulatory approval recently. BRIT initiated the marketing and supply of six brachytherapy sources during 2020-21.

Fig. 1: Cold kits for the preparation of ^{68}Ga-PSMA

- Supply of ready-to-use ^{68}Ga-PSMA for PET-based diagnosis of prostate cancers to PET centres around Mumbai was continued this year also.
- Cold kit for the facile preparation of ^{68}Ga-PSMA (Prostate specific membrane antigen) for PET based diagnosis of prostate cancer was introduced during this period and made available to the nuclear medicine practitioners.
- Production procedure for preparation of Sterile Evacuated Vials required for the generator/cyclotron-based radiopharmaceuticals was developed, and is now available for nuclear medicine practitioners. Currently, these Sterile Evacuated Vials are being used at Radiation Medicine Centre, Mumbai, and Medical Cyclotron Facility, BRIT Regional Centre, Kolkata.
- RIA procedure for the estimation of C-reactive protein, an indicator of infection or chronic inflammatory disease such as rheumatoid arthritis, lupus, as well as risk of heart disease was developed in collaboration with Mangalore University. A prototype kit is ready for clinical evaluation.
- Cell culture laboratory for *in-vitro* testing of new radiopharmaceuticals was maintained, various cell lines were sourced, propagated and made available whenever required.
- Magnetic cellulose particles required for the production of magnetic particle-based RIA and IRMA kits were produced for the in-house consumption and for Radiation Medicine Centre, Parel, Mumbai. Around 860 RIA & IRMA kits were supplied to RIA centres all over India.

(b) Medical Cyclotron Facility (MCF), RMC, Parel, Campus, 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 [^{18}F]-Fluro Ethyl–L-Tyrosine (FET).
- Regular and uninterrupted supply of about 164 consignments of PET radiopharmaceuticals

such as ^{18}F- FDG, ^{18}F-NaF, and ^{18}F-FET to various hospitals in and around Mumbai, accounting for nearly 106 Ci of radioactivity, during the year 2020-21. **More than 15000 patients benefitted with PET investigations in the reported year**.

- ^{64}Cu was produced by bombarding attenuated proton beam of 12 MeV at 10 µA for 90 minutes on enriched 30 µm thick ^{64}Ni target. Radiochemical separation and purification employing ion exchange column chromatography (IE-CCM - AG® 1-X8, 100-200 mesh, chloride form) has been carried out to obtain $^{64}CuCl_2$ in clinical grade form. *In-vivo* PET CT analysis was carried out using human prostate cancer cell line (LNCap) Xenograft model in Nude Mice . High-uptake and long-term retention of radioactivity were found in the tumor (10.04 ±1.08% ID/g) which corroborates with scintigraphy studies.

- 25mCi of ^{68}Ga- was produced via irradiation of enriched ^{68}Zn in the liquid target irradiation system.

(c) Medical Cyclotron Facility at RCR, BRIT, VECC Campus, Kolkata

- Regular Production, Quality Control & Quality Assuarance, before the supply of PET radiopharmaceutical, ^{18}F- FDG at MCF, BRIT, Kolkata, was carried out, since June 2020. Uninterrupted supply of nearly 57 Ci of ^{18}F- FDG was made to most of the cancer hospitals in the city, despite the lockdown due to COVID-19 pandemic.

- RC, Kolkata, BRIT, has also introduced another important ^{18}F product, namely, Sodium Fluoride [^{18}F]-NaF, in the market since December 2020. This product is a valuable imaging modality of the skeleton. The details about the product are included under, "Services extended by Regional Centres of BRIT“ Section.

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

Quality Control group is responsible for the analyses of various ready-to-use radiopharmaceuticals, radiochemical, TCK cold kits, certifying the product and the timely release of QC reports. During the year 2020-21, the following QC activities were carried out:

- **Routine sample analyses:** More than 500 batches of radiopharmaceutical samples and 41 batches of ^{99}Mo-^{99m}Tc COLTECH Generators were routinely analysed and certified by QC during this period. These samples are tested for their performance in physico-chemical analyses, sterility tests (ST), bacterial endotoxin tests (BET) and animal biodistribution studies (wherever necessary).

- **Refurbishment of Quality Control Laboratory and GMP Certification:** Work on replacement of asbestos ceiling of QC laboratory with SS was taken up with the help of Technology Development (TD) Group of RPh Programme. This work is completed.

- **GMP Certification and Testing Services:** QC laboratory was audited by third party auditor for GMP compliance. Based on the audit reports of TCK production and QC, GMP Certification for

Quality Control Laboratory was renewed. One imported TCK cold kit of ^{99m}Tc-labelled-Tetrafosmin (Myoview) was analyzed on request from DGCI and Certificate of Analysis (COA) was provided after evaluating the performance of the kit, in terms of Physicochemical tests, ST, BET and Animal Biodistribution studies.

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

- **Routine maintenance and documentation activities:** Activities such as microbiological environmental testing of clean rooms and production facilities during production and QC testing equipments such as radio TLC scanners, HPLC, spectrophotometers, micropipettes, biological safety cabinets etc., are continuously performed, documented and reported to Quality Assuarance.

  Quality Assurance (QA): Production and Quality Control Testing processes were routinely monitored and documented by QA Section and appropriate QA certification for a total of 285 batches of radiopharmaceuticals were released from April 2020 to March 2021. QA documents [Batch Manufacturing Production Records (BMPR)] were prepared ready and introduced for IOM-1, IOM-2, IOM-5 & IOM-5B. 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 and 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. Online QMS was introduced and is being followed as a pilot study since August 2019. In QMS, documentation & release of BMR's, QC documents & Batch Release Certificates is performed electronically. Completion of online QMS for production, QC & QA documents for TCK RPhs is expected from February 2021. This is a step towards eco-friendly (paperless), instantaneous retrieval of data and online computerized trend analysis study, thereby, simplifying the procedure.

(e) Labelled Compounds (LC)

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

- During 2020-21, Labelled Compounds Programme has supplied 29772 Nos. of Tritium Filled Self-luminous (TFS) sources of various sizes and shapes to defence establishments which are mainly used for illumination of different types of gadgets and instruments.

- A proposal has been submitted for setting up of Tritium gas facility at CIRUS Reactor building, BARC, Trombay, and the associated work has been initiated. Once this facility is ready for operation, the tritium gas handling operation related to Tritium filled light sources and tritium labelled compounds production activity will be shifted to CIRUS building.

- Preparation of selected ^{14}C and ^{3}H labelled products was carried our during the period. Custom synthesis of ^{14}C labelled Methylamine hydrochloride was carried out and supplied to IIT Mumbai. A total of 165 consignments of labelled compounds were supplied during the reported year 2020-21.

- Labelled Compounds Laboratory also continued the production and supply of ^{14}C-Urea Capsules which is used for diagnosis of Helicobacter pylori infection which causes stomach ulcers.

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

Fig. 2: Tritium trapping/recovery unit at LCL, Vashi

II. Engineering

The various engineering products offered by BRIT included the supply of more than 4700 kCi of radioactivity in various forms and for varied uses. The total revenue obtained by supplying Engineering Products, Equipment's & Devices, during the Financial Year 2020-21 is 77.04 Crores.

(a) Sealed Radiation Sources

- **^{60}Co Teletherapy Sources (CTS) for Cancer Hospitals: Thirteen** ^{60}Co-teletherapy sources with total activity of about 107 kCi in the range of 132 and 213 RMM were supplied to various cancer hospitals in India during the reported year 2020-21.

- **^{60}Co Irradiator sources were exported to Research & Development Centre for Radiation Technology (Vinagamma), Vietnam (350 kCi); Ansell Lanka, Sri Lanka (244 kCi), Malaysia (500 kCi) and Reviss Services (UK) Ltd., United Kingdom (499.99 kCi) during the reported period.**

- **Industrial Irradiator Sources: Seventy Nine nos. of W-91 irradiator sources and Two hundred Sixty Five nos. of BC-188 Irradiator sources with total activity of around 4731 kCi were supplied in Thirty Six consignments to various processing plants within the country and abroad.** The irradiators to which these sources are supplied are namely, (a) AVPPL, Ambernath – 123 kCi; (b) Gamma Agro, Hyderabad – 196 kCi; (c) Sotera, UK – 500 kCi (d) PINNACLE, Ahmadabad – 100 kCi; (e) Akshar, Ambernath – 300 kCi; (f) NIPRO, Pune – 224 kCi, (g) MICROTROL, Bangalore – 325 kCi; (h) MICROTROL, Haryana – 350 kCi; (i) KRUSHAK, Lasalgaon – 72 kCi; (j) Hi-Media, Ambernath – 300 kCi; (k) AMTZ, Vishakhapatnam – 300 kCi; (l) Ansell, Sri Lanka – 244 kCi; (m) AIIPL, Vasai – 124 kCi; (n) Vinnagamma, Vietnam – 350 kCi. (o) OGFL, Kolkata-100 kCi, (p) SARC, Delhi-125 kCi (q) EMI, Vadodara-300 kCi and (r) Malaysia-500 kCi.

- ^{60}Co sources, both for teletherapy machines and radiation processing plants, are fabricated at RAPPCOF, Kota, using indigenously produced ^{60}Co in nuclear power reactors. RAPPCOF received 06 Adjuster rods from RAPS-4 in this financial year.

- **^{192}Ir and ^{60}Co Radiography sources:** A total of **543** consignments of activity **20753.02** Ci of ^{192}Ir, ^{60}Co radiography sources – **6** nos with total activity **226.47** Ci and CMR sources – **19** nos with total activity **939** mCi were supplied from April 2020 to March 2021.

- Fifteen numbers of neutron sources were removed from the devices at RSMS, BARC for safe management of it and removal of sources stored at IFRT, Vashi are planned. Many other devices containing disused sources were also received from various users and sources are to be removed from the devices for safe management. 72 nos. of disused sources received from ISOMED were transferred in the hot cell and stored in the water pool for safe management of it.

(b) Radiography and other Radiation Equipment Devices

- **Radiography Camera:** A total of of 26 radiography camera (ROLI series) were supplied from April 2020 to March 2021. Inspection & servicing of 523 numbers of radiography devices were done after the removal of decayed ^{60}Co sealed source, during the reported period. **Indigenously designed and developed ^{60}Co based Industrial Radiography Device (COCAM-120) along with new light-weight remote controlled 'Cranking Device' were launched during the reported Year 2020-21.**

- **Gamma Chamber 5000:** There was no supply of any **units of** GC-5000 during the reported period 2020-21. No units of GC-5000 were decommissioned but Inspection & servicing was provided for **three units** of GC-5000.

- **Blood Irradiator:** Five Units of Blood Irradiators-2000 were **commissioned, three Units** were **decommissioned,** wheras, inspection & servicing was provided for **seven Units** during April 2020 to March 2021.

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, Neutron Irradiation Services, Services from ISOMED (for sterilization of medical & healthcare devices), located at BARC, Mumbai, and Radiation Processing Plant at Vashi Complex, KRUSHAK Services, Radioanalytical (both, at Vashi Complex and RCR, Bengaluru), Radiopharmaceutical Services provided by Regional Centres of BRIT etc. The total revenue collected by providing these Services during the Year 2020-21 amounted to 15.35 Crores.

I. Consultancy and MoU for Radiation Processing Plants

Fig. 3: MoU signed between BRIT and M/s Anshell Sterile Solutions Pvt. Ltd.

- MoU was signed with M/s Ansell Sterile Solutions Pvt.Ltd., for setting up a Gamma Radiation Processing Plant for disinfestation, shelf life extension of food products and sterilization applications of healthcare products, at Erode, Tamilnadu.

Fig. 4: MoU signed between BRIT and M/s Krushi Steritech Services Pvt. Ltd.

- MoU was signed with M/s Krushi Steritech Services Pvt. Ltd. for setting up a Gamma Radiation Processing Plant for disinfestations, shelf life extension of food products and sterilization applications of healthcare products, at Hubli, Karnataka.

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 2020-21.

- Safety System Upgradation and Refurbishment of ISOMED facility has been undertaken by BRIT with effect from November 2020. The project is poised to offer following deliverables within a span of 36 months.
- Rectification of the perennial issue of source interference (in compliance to regulatory recommendation) due to which round the clock commercial operations of the facility for terminal sterilisation of healthcare products have been kept in abeyance (after 44 years of service to the nation)
- Completely renovated and upgraded set of safety systems as per the latest safety regulations to ensure reliability of uninterrupted commercial operations for the healthcare industry in future.
- Completely renovated facility building thus ensuring full compliance to cGMP licensing requirements as per the latest provisions of Drug and Cosmetics Act - 1940 of the Government of India, would be made available.

Currently the structural repair work of the facility building is under progress. The design for the new set of Horizontal Transportation Casks, custom built to cater to the requirements of Category II type Land Based Stationary Gamma Irradiators is being undertaken.

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

- Radiation Processing Plant, Vashi, has provided gamma radiation processing services for Spices, Ayurvedic raw material, healthcare products and pet feed etc. to customers from all over the country. Nineteen new customers were registered during the current year. Sterilization of samples of PPE kits, supplied by TMH/BARC, was also carried out during COVID-19 lockdown period.
- BRIT has helped in commissioning of three new Gamma Irradiators in Private & State run Government Sectors, (a) M/s Andhra Pradesh Medtech Zone Ltd., Vishakhapatnam, AP; (b) M/s Himedia Labs Pvt. Ltd., Ambernath, Maharashtra; (c) M/s Akshar Gamma Sterile LLP, Ambernath (E), Maharashtra.
- During the current financial year, 2020-21, 3766.5 MT of spices, Ayurvedic raw material, healthcare products and other products were processed.
- Certification of RPP, Vashi Complex was upgraded to ISO 22000:2018 from ISO 22000:200. Surveillance audits for ISO 9001:2015 (Quality Management System) was also carried out by certifying agency and found in full compliance with the Standard's requirement. RPP was

found in compliance with the requirements of ISO 13485:2016 and certified accordingly. Gamma Radiation Processing Services are provided for hygienization of spices, ayurvedic raw materials, pet feed and packaging materials.

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

- Plant commissioning dosimetry for M/s Jamnadas, M/s Hi-media, M/s Akshar Gamma, M/s A.P. Medtech for sterilization of medical products and food products, was completed, during the reported period. Recommissioning dosimetry was carried out for two radiation processing plants. Dosimetry for radiation processing plant which was recommissioned for four plants, namely, M/s SARC, M/s Alligned, M/s EMI and M/s AMC, were completed.

- Dose rate certification was provided to three Cs-based Blood Irradiators and supplied to Apollo Hospital, Ahmedabad, National Institute of Immunology, Delhi and Rajiv Gandhi Cancer Institute, Delhi.

- Production & supply of ~2.0 Lakhs Ceric-Cerous Sulphate Dosimeters was done for various gamma irradiators in the country, for the measurement of absorbed dose.

- Production and supply of ~3000 Biological Indicators was done to the customers of Radiation Processing Plants in the country and ISOMED, for monitoring of the sterilization procedure.

III. Isotope Application Services

Isotope Application Services (IAS) Section of BRIT offered its valuable, timely and elegant services and solutions to various industries across the nation. During the reported period of 2020-21, following Services were provided by BRIT:

(a) Gamma scanning of Slug Catcher Downcomer and Condensate Header

IAS group was approached for gamma scanning of downcomers and headers to verify the suspected choking and internal conditions at gas terminal, ONGC Hazira plant.

As the slug catchers have remained in operation since commissioning and scheduled pigging was carried out in both 36" and 42" Trunk lines periodically, probability of deposition of black material inside the slug catcher fingers was high owing to the receipt of black material during pigging operation. The presence of black material had been manifested during the pigging operation inside the pig catcher as well as in the CFU trains where the Condensate is being processed. The other solid impurities present in the well fluid, howsoever small, might also add to the black material depositions over the time. Due to the possibility of solid depositions in the slug catcher fingers as well as in the 4" & 8" condensate down comers (SC-I&II and SC-III) which has the potential of disrupting the normal operations in case of sub-optimal gas-condensate separation due to partial or complete choking of 4" & 8" downcomer lines with these depositions.

Frequent condensate draining from MS filters were being done. Also, instances of carryover of condensate along with the gas have frequently been encountered during operations in the GSU trains. Poor separation of gas and condensate in some of the slug catcher fingers may be the cause for this condensate carry over. The choked/partially choked downcomers will allow the liquid to build up in the slug catcher fingers and may be responsible for this poor separation. In the event of any choked 4” or 8” downcomer, the liquid condensate will not get emptied out from the finger during draining and owing to its huge quantity will pose a greater safety risk during opening of the 48” end flange without indication of its presence. In view of this, gamma scanning was required urgently.

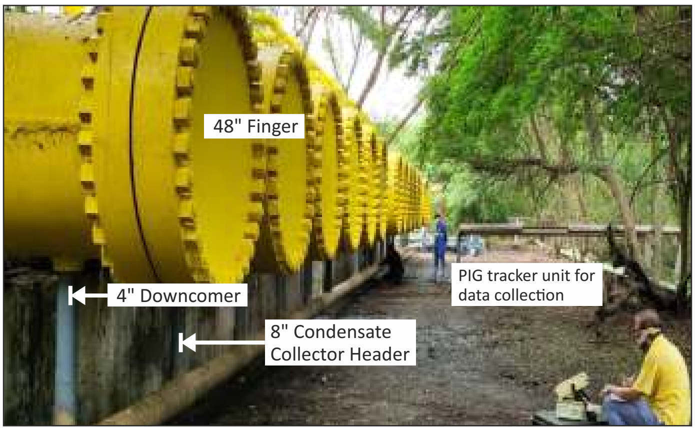


Fig. 5. Gamma scanning of condensate collector header being carried out at slug catcher II

Prompt action was taken by IAS group as per the urgency of the job. 10 µCi and 20 µCi of ^{60}Co radioactive source was selected as per the diameter of downcomers and header. Source transport NOC was obtained from AERB. All the formalities related to Covid-19 guidelines, including testing of the entire team, was completed. The job was planned thoroughly and the transportation of the men and materials to the site were arranged.

PIG tracker was used to monitor the radiation data measurement. Radiation survey of the area was carried out by calibrated RadEye survey meter. Scanning of the top joints of downcomer, downcomer pipe and condensate collector header was carried out at slug catcher area I, II and III respectively. Total 54 nos. of downcomers (total length approx. 110 m) and 120 m of collector header was scanned. Data was recorded at x, y & z orientation as required according to diameter of the pipes. In spite of harsh environmental conditions at the field, the scanning work was completed successfully and norms of social distancing, wearing mask etc were also followed throughout the job.

Data was recorded manually and plotted for top joints of downcomers, downcomer pipes and collector header separately and axis was selected accordingly. The preliminary observations were communicated to ONGC engineers immediately at site. Subsequently, mathematical treatment of the data was carried out at BRIT and detailed interpretations were made for slug catcher area I, II and III separately as per their process conditions. No significant abnormalities were observed in SC-I. Few of the top joints of the downcomers in SC-II were partially blocked.

Fig. 6. Gamma scanning of downcomer top joint

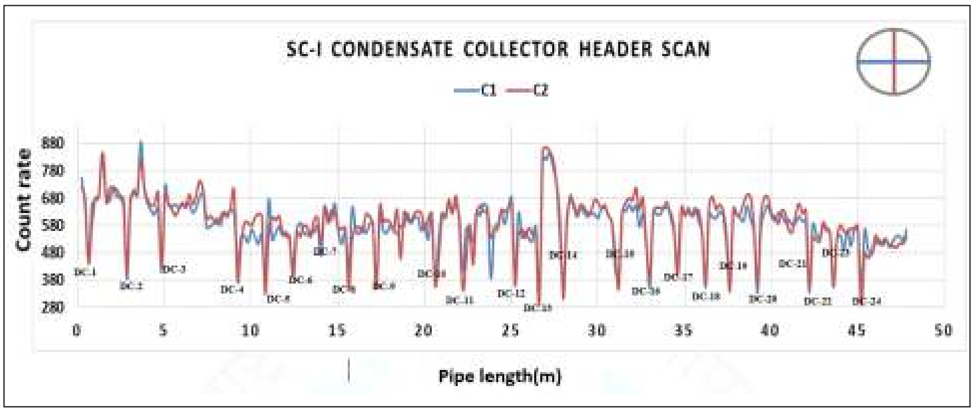


Fig. 7: Plot of the readings taken along the horizontal condensate collector header at two different scan orientations

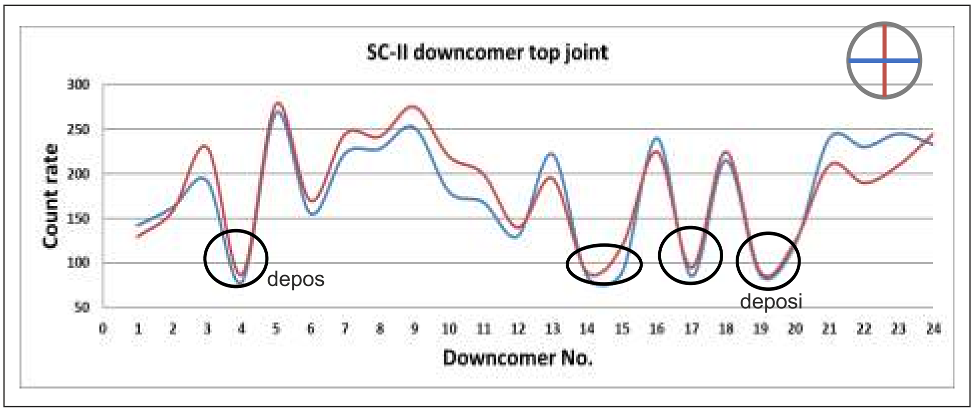


Fig. 8: Graphical representation of the readings taken at the top joints of downcomers in SC-II

Lesser liquid flow and dead zones were appeared in SC-II as compared to SC-I. In SC-III, partial depositions were observed on two downcomer pipes.

The detailed report was presented to the ONGC, Hazira management and findings were discussed for their concurrence. Hard copy of the report was submitted to ONGC and it was recommended to do the signature scanning of the downcomers, headers and columns to record the readings in healthy operating conditions for future reference.

(b) Gamma scanning of Demethaniser Column at ONGC, Dahej Plant

Oil and Natural Gas Corporation, a premier national oil and gas exploration company of India had established C2-C3 Plant at Dame, Gujarat, for processing rich LNG to extract value added products like Ethane, Propane and Butane.

The feed LNG sourced from neighbouring plant (PLL) is taken into Demethaniser column and methane is taken out as top product. This column was able to process only about 95 % of the design feed rate (625 tons/hr) without column parameters getting upset. The column was operating at 600 tons/hr and pressure drop across the column increased drastically at 605 tons/hr feed rate.

As there was an opportunity to take a turnaround of the plant in near future, to understand the internal status of the column using Isotope Application Services (Gamma scanning), ONGC contacted BRIT to carry out the above said job. This would help in decision making for the turnaround schedule and initiate necessary preparation for rectification if any malfunctions found.

Work Execution:

The problem was taken up by IAS group and as per the internals of the demethaniser column, it was decided to divide it in top, middle and bottom section to carry out the gamma scanning. One scan line, L1 for top section, two scan lines L2 & L3 for middle section and four scanlines L4, L5, L6 & L7 were scanned in normal as well as disturbed condition. Automatic column scanner was used with 80 mCi of ^{60}Co in tungsten collimator as the gamma source and BGO scintillation detector assembly for radiation intensity measurement.

Findings:

Top section:

In normal condition, vapor space was not clearly distinguished between tray 6 and tray 7, whereas in disturbed condition, liquid accumulation was observed in the region above these trays.

Middle Section:

1. Uneven distribution of liquid was seen below distributor / chimney tray section.

2. Due to this, the entire middle region was affected with respect to liquid vapor distribution.

Bottom section:

In disturbed condition, all the trays above tray 31 were partially flooded. (L6 scanline location).

These findings were shared with the technology provider and this helped them to decide further course of action.

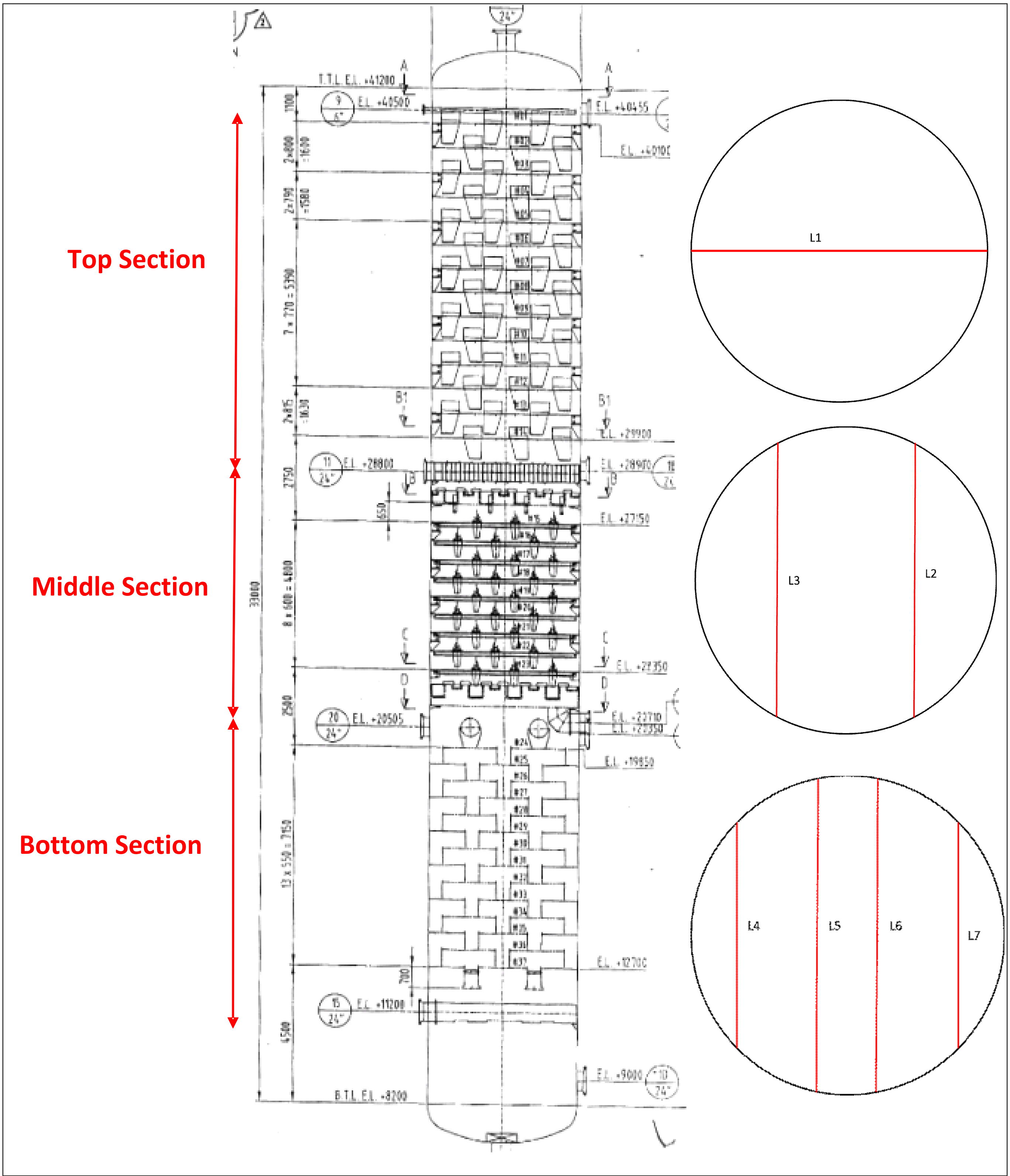


Fig. 9: GA of Demethaniser column & scan line orientation for each section of column

Top section:

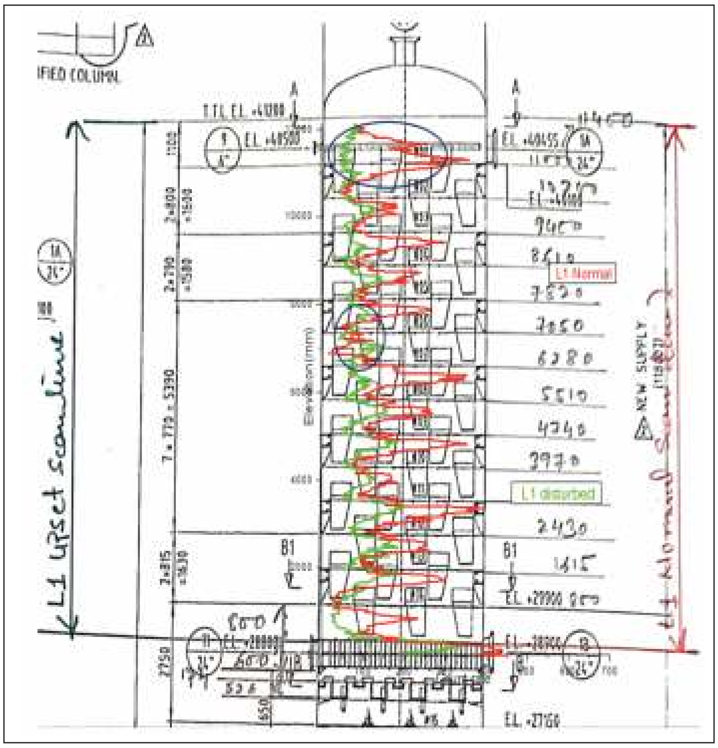


Fig. 10: Superimposed scanlines in disturbed and normal condition for top section (L1)

Middle Section:

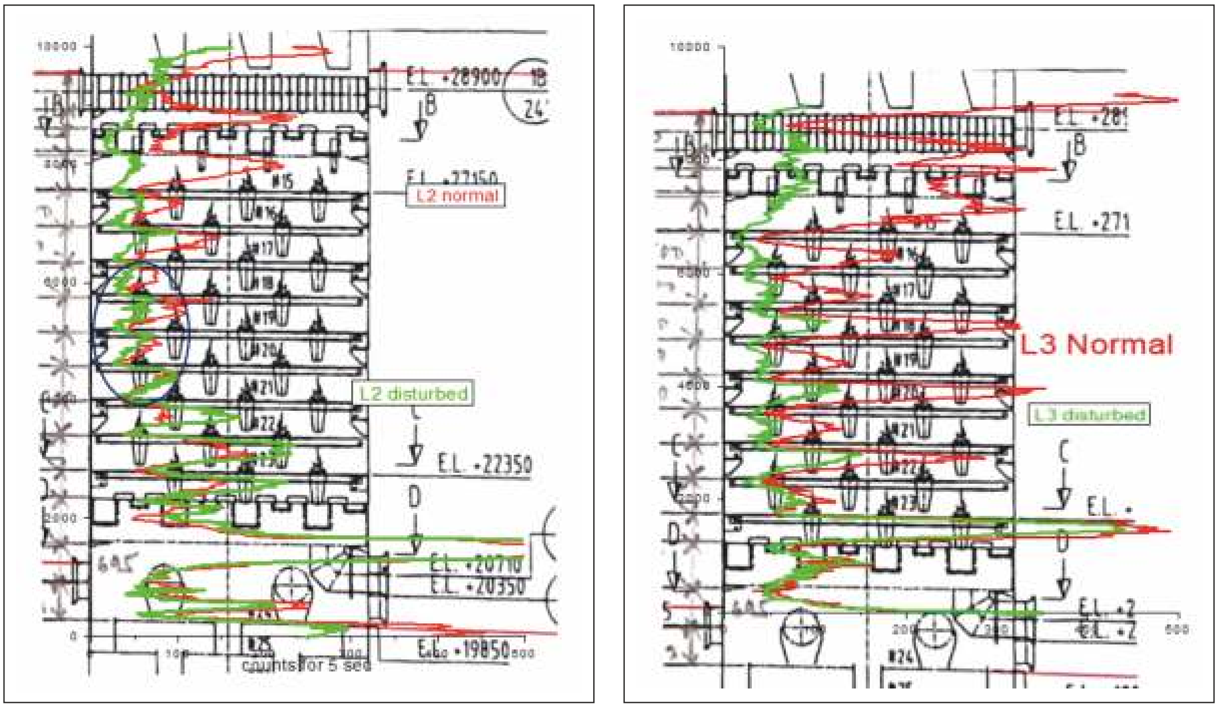


Fig. 11: Superimposed scanlines in disturbed and normal condition for Middle Section (L2 & L3)

Bottom section:

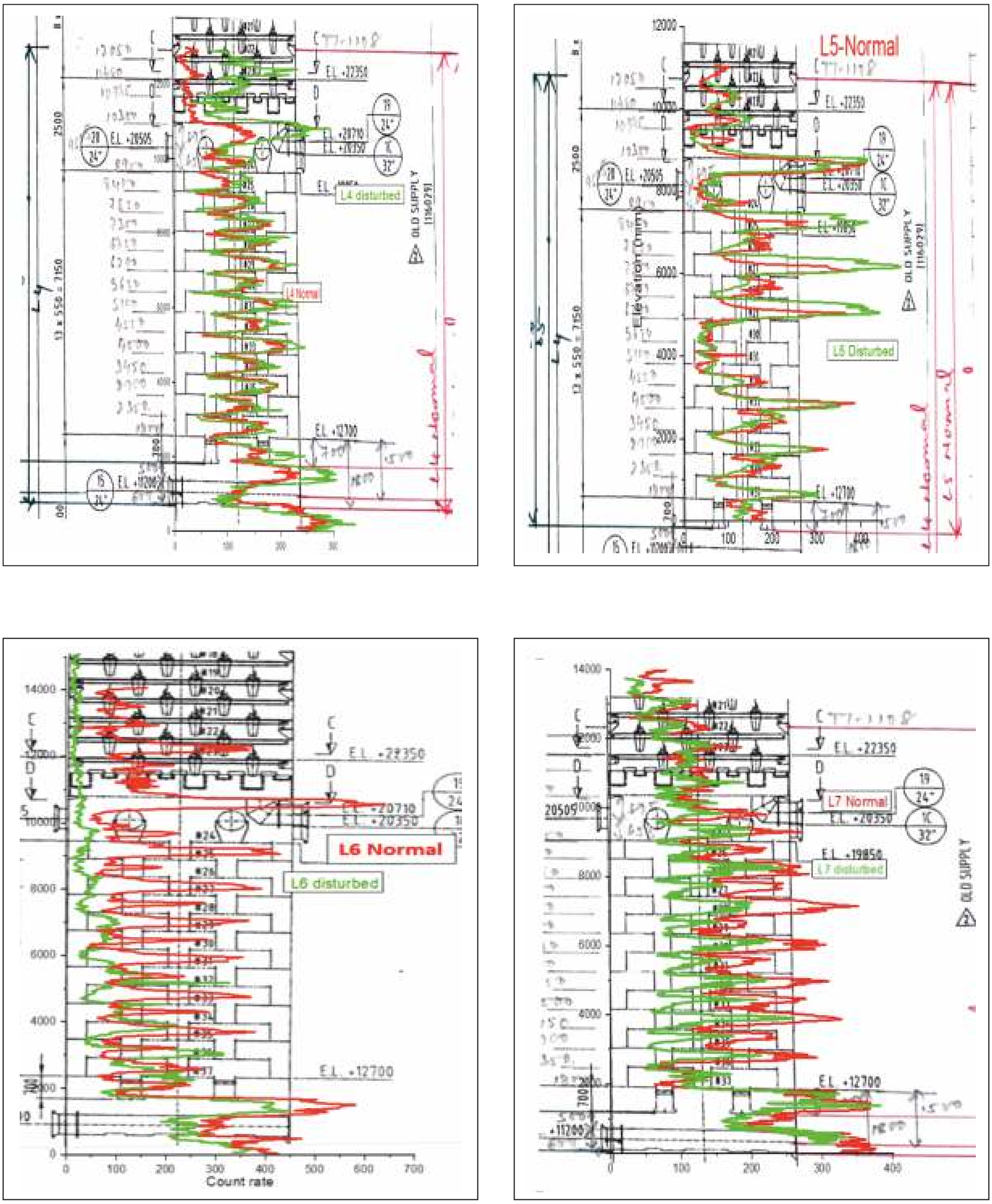


Fig. 12: Superimposed scanlines L4, L5. L6 & L7 of bottom section in disturbed and normal condition

IV. Radiation Physics Services Group

1. Total ^{60}Co-activity of the medical sterilization plant of M/s. Ansell Lanka Pvt. Ltd. was 2123.67 kCi as on 27/11/2020, distributed in 579 source pencils. This was inclusive of 245 kCi ^{60}Co supplied by BRIT in 24 BC-188 type source pencils. The source loading configuration was designed by simulating the geometry of the plant using analytical as well as statistical methods. The whole no. of pencils were arranged in an 8-Tier source frame. The product carriers move along a 4 + 4 Pass system around the source frame to receive the desired sterilization dose within the prescribed Dose Uniformity.

2. Source Loading Configuration was designed for M/s. GTH, Malaysia Irradiator IRN-189. Total ^{60}Co activity was 2864.402 kCi as on 10/03/2021 in 496 source pencils after adding 500 kCi in 54 no. of BRIT's sources. The source frame comprised of 4 Tiers with 32 modules, 50 pencils in one module. The dose distribution in the product was simulated to design the best source loading pattern.

3. As part of expansion of the Cobalt Facility, BRIT-RAPPCOF, at Kota (ERF Project), the shielding assessment of 4 hot cells which are designed to handle maximum 1MCi ^{60}Co activity each, was assessed.

4. Evaluation of Noxious Gas generation and Time-delay requirement was also carried out for the proposed hot cells of ERF Project, Kota.

5. Install & Operate Irradiator also known as Marine Product Irradiator, was designed and installed in BRIT for Marine-product processing. It was designed for ^{60}Co source of 400 kCi strength. It has an issue of very high leakage radiation level in the duplex plug region during installation of source cage. In order to solve this issue, the existing design was studied by simulating the design by MCNP and the radiation levels were evaluated. A modification proposed in the design by introducing a Lead cylinder around the product area of the duplex plug & reducing the radius of the duplex plug from 37.5 to 32.5 cm was simulated again to see the reduction in the radiation levels in the problem region.

6. A Comparison study of Dose Uniformity Ratio (DUR) and Throughput of a Gamma Irradiator while using BC 188 type ^{60}Co source pencils of two different configurations was done. Case 1). Pencil with 2 inner slugs & Case 2). Pencil with 1 inner slug. For the study, a generic design geometry of a Product- overlapping type gamma irradiator with 100 kCi ^{60}Co is considered. DUR & Throughput were evaluated in material of 0.5 g/cc for a target dose 10kGy.

7. Shielding Assessment of Type A package designed for the transportation of ^{99}Mo, which is supplied in the form of Sodium Molybdate aqueous (Na_2MoO_4. H_2 O) solution, was done. Surface dose rates of the package, when the solution is at the bottom of the vial, are evaluated for an activity of 16.2 Ci.

8. HTC-300 is a Transportation Cask of Type B(U) package used for the transportation of ^{60}Co sources for ISOMED plant. Adequacy of the shielding thickness is evaluated by assuming that 300 kCi of ^{60}Co is distributed in 11 Integrated Source Units (ISUs) of 637 mm active length.

These 11 source units & one dummy pencil are arranged in 196 mm PCD. Each ISU is of dimensions 698.5 mm (L) and 38.1 mm (Dia.).

9. Performed the study of the feasibility of medical sterilization in AMC plant at Vadodara, which is a gamma irradiator designed for processing of sewage/ sludge.

10. Theoretical dose evaluations were done for 3 newly commissioned Gamma plants 1). M/s Akshar Gamma, 2). M/s. HiMedia Labs. & 3). M/s. AMTZ and the results were validated with commissioning dosimetry.

11. Source (W-91/ BC-188) Loading patterns were designed for the following 19 gamma irradiators with a view to get the desired Dose Uniformity Ratio well within the prescribed limits for the concerned products which are to be radiation processed in each plant.

- NIPRO, Satara (added 230 kCi in 18 pencils to existing 240 pencils)
- AVPPL, Ambernath (added 125 kCi in 6 pencils to existing 128 pencils)
- Akshar Gamma, Ambernath (300 kCi in 14 pencils – first loading)
- Microtrol, Bawal (added 350 kCi 14 pencils to existing 6 pencils)
- HiMedia Labs., Ambernath (300 kCi 30 pencils – first loading)
- Pinnacles Therapeutics, Ahmedabad (added 100 kCi in 9 pencils to existing 27 pencils)
- AMTZ, Vizag (300 kCi 26 pencils – first loading)
- Microtrol, Bengaluru (added 325 kCi in 13 pencils to existing 134 pencils)
- Microtrol, Bawal (added 40 kCi in 24 pencils to existing 20 pencils)
- AIIPL, Vasai (added 125 kCi in 5 pencils to existing 93 pencils)
- KRUSHAK, Lasalgaon (added 75 kCi in 3 pencils to existing 48 pencils)
- Ansell, Sri Lanka (added 245 kCi in 24 pencils to existing 555 pencils)
- GAMPPL, Hyderabad (added 200 kCi in 7 pencils to existing 60 pencils)
- Aligned Industries, Gurgaon (added 200 kCi in 8 pencils to existing 30 pencils)
- SARC, Delhi (added 125 kCi in 5 pencils to existing 102 pencils, removing 5 pencils)
- OGFL, Kolkata (added 100 kCi in 4 pencils to existing 56 pencils)
- EMI, Vadodara (300 kCi in 24 pencils to existing 68 pencils)
- GTH, Malaysia (500 kCi in 54 pencils to existing 442 pencils)
- HiMedia Labs., Ambernath (400 kCi in 44 pencils to existing 32 pencils)

12. An industrial gamma radiography exposure device (IGRED) has been developed in BRIT with maximum capacity of 8 Ci ^{60}Co source. The design consists of Lead as the shielding material. S-tube is made up of SS-304L for smooth movement of the pigtail with source. This IGRED named COCAM-A categorizes as Class M. The radiation levels on the surface, at 5 cm from the surface and at 1 m from the surface are evaluated.

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

V. Calibration Services for Portable Radiation Monitoring Instruments

- BRIT is providing calibration services for gamma radiation survey instruments. A total of 102 numbers of radiation monitoring instruments such as survey meters, dosimeters and portable area monitors are calibrated during the reported year 2020-21.

VI. Radioanalytical Laboratory Services

Radioanalytical Laboratory (RAL) carried out the assay for the following measurement and certification services:

- Man-made (artificial) radioactivity levels in food items for human & animal consumption, which facilitated the export of food items to various countries where the radioactivity test certificate is a mandatory requirement.

- Naturally occurring radioisotopes (NORMS) in environmental samples, such as coal, fly ash, soil, rock phosphate, phosphogypsum etc. Testing and certification of NORMS in coal and fly ash helped many thermal power plants in the country to obtain MoEF clearance for their operation.

- Gross alpha, gross beta content in water samples. Testing of water samples received from BIS helped in BIS licensing of many packaged drinking water plants in the western region (especially, Maharashtra and Gujarat).

- ^{60}Co contamination level in steel samples helped in the export of steel products to different countries.

During the year 2020-21, Radioanalytical Services at Vashi Complex carried out 5556 tests on export/domestic commodities and on water samples (gross alpha, gross beta ^{226}Ra & ^{228}Ra).

The laboratory is accredited by NABL for certifying many of the parameters and empanelled by BIS for the testing of gross alpha and gross beta in water samples.

Fig. 13: Simultaneous Alpha/Beta Counting System at RAL, Vashi Complex

VII Services extended by Regional Centres of BRIT

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

RCR, Kolkata & Dibrugarh:

- **Services at RC, Dibrugarh:** Regional centre BRIT, Dibrugarh located at Assam Medical College & Hospital is rendering RIA and IRMA diagnostic services for the benefit of patients of the entire North-Eastern region. The Radiopharmaceutical products produced and supplied by BRIT, Vashi complex are extensively used by the RC, Dibrugarh for the diagnosis & investigation of various diseases. More than 4000 patients of the region avail the (RIA & IRMA tests as well as RPhs products supply) services from this centre.

- **Sale of cold kits for Tc-radiopharmaceuticals from the retail outlet at RC, Kolkata:** During the year 2020-21, approximately 113 Nos. of Technetium cold kits for formulation of ^{99m}Tc-radiopharmaceuticals were supplied to various Nuclear Medicine Hospitals in Kolkata

- **Around 53.6 Ci in 200 batches of ^{18}F-FDG were supplied to around 10 NM Centres/diagnostic centres after they were analysed and certified by Quality Control, during this period. Regular Quality Assuarance was performed before the batch release of all the RPhs, which were supplied through the Centre during the reported period.**

- **Production of new product, pharmaceutical grade Na[^{18}F]F injection, bone imaging radiopharmaceutical was done, using modified Integrated Fluidic Processor in IBA Synthera module. This new product has been launched in December, 2020.**

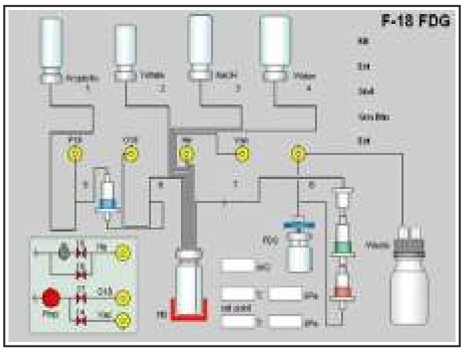
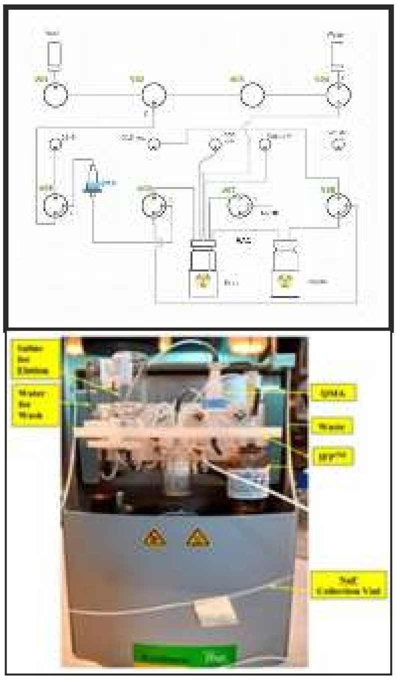


Fig. 14: ^{18}F-FDG Synthesis Flow Diagram

Fig. 15: PET-CT scan of ^{18}F-FDG



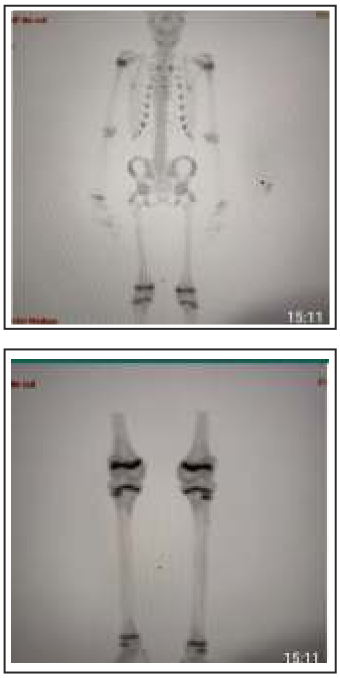


Fig. 16: ^{18}F-NaF Synthesis Flow Diagram and Automated Fluorination module

Fig. 17: PET-CT Scan of bone using ^{18}F-NaF injection made at RCR, Kolkata

RCR, Bengaluru:

- Regional Centre, BRIT, Bengaluru supplied ~90 Ci of ready-to-use ^{99m}Tc-pertechnatate to nuclear medicine hospitals and more than 500 TCK cold kits were sold through retail outlet and door delivery for the preparation of ^{99m}Tc-radiopharmaceuticals to nearby nuclear medicine centres.

- Gamma irradiation unit, BI-2000 with ^{137}Cs source is received at RCR, Bengaluru and is ready of its installation and commissioning.

- Radioanalytical Laboratory analyzed and certified 50 samples for the measurement of residual radioactivity in various commodities such as food items for human & animal consumption, medicine and miscellaneous items.

RCR, Delhi:

- Regional Centre, Delhi, continued the supply of clinical grade, ready to use diagnostic ^{99m}Tc-radiopharmaceuticals injections in compliance with GMP and RPC, ready-to-use radioactive therapeutic injections of ^{131}I-mIBG, ^{177}Lu, ^{153}Sm, COLTECH/GELTECH Generators and TCM-2 (^{99}Mo Generator kit for Solvent Extraction), for nuclear medicine centres in Delhi and NCR regions. During the period, 2020-21, Regional Centre, Delhi has been involved in production & supply of ~145 consignments, of clinical grade, ready-to-use ^{99m}Tc- radiopharmaceuticals injections.

- Quality Control of ready-to-use ^{99m}Tc-sodium pertechnatate & its labelled RPhs from 106 batches was carried out during the said period.

RCR, Hyderabad (Jonaki):

- During the period, Regional Centre of BRIT, Hyderabad (Jonaki) supplied ready-to-use ^{99m}Tc- as Sodium Pertechnatate (2.935 Ci) to local Nuclear Medicine Centres. It has supplied 406 Nos. of TCK Cold kits (produced at BRIT, Vashi Complex).

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

- Also, during the Year 2020-21, RC, BRIT, Hyderabad continued the synthesis and supply ^{32}P labelled nucleotides (57.75 mCi) and molecular biology reagents such as Taq DNA Polymerase, PCR master mix and enzymes for research in frontier areas of Molecular Biology, Biotechnology, Biomedical and Drug Discovery research of the country.

RCR, Kota (RAPPCOF):

BRIT handles several Million Curies of ^{60}Co activity per annum in a safe manner at BRIT-Regional Centre, Kota, also called RAPP Cobalt Facility (RAPPCOF), to supply ^{60}Co sources to healthcare and industrial user in India and abroad. Cobalt facility has been engaged in cutting and recovery of ^{60}Co activity from adjuster rods of various power reactors in the country since its inception and it started fabricating various sealed sources in 2006 when the facility was augmented. It is the only facility in the country with a complete production cycle, where all works such as receiving of cobalt adjusters from reactors to fabrication, supply & post supply jobs of ^{60}Co sealed sources are carried out. The production RAPPCOF increased nearly four to five times in last 10 years.

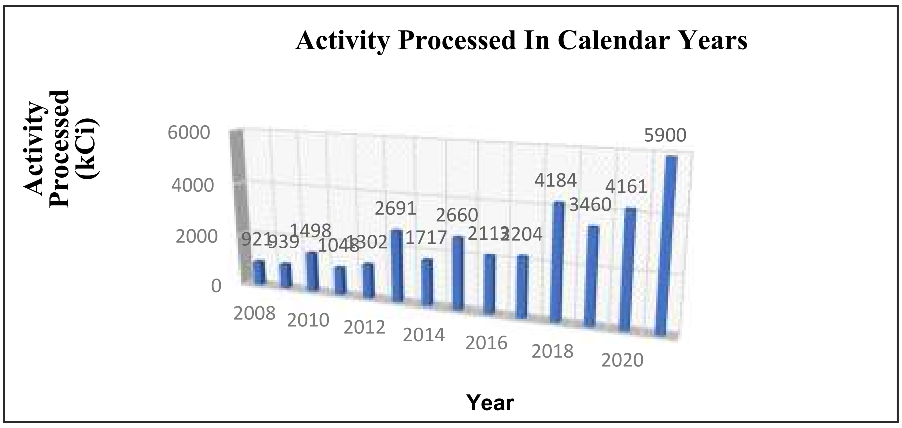


Fig. 18: ^{60}Co processed at RAPPCOF in calendar years

- RAPPCOF processed 4.817 MCi of ^{60}Co activity in 2020-2021 financial year which includes 325 Gamma Irradiator sources and 17 numbers of ^{60}Co Teletherapy Sources (CTS).

- RAPPCOF transported 4.838 MCi of ^{60}Co sealed source activity to various Multi-Purpose Gamma irradiators and Radiotherapy Hospitals in the country and abroad in 2020-2021 financial year which includes 79 nos. of W-91 irradator sources, 265 nos. of BC-188 irradiator sources and 13 nos. of ^{60}Co Teletherapy Sources (CTS) with 130-213 RMM were supplied to various Radiotherapy Hospitals in the country, as per the demand.

- The export orders of 500 kCi to M/s. REVISS, UK, 500kCi to MALAYSIA, 244kCi to M/s. Ansell Lanka-SRI LANKA and 350 kCi to M/s. Vinagamma, VIETNAM are successfully executed after catering domestic demands as given here. 1) AVPPL, Ambernath -123kCi, 2) GAMMA AGRO, Hyderabad – 196kCi, 3) PINNACLE, Ahmedabad – 100kCi, 4) AKSHAR GAMMA, Ambernath – 300kCi, 5) NIPRO, Pune – 225kCi, 6) MICROTROL, Bangalore – 325 kCi, 7) MICROTROL, Haryana -350kCi, 8) KRUSHAK, Lasalgoan – 72kCi, 9) HI-MEDIA, Ambernath – 300kCi, 10) AMTZ, Vishakhapatnam – 300kCi 11) AIPPL, Vasai – 124kCi, 12) OGFL, Kolkata – 100kCi, 13) SARC, Delhi – 125kCi, and 13) EMI, Vadodara – 300kCi. RAPPCOF also supplied

- RAPPCOF received 06 Adjuster rods from RAPS-4 in the financial year 2021-2021. RAPPCOF trained staff carried out source loading operation of 12 Multi-Purpose Gamma irradiators plants in the country.

Fig. 19. Discharging operation of highly radioactive ^{60}Co Adjuster rods received from RAPS Unit #4 in RAPPCOF Storage pool

Fig. 20: High intensity ^{60}Co Sealed sources (^{60}Co Teletherapy Sources (CTS), W-91 and BC-188 irradiator sources) fabricated at RAPPCOF

Fig. 21: Highly intensity ^{60}Co irradiator source ready to despatch to M/s. VINNAGAMMA, VIETNAM

Fig. 22: Shri. Saeed Anwer Tariq, OIC, RAPPCOF flagged off the M/s Reviss, UK export order at RAPPCOF on May 22, 2020

Fig. 23: Shri. Saeed Anwer Tariq, OIC, RAPPCOF, flagged off the M/s Reviss, UK export order at RAPPCOF on May 22, 2020

C. Engineering Design & Development

1. Fabrication of ROTEX-I: an Industrial Radiography Device

Board of Radiation and Isotope Technology (BRIT), India has indigenously developed Remotely Operated Tungsten shielded Exposure Device (ROTEX-I), an industrial radiography device using ^{192}Ir radio-isotope. The device has been designed as a portable type, Cat. II radiography device and having a maximum source capacity of 2.405 TBq (65 Ci) of ^{192}Ir. The device uses tungsten as shielding material to make it compact & light weight. The tungsten shielding of ROTEX-I have been developed in an optimized geometry with an s-shape cavity at the centre to facilitate smooth movement of radioactive source while minimising the chances of radiation streaming. ROTEX-I has been designed to meet the requirements to qualify as a Type B (U) transportation package & as an industrial portable radiography device. The outer jacket of the device made of High Density Poly-ethylene (HDPE) was produced using injection moulding process as shown in Fig. 1. Two nos. of die each weighing 1.5 tons were machined for the injection moulding of the HDPE jackets. The fabrication of the first operational prototype (shown in Fig. 2) of the device is completed. The device is checked for its operation functionality & found satisfactory. The shielding integrity of the device is also checked by the radiometry test using 27 Ci of ^{192}Ir radio-isotope & the observed results were well within acceptable range.

Fig. 1. Development Process of High Density Polyethylene Jacket

Fig. 2. Development of ROTEX-I Industrial Radiography Device

2. Fabrication of ^{99}Mo Transportation Package

Board of Radiation & Isotope Technology (BRIT) has designed a ^{99}Mo radioisotope transportation package. It has been designed for a maximum capacity of 44.4 TBq (1200 Ci) of ^{99}Mo radioisotope. Tungsten has been used as shielding material in the package to make it comparatively light and compact. The package has been designed to qualify as a type B(U) transportation package for the transport & storage of special forms & other than special forms of radioactive. For the first time in India, the tungsten block of such big size (diameter of 210mm & 300mm long) weighing 160 kg has been developed in single piece lauding the 'Make in India' initiative. The fabrication has been completed for the first prototype (shown in Fig. 3) of the transportation package. The radiometry test is also carried out to ascertain the shielding integrity of the package & the package successfully showed its adherence to the standards.

Fig. 3. Development of ^{99}Mo Transportation Package

3. Conceptual Design of Mobile Food Irradiator

Board of Radiation & Isotope Technology (India) has conceptualized Mobile Food Irradiator (MFI), a Category-II, batch type irradiator designed to irradiate low dose food products such as fresh fruits, vegetables, cereals, pulses and medium dose food products like fish & frozen meat etc. The very concept of Mobile Food Irradiator is based on the idea of making the irradiator itself capable to reach to the location of food produce. The irradiator will be mounted on a 40 feet trailer bed as shown in figure 4 and can be moved to different places as per the irradiation schedule. The irradiator is designed for 100 kCi of ^{60}Co radioactive source which is expected to give a typical throughput of 12-13 tons/day for low dose food products.

The Mobile Food Irradiator (MFI) has been conceived as an irradiator that can be extended to smaller districts at remote locations of India, so that it can benefit the farmers or distributor at the lower level of supply chain & storage. This can help the farmers or the local distributors to preserves the food for a longer period of time. In addition, farmer will also be empowered to be able to sell their food produce as per their convenience, jeopardizing the monopoly of the existing market & can also explore for exportation of foods that would have otherwise spoiled en-route.

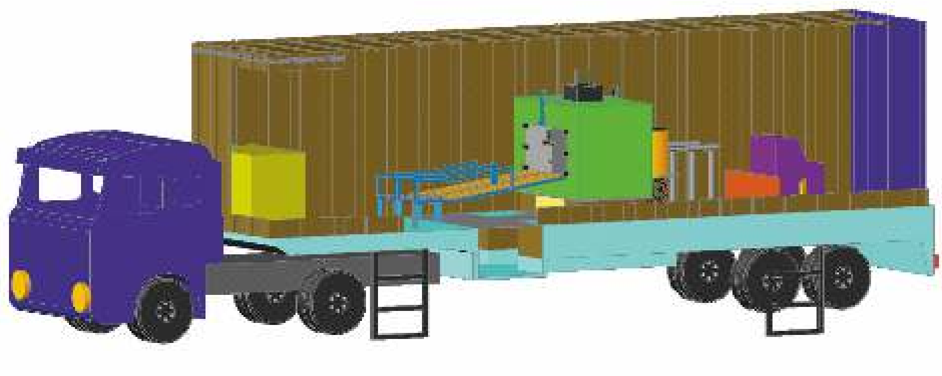


Fig. 4. Overview of Mobile Food Irradiator

4. Development of Cranking Unit

BRIT has developed a new comparatively efficient & light weight cranking unit for the safe remote operate the indigenous industrial radiography device. The new cranking unit is around 4 kg lighter than the existing one. It has also been ensured that the unit can operated in any orientation with near zero slippage. In the cranking unit, the Teleflex cable used to provide the necessary motion has also been the developed in India with on-par quality as its imported counterparts possess. The developed tele-flex cable is made of 26 strand spring steel wire winded together to achieve the necessary flexibility, corrosion resistant & strength. The protective sheath over the Teleflex is also been developed with 5 layer of protection using Teflon tube, stainless steel braiding (with 96 nos. of wire), PVC covering etc. The fabrication of the cranking unit prototype shown in Fig. 5 has been completed. The prototypes were subjected to the regulatory required qualifying tests (as shown in Fig. 6) & it was observed that the same were successfully meeting all the qualifying criterion required by the standard to use them for the remote operation of the radiography devices.

Fig. 5. First prototypes of Cranking Unit

Fig. 6. Regulatory requirement qualifying tests of Cranking Unit prototype

D. Customer Support

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

With a vision to incorporate paperless transactions, BRIT commenced processing of orders online through the URL eportal.britatom.gov.in. All the orders were solicited and processed online. This made the process user-friendly for the customers, who could place requests for all BRIT products and services., Customers can now place their orders from any part of the country, through this e-portal system. Further, this online system enables them to track their order right from the moment of placing them to the various processes it undergoes, viz. from registration of required products & services, up till despatch, including getting airway bill numbers on-hand. Exact online information about the status of the order placed can be scrutinised by the customer. Further this e-portal also provides facility for receiving online payments as well as display their outstanding dues / credits.

E. Activities related to Official Language Implementation

- BRIT has, in addition to its scientific activities, continuously encouraged the use of Official Language, Hindi, in all its official correspondence by complying with the directions issued jointly by Department of Official Language and Department of Atomic Energy (DAE). The quarterly meetings of Official Language Implementation Committee (OLIC) are organized regularly, during which the OLIC members positively discuss the various activities with regard to implementation and propagation of official language and also monitor its progress. **Due to covid -19, as instructed by Deptt of OL, to organize the quarterly meetings through video conferencing or via emails, these instructions were followed and the implementation of Official Language policies was continued in BRIT.**

- **As a result of endeavor and commitment of the BRIT employees, Town Official Language Committee (TOLIC) consisting of more than 100 Central Govt Offices/Corporations/PSU, BRIT is declared as the third winner of the Half Yearly Shield Award 2020, for its implementation and propagation of Official Language.**

- Officers and Staff of BRIT participated in the competitions held by TOLIC (Kavya Pratiyogita) and the Joint Official Language Coordination Committee consisting of 5 Units (AERB, BRIT, DCSEM, DPS and HWB) (JOLCC) (Essay Competition, Kavya Pratiyogita and Slogan writing).

The following steps/measures were taken for training the employees to work in Hindi and propagate the use of Hindi in day to day official work:

- Two Unicode Workshops, were organized. The Speaker Shri Vishwanath Jha, Deputy Director (HTS), shared the information in Simple Hindi Language with regard to the Kanthast Translation Software, Inscript and phonetic typing methods, and Google invoice typing etc. was interesting and the staff was encouraged to do their routine work in Hindi.

Unicode Workshop Speaker Shri Vishwanath Jha, Deputy Director (HTS) with the participants

- 14th September, Hindi Day, was celebrated virtually and all the Heads of Units of JOLCC addressed the gathering. Their speech was informative and encouraged the staff members to do their work in Hindi. Apart from this soft copy of "Saral Shabdavali" of Rajbhasha Vibhag was circulated to all for installing on their computers.

- BRIT OLIC has taken initiative to include innovative programs in the direction of propagating and implementing Rajbhasha in day to day official work.

- Books of Administrative and Accounts Rules and Procedures were purchased in Hindi.

- With a view to propagate Hindi and to facilitate/encourage the officers/employees to work in Hindi, BRIT has been purchasing Hindi books and to motivate the officers/employees to read these books and to know about them an appealing short description of the books is being displayed on the Notice Board.

- The Republic Day and the Independence Day functions are organized in BRIT and the Chief Executive & Chairman, OLIC of BRIT, addresses the gatherings in Hindi and English.
- The Incentive Scheme of DAE for the officers/employees doing work in Hindi has been implemented and the officers and employees participating in these schemes are to be felicitated during the prize distribution ceremony, if held.
- Lecture on BRIT activites in Hindi during the Workshop held was a part of Propagation delivered by BRIT Officers to the partipants of JOLCC Unit personnels attending the workshop .
- Vishwa Hindi Divas was celebrated virtually and Ex CE, HWB was invited for the talk. The talk was appreciated and was interesting with the glimpses of the teaching of Mahabharata. The address of CE, BRIT was appreciated by the JOLCC.
- Hindi Competitions, only for the BRIT, will be organized during Jan-Mar. 2021 quarter and a Hindi Workshop will organized by BRIT for the JOLCC staff members.

Hindi Extempore Speech Competitions 2020

Hindi Essay Writing Competition 2020

कार्यशाला 2020 का आयोजन

Closing ceremony and Certificate distribution by Chief Guest Shri Pradip Mukherjee CE, BRIT

F. Plan Projects

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

- DCSEM, DAE, completed major civil modification jobs comprising of construction of internal partitions, annex building, installation of DG set, installation of elevator, epoxy flooring & painting of wall in the active area, installing metal ceiling, fire rated fibro-silicate board, etc. and the same is handed over to BRIT.

- **Installation of Radiation Shielding Windows (RSW):** Three radiation shielding meant for (1) Dissolution hot cell; (2) Purification hot cell and (3) Conditioning and packaging hot cell was received from NRG, BARC, and were installed in the respective hot cells by M/s. INVAP.

Fig. 1: Installation of Radiation Shielding Windows (RSW)

- **Cold commissioning of FMP initiated:** M/s. INVAP conducted cold trials of the process thereby checking the efficacy of all in-cell/ external gadgets to be utilized for actual process. All process equipment's including vacuum tanks and process lines have been satisfactorily cold tested.


Fig. 2: Cold trials of the Processes (Under Progress)

- **Updated PSAR submitted to AERB:** FMP group concluded the drafting of the updated PSAR and the same was submitted it to AERB for review for obtaining layout approval of the FMP project. Further the PSAR has been defended in front of SARCAR committee (an expert advisory committee constituted by AERB for review and recommendations of approval process of such facilities). The evaluation processes are currently in advanced stage and FMP group is expecting the layout approval anytime soon.

- **Consumables and sealed reference sources imported at FMP site:** Imported sealed reference sources meant for calibration of radiation instruments, process parameters, etc. has been received by FMP. Also, consumables including major chemicals, resins, etc. have been received.

- **Motor vehicles procurement completed and deployed in service:** Under FMP project, three motor vehicles viz. (1) Heavy Duty Truck; (2) Medium Duty Truck; (3) Passenger Vehicle was proposed, for which approval of DAE was obtained. Subsequently, DPS indent was raised and all three vehicles viz. Tata LPT 1613, Tata LPT 407 and Maruti Suzuki Ertiga were received. Later-on bodybuilding of Tata LPT 407 including lead lining/ shielding work was undertaken and completed. All the three vehicles were registered by RTO.


Fig. 3: Motor Vehicles procured for FMP Facility

(b) Advanced Facilities for Radiopharmaceuticals Production

- Commissioned new GMP compliant facility for the production of ^{131}I mIBG injection doses.
- Facility for production of ^{177}Lu based radiopharmaceuticals commissioned
- Replacing asbestos false ceiling with SS panel type false ceiling completed. Improvised GMP standards.
- Flooring replaced with PVC flooring as per GMP standards.
- New exempt waste system (SS dump tank and SS delay tanks) commissioned in RPL & Old system discarded.
- GMP compliant cold storage, freeze drying machine commissioned to enhance production capacity of TCK cold kits.
- RAL facility set-up in Project house, Anushakti Nagar, Mumbai
- For improving radiological safety during production of TFS in LCL, advance SS manifold unit installed. For reducing release of tritium through LCL stack, advance tritium trapping system commissioned.
- Real time PCR machine commissioned at Regional Centre, Hyderabad, and put to use for the development of kits for detection and determination of virus load.

Hot cell facility for production facility ^{131}mIBG therapeutic doses

New glass ware cleaning facility in RPL

Fig. 4: Completion of various Projects under AFRP

Fig. 5: SS panel type False ceiling installed in Radiopharmaceutical Production Laboratory

Fig. 6: Hot Cell Facility for production of ^{177}Lu-based Radiopharmaceuticals

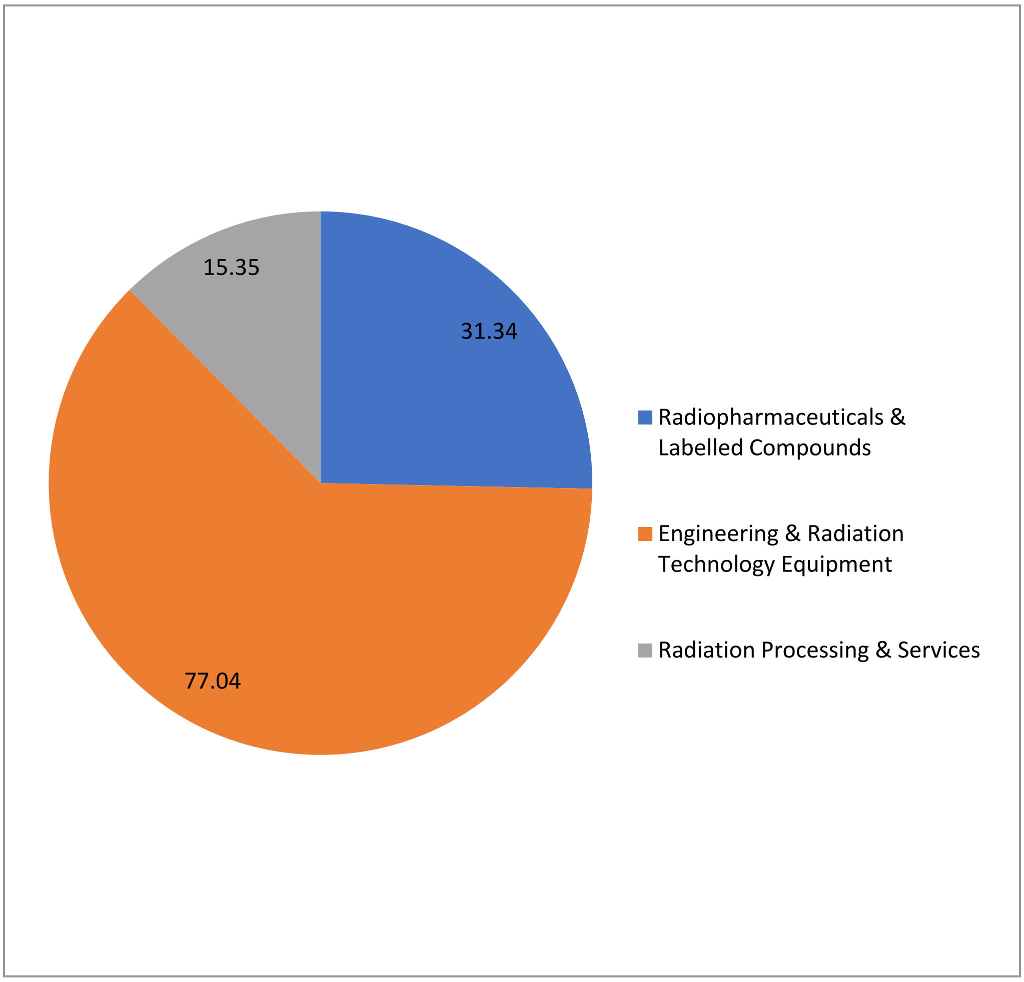
BRIT Website

New updated website of Board of Radiation & Isotope Technology (BRIT) and a customer-facing mobile application, namely, "BRIT Bandhu" was launched during the reported year 2020-21. New website will provide our visitors with an easier way to learn and get an up-to-date information about BRIT's activities. New website will allow the visitor to browse information based on their own choice. It is very interactive and gives better access to the following: 'About BRIT', 'Products', 'Services' and 'Support' Sections.

BRIT website provides easy navigation link to BRIT e-portal for online purchase, which allows customers to place order online. Our current and prospective customer will find useful information about BRIT Products and Services on the 'Homepage' of BRIT Website. BRIT website also provides regular updates on various programs and activities related to developments in BRIT. It is constantly updated with helpful information, newsletters, announcements, and News Section. Customer oriented reports are uploaded on website, almost on daily basis, thus enhancing co-ordination and communication with the customers.

Sales Turnover

Sales data of BRIT Products and Services (Revenue in Crores) during 2020-21



Total Sales Turnover

Rs. 123.73 Cr

CHAPTER 2

RESEARCH & DEVELOPMENT ACTIVITIES

A. Quality Control & Quality Assuarance, RPL, Vashi Complex

(a) Development of UV-C based disinfection module for use in COVID-19 pandemic

A noncontact UV- based system to sterilize personal belongings such as keys, watches, belts, etc. was developed by TD Group. A sensor built into the system detects the presence of an object placed in the sterilizing chamber which automatically rotates in the direction of the UV-C light. The chamber turns on for a pre-programmed time of exposure and after the UV–C lamp is turned off; the original position of the chamber is restored. The user can hence safely collect his disinfected belongings with nil exposure to the UV-C rays.

Microbiological testing of this system was undertaken by QC. A total of four bacterial cultures - Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa and Bacillus pumilus - each using three different populations were tested for two different UV-C exposure durations. The experimental design was standardized such that safety of the researcher was not compromised nor were the microbial discs used contaminated inadvertently by exposure to any environmental flora which could have led to erroneous data. The results obtained confirmed the efficacy of the UVC disinfection machine to inactivate all vegetative forms of the microorganisms tested. This work was completed employing the minimal manpower and resources available during the peak of the COVID pandemic in the laboratory facility, kindly provided by Shri Milind Kumbhare (RPP).

(b) Standardization of SPECT-imaging protocol for assessment of ^{177}Lu-EDTMP kit in Wistar rats

As per RPC monograph, imaging studies for the assessment of ^{177}Lu-EDTMP radiopharmaceutical, should be done for every batch until five batches, followed by once in 5 batches initially, until 25 batches, and then once in ten batches using a single-head digital SPECT gamma camera employing LEHR collimator. But due to non-availability of this facility, there was a need to standardize new protocol with the new type of gamma camera that is available. Investigations carried out revealed that images with optimal quality could be obtained with activities greater than 5mci of injected activity, with 15min acquisition time, under isofluorane anesthesia system. Furthermore, the image processing details (the reconstruction parameters offering the best signal-to-noise ratio) was also standardized.

(c) Mechanistic evaluation of ^{177}Lu-DOTATATE adjuvant therapies with stilbene derivatives for treatment of Pancreatic Adenocarcinoma *in vitro.*

Carcinoma of the pancreas causes more than a quarter of a million deaths annually worldwide, being the thirteenth most common cancer and the eighth most frequent cause of death from cancer. Survival rates are among the worst for any tumor, being the mortality to incidence ratio of 98 %. Pancreatic cancer is associated with poor survival and ranks as the fourth or fifth most common cause of cancer mortality. In spite of significant progress in the area of cancer therapeutics, pancreatic cancer still remains by and large untreatable with an extremely poor 5-year survival rate. Patients with PC are usually diagnosed late in the cancer's progression, and therefore only 15–20% of patients are eligible for curative-intent surgery. For patients diagnosed with resectable or locally advanced disease, accounting for 40% of PC patients, external beam radiation therapy (EBRT) is considered a staple therapy.

Molecular radiotherapy using ^{177}Lu-DOTATATE has been found effective in treatment of somatostatin receptor-expressing tumors including pancreatic cancer. Despite its moderately successful use in the clinic, tumour progression is still frequent and treatment strategies needed further improvement. Treatment that can modulate tumor microenvironment using a natural dietary agent would be considered a novel therapeutic strategy. Our preliminary investigation showed that a resveratrol derivative, Stilbene, causes robust radio-sensitization of pancreatic cancer cells for EBRT. On positive uptake of octreotide-based PET/SPECT imaging, treatment is usually administered as a standard dose and number of cycles without adjustment for radiobiological effects in the tumor necessitating further investigations for a better cure. In the current study, two pancreatic cell lines viz., Mia Paca-2 and Panc-1 were exposed to various types and concentrations of stilbene derivatives along with varying doses of ^{177}Lu-DOTATATE, after which synergistic effects in clonogenic assays, Sub G1 Analysis, Mitochondrial Redox assays were measured. Clonogenic survival after molecular radiotherapy with ^{177}Lu-DOTATATE was cell-line-specific, indicating varying levels of intrinsic radiosensitivity. Post ^{177}Lu-DOTATATE treatment, clonogenic survival, Sub G1 population, Mitochondrial Redox potential decreased for cells expressing greater levels of somatostatin receptor subtype 2 such as Mia Paca-2. This effect was more pronounced in combination of stilbene derivatives especially with Dihydroxystilbene. In conclusion, the mechanistic studies of cancer cell death after ^{177}Lu-DOTATATE therapy reveals heterogeneous cancer cell damage responses warranting for further fine tuning of the treatment as per the molecular response of the patient tumor cells.

(d) Alternative vendor development for procuring BET reagents

To avoid dependency on single vendor, BET reagents commercially available from new vendor was evaluated as a part of vendor development. The following products were tested: Cold kits for production of ^{99m}Tc-radiopharmaceuticals (TCK 7, TCK 42, TCK 16), ^{131}I-mIBG injection and $^{99m}TcO_4$ eluate from Coltech Generator.

Gel Clot assay, performed using this new kit, gave satisfactory results and hence a viable alternative to the current vendor has been established. This is of special importance in view of the challenge encountered for import of BET reagents during the COVID lockdown period.

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 2020-21 the following R&D assignments were carried out:

(a) Production, Quality Control analysis and Supply of New Radiopharmaceutical, [^{18}F]-FDG, using IBA-SYNTHERA Module at MCF, VECC, Kolkata

Currently, [^{18}F]-FDG is the most successful PET radiopharmaceutical so far. The advancement in synthesis and quality control of [^{18}F]-FDG, together with its approval by the US FDA and the availability of reimbursement, are probably the main reasons for the flourish of clinical PET. Nucleophilic fluorination using mannose triflate as precursor and Kryptofix or tetrabutylammonium salts (TBA) is widely used because of higher yield and shorter reaction time. F-18 is produced in the IBA Cyclone-30 cyclotron by irradiation of $H_2{}^{18}O$ (97% enriched) [$^{18}O(p,n)^{18}F$] using 18 MeV proton beam (35-45 µA current) for 30 min to 2 hours and the synthesis of [^{18}F]-FDG is carried out using automated, closed loop and computer- controlled IBA synthera module inside Comecer make Hot cells (75 mm Pb thickness wall). ABX, Germany reagents and ancillary kits along with IFP (Integrated Fluidic Processor) are utilized in the IBA Synthera module for the synthesis and purification of [^{18}F]-FDG.

Production of ^{18}F from O-18-Water

- Proton bombardment of [^{18}O] water in specially designed target
- $^{18}O(p,n)^{18}F$ reaction produces [^{18}F] fluoride ion and only small fraction of protons undergo reaction
- Transfer solution of [^{18}F] fluoride ion / [^{18}O] water from target to chemistry module

Synthera® system is designed to make operation as simple as possible. Although specific training and attention to details is essential, all manual operations are extremely simple and, in many cases, designed to prevent mistakes. To further simplify FDG processing the FDG IFP™ is supplied complete with reagent vials and cartridges.

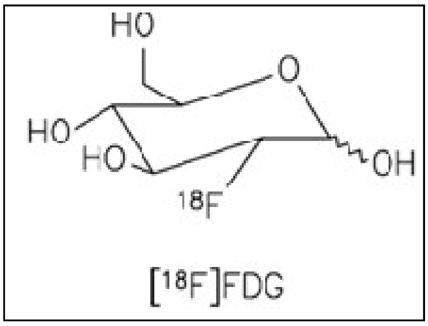


Fig. 1: Structure of [^{18}F]-FDG

Power on and start up

The inert gas (He or N_2; moisture content <0.003%) supply is turned on to the unit; verify the pressure level is between 2 and 2.2 bar absolute

The compressed air supply is turned on and air pressure is checked to be minimum 7 bar gauge

The electrical power to the unit is turned on; switch is located on the bottom of control box. If PC is off or is not connected an audible signal will be heard approximately every second indicating that the unit is functional but not communicating with PC

The PC is turned on, logged on to Windows and the control program is started. FDG method is loaded and indicators on the screen are checked

It is verified that IFP™ holder is in its neutral position and no IFP™ is installed. If not, the red button is pressed once to eject the IFP™. STAY CLEAR OF THE IFP™ HOLDER

The fluid connectors and actuators are inspected and verified that they are undamaged.

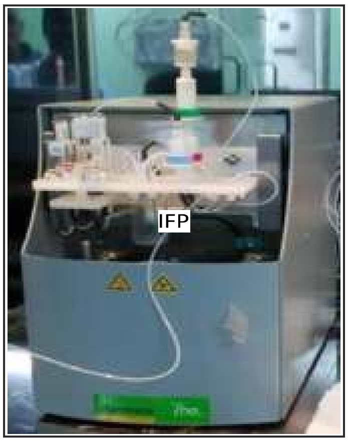


Fig. 2: IBA-SYNTHERA Module

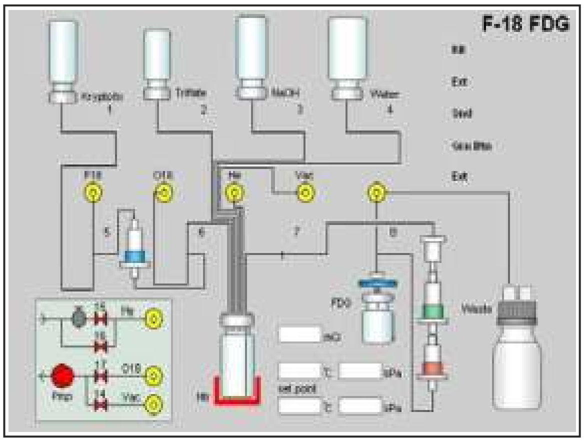


Fig. 3: [^{18}F]-FDG Synthesis Flow Diagram

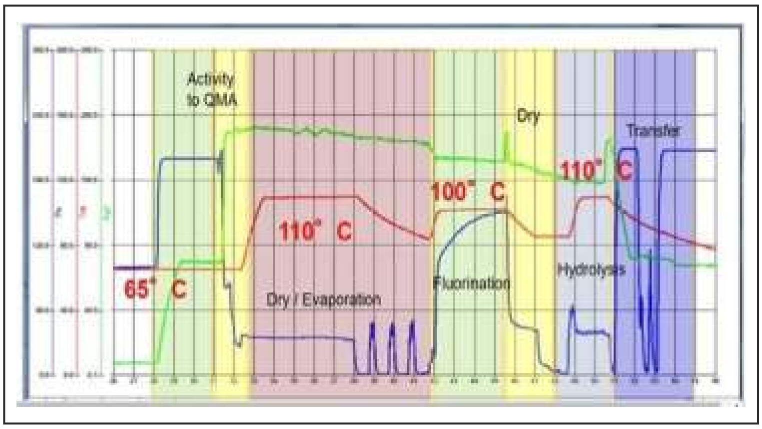


Fig. 4: Steps in the synthesis of [^{18}F]-FDG

The dispensing of the product is carried out using Comecer made Timotheo-LT dispensing module inside hot cell having ISO Class A environment. [^{18}F]-FDG injections are produced following GMP. The final [^{18}F]-FDG product obtained from IBA Synthera synthesis module is collected in 30 ml sterile glass vial (supplied by ABX Germany) containing 0.68 ml of 14.6% sodium chloride (inactive ingredient) to make the final solution isotonic, in the dispensing hot cells. The production yield of [^{18}F]-FDG varied from 65-70 % (without decay corrected). A 0.5ml. of sample from each FDG batch was taken in a sterile vial for Q.C. analysis.

Quality Control Analysis & Quality Assurance of Cyclotron produced [^{18}F]-FDG

The quality control requirements of [^{18}F]-FDG can be found in United States Pharmacopeia (USP), British Pharmacopeia (BP), European Pharmacopeia (EP), Indian Pharmacopeia (IP) and the Chemistry, Manufacturing, and Controls (CMC) section from United States Food and Drug Administration (US-FDA) PET draft guidance documents. Basic requirements include radio nuclidic identity, radiochemical purity, chemical purity, pH, residual solvent, sterility, and bacterial endotoxin level. Some of these tests (sterility, endotoxins and radio nuclidic purity) can be finished after the [^{18}F]-FDG has been released. The labelled [^{18}F]-FDG compound has a relatively short shelf life, which is dominated by the physical decay of ^{18}F with a half-life of 109.8 minutes, or slightly less than 2 hours. Still, this half-life is sufficiently long to allow shipping the compound to remote PET scanning facilities, in contrast to other medical radioisotopes like ^{11}C. In PET imaging, [^{18}F]-FDG can be used for the assessment of glucose metabolism in the heart, lungs, and the brain. It is also used for imaging tumors in oncology, where a static [^{18}F]-FDG PET scan is performed and the tumor [^{18}F]-FDG uptake is analysed in terms of Standardized Uptake Value (SUV). [^{18}F]-FDG is taken up by cells, phosphorylated by hexokinase (whose mitochondrial form is greatly elevated in rapidly growing. The quality control tests of 190 batches of [^{18}F]-FDG have been performed till March, 2021.

- The physicochemical quality control tests of [^{18}F]-FDG were performed by its checking appearance, pH, radiochemical purity by either method A (HPLC) or method B (TLC). The HPLC system is more expensive and elaborate than the TLC system, radionuclides purity by HPGe method. HPLC study is required to know any radiochemical impurities like free ^{18}F, [^{18}F]-FDM and [^{18}F]-ClDG are present or not.
- The radioactivity assay i.e. yields determination and half-life estimation were performed in dose calibrator.
- The presence of bacterial endotoxin in the [^{18}F]-FDG were assayed by Charles River's endosafe PTS (Portable Endotoxin Testing System)
- The sterility testing for every individual batch of [^{18}F]-FDG has been inoculated on both fluid thioglycolate medium (FTM) and soybean casein digest medium (SCDM) within 30 hours of production at 37°C and 25°C respectively
- The residual solvent in [^{18}F]-FDG, *viz.* ethanol and acetonitrile, were estimated in Gas chromatography (GC)
- The radiochemical purity of the [^{18}F]-FDG has been found to be 99.9% by using TLC method
- The presence of Kryptofix in the final product was found to be less than 22 ppm
- The Bacterial endotoxin in ^{18}F-FDG was found <10 EU/ml determined by PTS method
- Each batch was evaluated for sterility test and each of the batches passed the sterility test

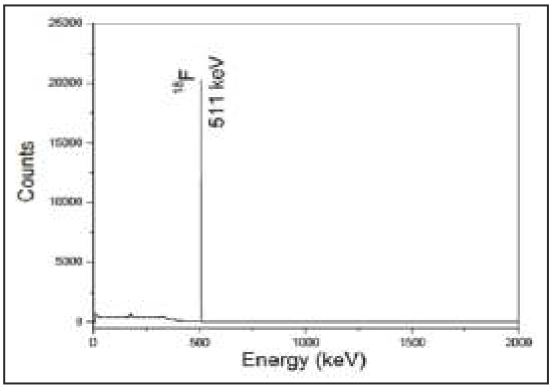


Fig. 5: HPGe spectra Gamma spectra of [^{18}F]-FDG

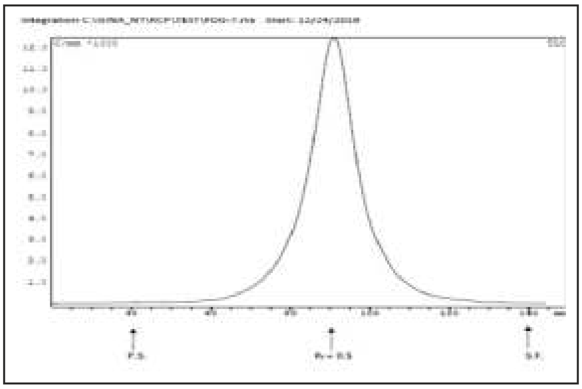


Fig. 6: TLC of [^{18}F]-FDG

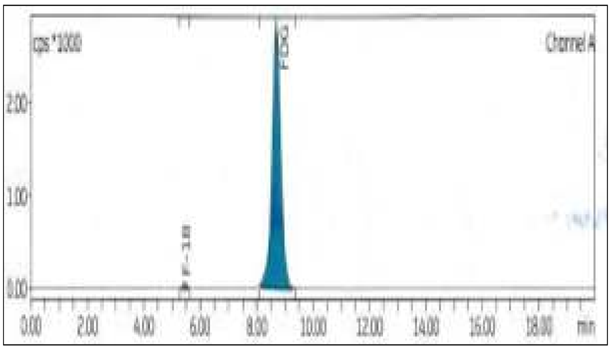


Fig. 7: HPLC spectra of [^{18}F]-FDG

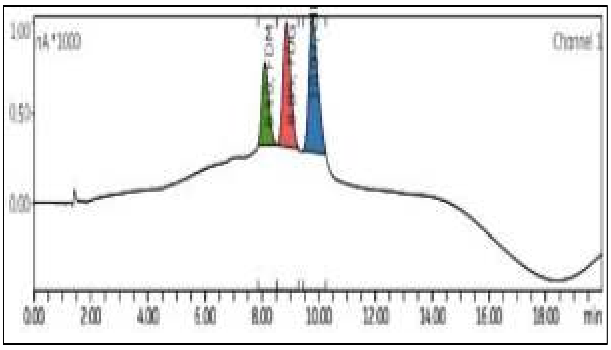


Fig. 8: HPLC spectra of cold samples of FDM, FDG & ClDG

Table 3: Physicochemical and Biological Quality control tests of [^{18}F]-FDG

Batch no.	Appearance	pH	Half life (min)	RC Purity	RN Purity	Chemical Purity			BET test	Sterility test
						Kryptofix	Acetonitrile (ppm)	Ethanol (ppm)		
1	Clear solution	6.5	109.1	100 %	99.9 %	Passed	Passed 17.88	Passed 1705.96	Passed (<10 EU/ml)	Passed
2	Clear solution	6.0	110.76	100 %	99.9 %	Passed (<22 µg/ml)	Passed 14.04	Passed 1756.94	Passed (<10 EU/ml)	Passed
3	Clear solution	6.0	109.9	100 %	99.9 %	Passed (<22 µg/ml)	Passed 18.21	Passed 1641.40	Passed (<10 EU/ml)	Passed
4	Clear solution	6.5	108.9	100 %	99.9 %	Passed (<22 µg/ml)	Passed <5	Passed 1344.48	Passed (<10 EU/ml)	Passed
5	Clear solution	6.0	109.5	100 %	99.9 %	Passed (<22 µg/ml)	Passed 14.60	Passed 1481.30	Passed (<10 EU/ml)	Passed
6	Clear solution	6.5	109.8	100 %	99.9 %	Passed (<22 µg/ml)	Passed 15.59	Passed 1506.85	Passed (<10 EU/ml)	Passed

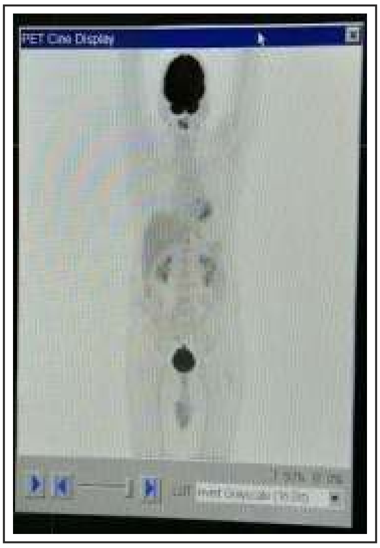


Fig. 9: PET-CT scan of [^{18}F]-FDG

[^{18}F]-FDG injection is a sterile solution buffer/saline solvent containing radioactivity suitable for intravenous administration. It contains not less than 90% of the radioactivity of [^{18}F]-FDG injection and not more than 110% of the labelled amount of [^{18}F]-FDG, expressed in MBq (or mCi) per mL, at the time indicated on the label. Other chemical forms of radioactivity do not exceed 5% of the total radioactivity. The [^{18}F]-FDG was administered in normal volunteer and PET-CT scan was successfully performed with requisite uptake in desired organs (Fig.9). The RPC clearance was obtained for routine production and supply of Cyclone-30 produced [^{18}F]-FDG to nuclear medicine hospitals / PET centres in the Eastern India.

(b) Production and QC analysis of pharmaceutical grade Na[^{18}F]F injection, a bone imaging Radiopharmaceutical, using modified Integrated Fluidic Processor in IBA Synthera module

Sodium ^{18}F-fluoride is a valuable imaging modality of the skeleton. ^{18}F-fluoride PET is highly sensitive for detection of malignant and benign bone abnormalities, for monitoring response to therapy, separation between uneventful and impaired healing processes of bone fracture, osteonecrosis and graft incorporation. The production of ^{18}F was achieved by irradiating $H_2{}^{18}O$ (1.8ml) using IBA niobium target assembly with 18 MeV, 25-30µA proton beam current (total beam on target 25µAh). The synthesis of Na[^{18}F]F was carried out with modified IFP cartridge (IFP cartridge for FDG production has been modified) in IBA synthera module with indigenously developed software programme. The[^{18}F]F- ions were trapped into the conditioned QMA anion exchange cartridge while the irradiated water was flushed out of the column with vacuum. Then the QMA cartridge was washed with water and [^{18}F]F-was eluted from the column with sterile, pyrogen-free 5-10 ml of physiological saline (0.9 % saline). The product Na[^{18}F]F is collected in sterile, endotoxin free, evacuated vials through a 0.22 µm membrane filter. The automated fluorination module using IBA Synthera module and graphics based schematic for radiopharmaceutical synthesis of Na[^{18}F]F are represented in Fig. 10 and Fig. 11 respectively.

The physicochemical quality control tests of Na[^{18}F]F include checking appearance, pH, radiochemical purity by TLC method, radionuclides purity by HPGe and residual solvent analysis by GC method were performed. The radioactivity assay i.e. yields determination and half-life estimation were performed in dose calibrator. The biological quality control test including bacterial endotoxin test and sterility test in the Na[^{18}F]F were assayed by PTS and sterility kits respectively.

The production yield of Na[^{18}F]F is >99% and the radioactive concentration is 2-50 mCi/ml. The radiochemical purity of the Na[^{18}F]F has been found to be 99.9% (Fig. 12). The radionuclidic purity was greater than 99.99% (determined by HPGe) (Fig. 13). The concentration of ethanol in Na[^{18}F]F was found < 4000 ppm (Fig. 14). The Bacterial endotoxin in the Na[^{18}F]F was found <5 EU/ml determined by PTS method and passed the sterility test. The production of Na[^{18}F]F in Cyclone-30 has been achieved successfully. Regular production and supply to hospitals will commence after getting regulatory clearance.

The Na[^{18}F]F radiopharmaceutical was administered in a volunteer and PET-CT bone scan was successfully performed with requisite uptake in desired organs (Fig.15) followed by the positive feedback obtained by the nuclear medicine practitioner.

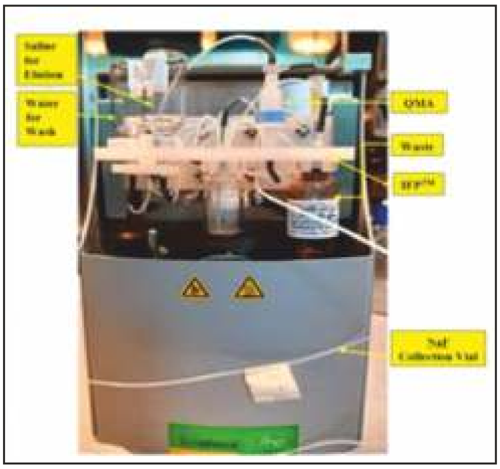


Fig. 10: Automated Fluorination module

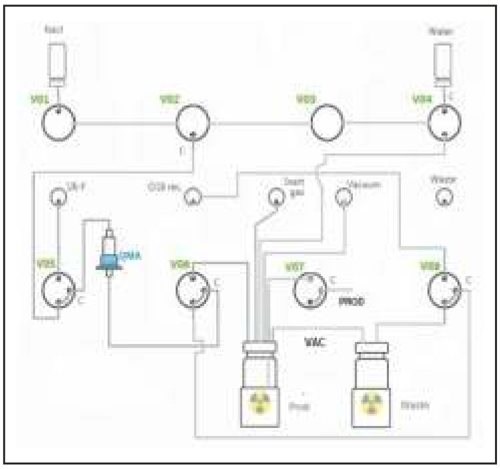


Fig. 11: Graphics based GUI for the synthesis of Na[^{18}F]F

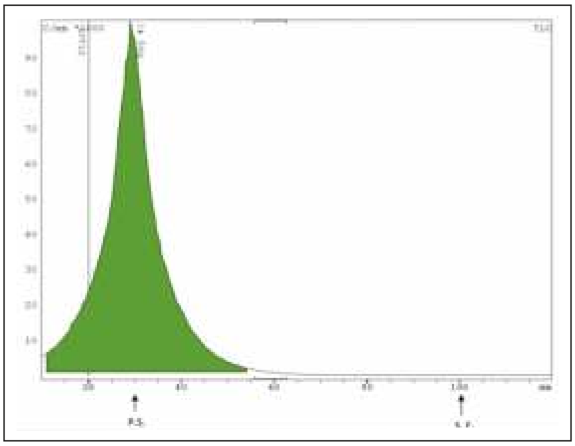


Fig. 12: TLC spectra of Na[^{18}F]F

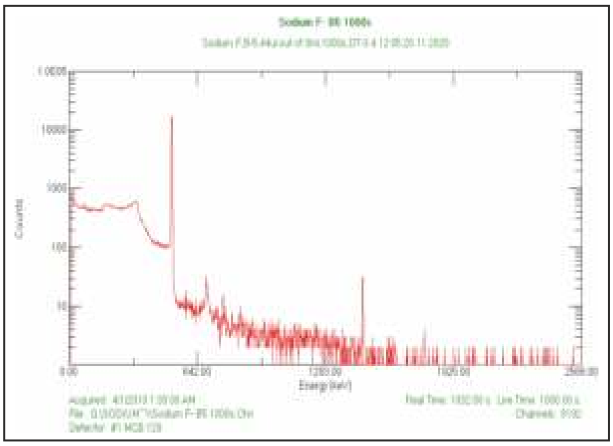


Fig. 13: HPGe Gamma Spectra of Na[^{18}F]F

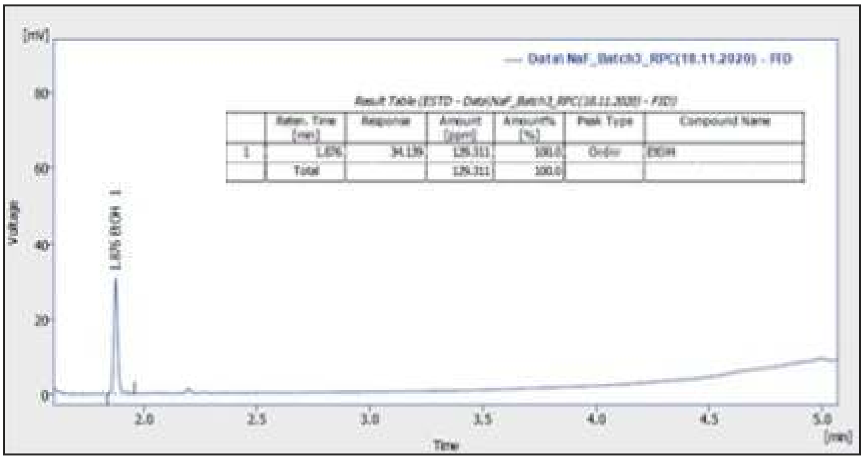


Fig. 14: Gas Chromatograph spectra of Na[^{18}F]F

Case Study of Na[^{18}F]F

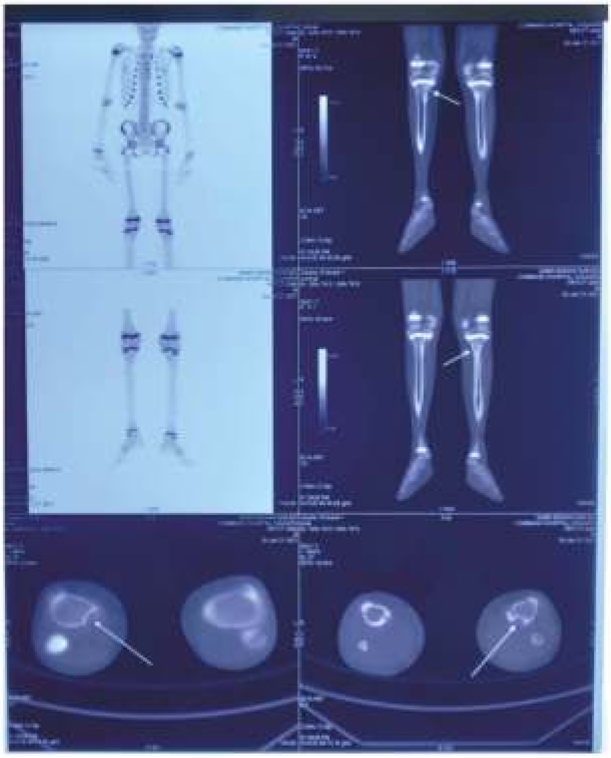


Fig. 15: PET-CT Scan of Bone using Na[^{18}F]F, followed by Feedback from NM Practitioner

(C) Development of new dispensing system for remote dispensing of [^{18}F]-FDG

The [^{18}F]-FDG synthesized in the PET hot cell of the DAE Medical Cyclotron Facility, using IBA Synthera module, is transferred aseptically using 10mL of sterile water in a capped sterile vial (stock) with a required amount of sodium chloride (to make 0.9% sodium chloride), through a 0.22mm Millipore filter kept in the dispensing hot cell (Class A) through an interconnector 1/16 inch diameter Teflon tube. The activity of [^{18}F]-FDG is measured in a dose calibrator, installed in dispensing hot cell and dispensed into the several dispensing vials. The standard procedure for dispensing of the [^{18}F]-FDG to the dispensing vials is to place an empty sterile vial on the M/s Comecer make weighing system for measuring the actual volume of activity dispensed and a pre-set volume of activity and saline are dispensed automatically from the stock [^{18}F]-FDG product vial by means of the peristaltic pump system (M/s Comecer make) which is controlled by the control program installed in the PC from outside of the dispensing hot cell. Thereafter the dispensed vial is removed by tele-manipulator and finally capped by means of M/s Comecer make capping system. Then the capped dispensed vials containing required amount of activity is autoclaved in M/s Comecer make autoclave system to get [^{18}F]-FDG in injectable form. This procedure is not only cumbersome and time consuming but also has a chance of compromising the sterility of the product. To overcome this, a dispensing system has been developed that not only made the procedure more user- friendly but also reduced the chance of contamination from bacteria. The newly developed dispensing system consisted of dose calibrator, peristaltic pump and an electromechanical module. Moreover, the dispensing system is a compact filling system which allows the dispensing of the radioactive liquid in a sealed glass vial. This system is PLC controlled and the HMI program installed in the PC will act as the operator's interface. The system comprises of an activity vial placed inside the dose calibrator, a dilution saline vial and a dispensing vial where calculated amount of activity is dispensed. The peristaltic pump is operated from the computer terminal till the required activity is dispensed. Two pinch-valves allow the closing of the dilution tubes while the radioisotope is being pumped, and vice versa. The electromechanical module consists of a motor driven screw assembly to vertically move the dispensing needle in both the directions of the pre-capped sterile product vial. The vial for dispensing of [^{18}F]-FDG activity is kept in position by a grip arrangement mechanism from which the vial can be easily released by the tele-manipulator. Limit switches and relays are used to limit the vertical range of the movement of the product vial. The entire operation is carried out with electrical toggle switches installed outside the hot cell and manipulators. The requisite volume of [^{18}F]-FDG activity from the stock vial kept in the dose. calibrator and requisite volume of saline were dispensed by means of a M/s Comecer make peristaltic pump through the respective sterile polypropylene tubes connected to the needle of the mechanical module to the pre-capped sterile vial. During dispensing, the motor was driven to move the needle down the capped vial, till the needle punctures its rubber stopper. Then the transfer of product as well as saline were carried out by peristaltic pump assembly. Since we have

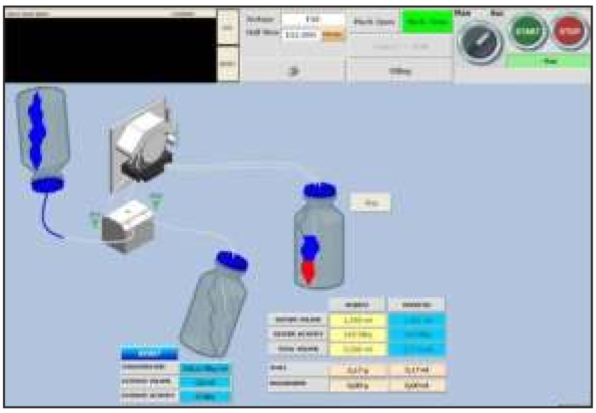


Fig. 16: Automated HMI Control program

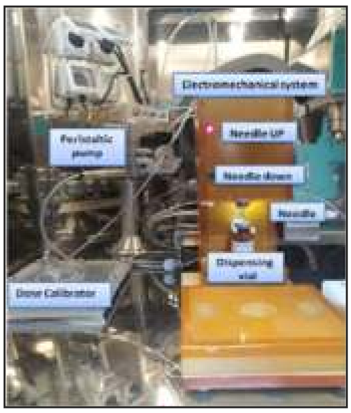


Fig. 17: Dispensing system inside Hot cell

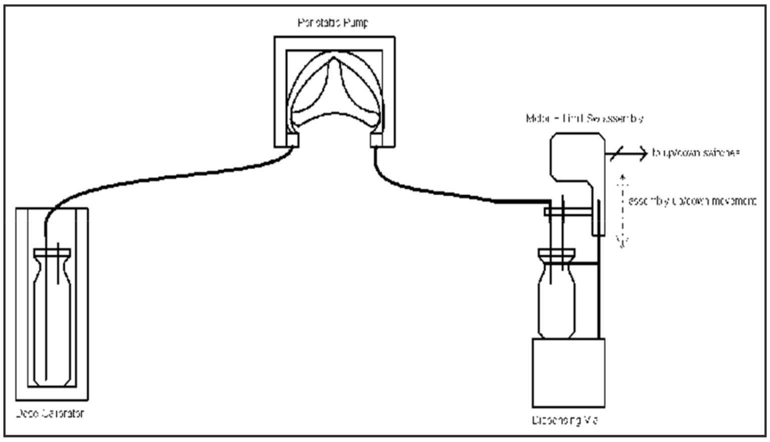


Fig. 18: Schematic diagram of the newly developed dispensing system

used sterilized capped vial for dispensing the product, there is a minimum chance of the product getting contaminated with respect to sterility point of view. Since the sealed vials are used to dispense the activity, capping and crimping operations are not required to be done.

(d) Preparation of solid target by pulse current electro-deposition for production of ^{201}Tl, ^{68}Ga and ^{67}Ga

For production of radioisotopes ^{201}Tl, ^{68}Ga and ^{67}Ga in cyclotron via ^{203}Tl(p,3n)^{201}Pb (decays in 34 hour) ^{201}Tl, ^{68}Zn(p,n)^{68}Ga and ^{68}Zn(p,2n)^{67}Ga nuclear reactions, enriched target materials ^{203}Tl and ^{68}Zn are being irradiated with high energy and high intensity proton beam. Since the enriched materials are very expensive, minimum amount of enriched materials need to be irradiated, so as to reduce the production cost. Pulse current electro-deposition is the most important technique for preparation of solid target for irradiation at high beam current (200µA or more) for radioisotope production. Enriched ^{203}Tl and ^{68}Zn Solid targets have been prepared by pulse electro-deposition technique for production of ^{201}Tl and ^{67}Ga at Medical Cyclotron.

Procedure:

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

- The target layer should adhere strongly to the copper target carrier (generally copper) at a temperature about 50^{0}C below the melting point of the corresponding metal.
- Target layer should be homogeneous all over the surface area (±5%) & show a well defined thickness that may vary from a few tens to several hundred microns.
- Target layer should be smooth (not spongy), dense (no occlusions, nor vacuoles) and stress-free
- The metal deposit & the carrier layer interface should be free of organic plating additives. Pulsed current electroplating technology is required to get the desired quality of the electro-deposited target layer, where pulsed current and voltage waveform and its parameters are

different for different materials which need to be optimized experimentally for individual metal. The electro-deposition vessel is a hollow Perspex cylinder fitted with a central Pt-anode, four slots for copper carriers for simultaneous production of four targets and a stirrer-motor combination.

Fig. 19: Electro-deposition vessel

a) ^{203}Tl Electro-deposition for ^{201}Tl production:

The electro-deposition bath was prepared by dissolving an amount of $^{203}Tl_2O_3$ (corresponding to the Tl weight of 8 targets) in an aqueous alkaline solution containing a complexing agent (EDTA), an anodic depolarizer and a wetting agent. From this bath, four targets were prepared by constant current electrolysis (current efficiency > 99%) involving the application of a bipolar chopped saw-tooth voltage between a central grounded Pt anode wire and four cathodes, i.e. four copper carriers, mounted vertically in appropriate windows of the electro-deposition vessel. Thereby after one electro-deposition cycle a 50 % ^{203}Tl depletion is obtained i.e.: half of the ^{203}Tl-EDTA- is reduced to $^{203}Tl^0$ and deposited on the Cu backings. The control electronics involves a single generator, 4 voltage controlled current sources, and the stirrer-control.

b) ^{68}Zn Electro-deposition for ^{67}Ga & ^{68}Ga Production:

The electro-deposition bath was prepared by dissolving an amount of Zn or ZnO (corresponding to the ^{68}Zn weight of 8 targets) in a diluted acid aqueous solution containing an anodic depolarizer. The required amount of enriched Zn for 1 plating bath is 5g. Reuse of the plating bath up to 10 times is possible after addition of 2.5 g. From this bath, four targets were prepared by constant current electrolysis (current efficiency > 99%) involving the application of a chopped sine wave voltage between a central Pt anode wire and four grounded cathodes, i.e. four grounded copper carriers, mounted vertically in appropriate windows of the electro-deposition vessel. Thereby a 50% ^{68}Zn depletion is obtained i.e. half of the $^{68}Zn^{++}$ is reduced to $^{68}Zn^0$ and deposited on the Cu backings.

Fig. 20: Electronics for ^{203}Tl electrodeposition

Fig. 21: ^{203}Tl Target

Fig. 22: Electroplated ^{68}Zn targets

Fig. 23: Electrodeposition vessel

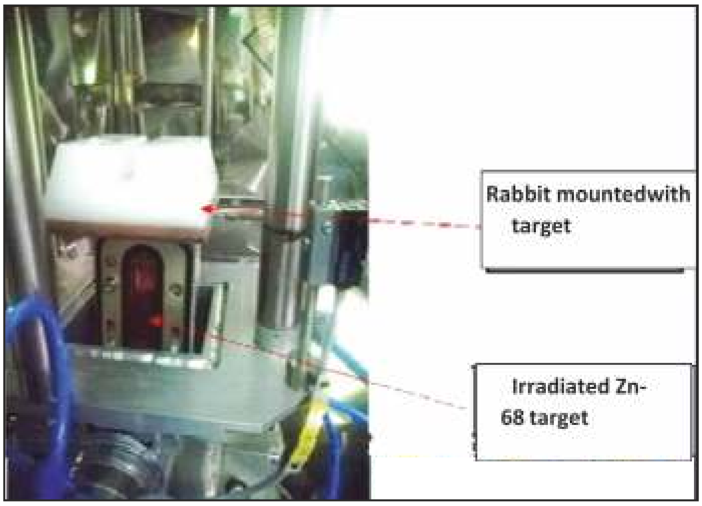


Fig. 24: Irradiated target system received in the receiving hot cell

Results:

^{203}Tl electrodeposition: 1092 mg per target of ^{203}Tl deposits (approx 110 micron) obtained in 5 hrs 50 mins time.

^{68}Zn electrodeposition: 834 mg per target of ^{68}Zn deposits (approx 120 micron) obtained in 1 hr 50 mins time

(e) Direct production of ^{68}Ga from solid ^{68}Zn target in Cyclone-30 (First time in India) and preparation of $^{68}GaCl_3$, ^{68}Ga-PSMA & ^{68}Ga-DOTA-TATE Radiopharmaceuticals

The supply of ^{68}Ga for medical imaging, is primarily based on the costly [^{68}Ge]Ge/[^{68}Ga]Ga generator. Direct production of ^{68}Ga from enriched ^{68}Zn was tried in DAE Medical cyclotron, Cyclone-30. ^{68}Ga has been directly produced from electroplated ^{68}Zn target via $^{68}Zn(p,n)^{68}Ga$ transformation. Enriched ^{68}Zn solid targets were prepared by electro-deposition technique for production of ^{68}Ga. The enriched ^{68}Zn targets were irradiated with 15MeV proton beam in the Cyclone-30, with an average integrated beam current of 25 µAh (40-60 µA). The irradiated target was transferred to the solid target processing SPECT hot cell from the irradiation vault by remote-controlled rabbit transport system, for further radiochemical processing. The ^{68}Ga was separated from the target, resulted in a very dilute HCl solution. All the operations were carried out remotely using the computer operated chemistry modules installed inside the processing hot cell. The ^{68}Ga chloride was labelled with PSMA-11 & DOTA-TATE ligands.

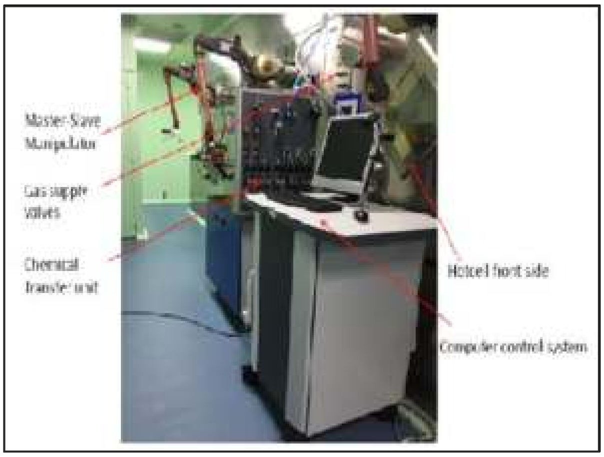


Fig. 25: Gallium Chemistry module computer-based controller system

Fig. 26: Gallium Chemistry hot cell with module

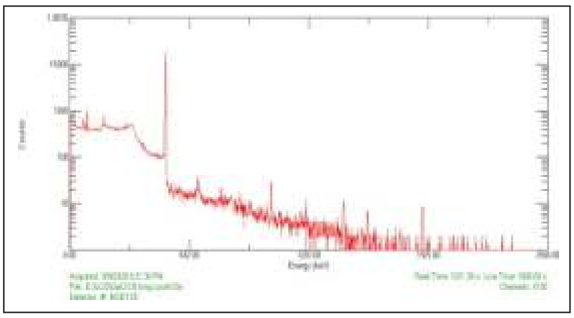


Fig. 27: HPGe spectra of $^{68}GaCl_3$

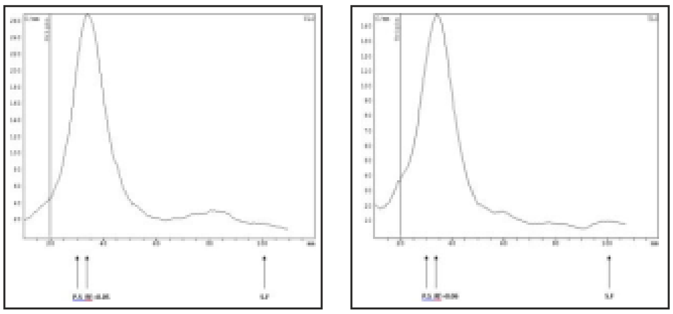


Fig. 28: TLC spectra of ^{68}Ga-PSMA-11 & ^{68}Ga-DOTA-TATE

(f) Preparation of ^{67}Ga-Citrate in Medical Cyclotron Facility, VECC

^{67}Ga isotope has a physical half-life of 78.3 hours and decays by electron capture emitting gamma radiation. It can be produced by a variety of reactions in a cyclotron. The principal gamma photons from ^{67}Ga are 93 keV (40%), 184 keV (24%), 296 keV (22%), and 388 keV (7%).

Production of ^{67}Ga Citrate:

Electroplating of ^{68}Zn target has been prepared as per methodology given in the manual (Fig. 22 shown above), VUB, Belgium. ^{67}Ga has been produced by irradiating enriched ^{68}Zn target electroplated on the copper base material in the solid target station in the beam line 1.1. The target was irradiated with energy of 28 MeV proton beam, 10-50 µA current for a total integrated current of 50-200 µAh. The irradiated target was transferred to the SPECT hot cell (100mm lead shield) by the rabbit transport system [Fig. 29]. The following steps are involved in production of ^{67}Ga-citrate radiopharmaceutical

Step 1: Loading of the electroplated target to the receiving SPECT hot cell through loading/unloading window.

Step 2: Fixing of the electroplated target to the solid target irradiation station (either solid target 1 or 2) located in SPECT vault by transferring the target through the pneumatic rabbit transfer facilities from the receiving SPECT hot cell by computer-controlled software system.

Step 3: Irradiation of the target to the respective target station as required for the production of a particular radioisotope (here ^{67}Ga).

Step 4: Receiving of irradiated target to the receiving SPECT hot cell through the pneumatic rabbit transfer implanted inside the lead shielded trench.

Step 5: Transfer of the irradiated target to the respective SPECT hot cell from the receiving SPECT hot cell through Pb shielded conveyor belt for production of the respective radioisotope by computer controlled automated chemistry module where separation of the desired radioisotope from the target matrix and formulation of the desired radio-chemical will take place.

Step 6: Transferring of the radiochemical to the dispensing SPECT hot cell through conveyor belt, sterilization of the same for preparation of radiopharmaceutical, and dispensing of the product in vials (for quality control) through fully automated device.

Step 7: Collection of the final product vials from SPECT dispensing hot cell in LP30 container by remote control operation and transfer of the product through the conveyor belt to the loading/unloading window.

Step 8: Transfer of product for performing physio-chemical tests (Radio nuclidic purity & Radio Chemical purity). The irradiated target was chemically processed in Ga-Chemistry hot cell to get carrier-free ^{67}Ga citrate (Radiopharmaceutical). All the operations were carried out remotely using the computer-based controller system, operated the IBA chemistry modules installed inside the Gallium processing hot cell.

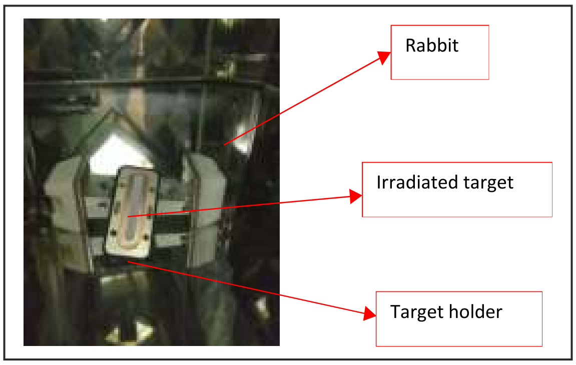


Fig. 29: Irradiated Target with rabbit system inside receiving Hot cell

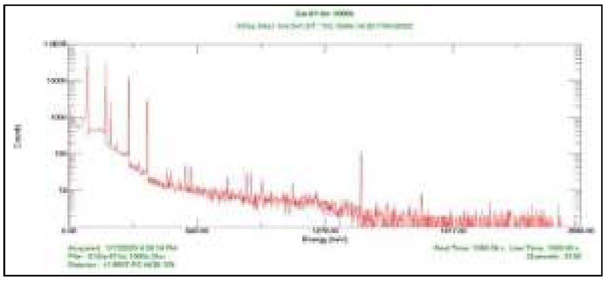


Fig. 30: g-spectra of ^{67}Ga-citrate (HPGe) for RN Purity

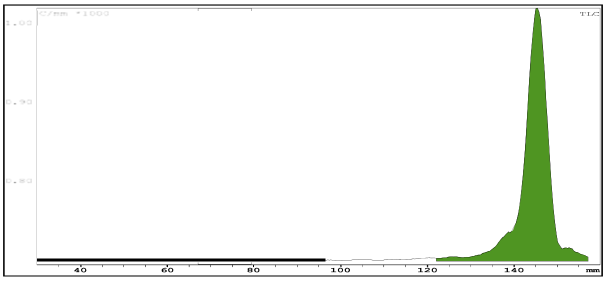


Fig. 31: TLC of ^{67}Ga-citrate for RC Purity

^{67}Ga citrate was evaluated by performing physio-chemical tests (Radio nuclidic purity [Fig 30], Radio Chemical purity [Fig 31]. 80-200 mCi of ^{67}Ga citrate has been successfully produced in Medical Cyclotron. The radionuclidic purity and radiochemical purity of ^{67}Ga-citrate are 99.8% and 99.9%, respectively.

(g) Preparation of ^{201}Tl-Chloride in Medical Cyclotron Facility, VECC

^{201}Tl is a potentially useful radioisotope for a variety of medical applications, including a functional assessment of the myocardium, which in turn allows an assessment of the extent of damage after a heart attack or from chronic heart disease and possible assessment of physiology, as a renal medullary imaging agent, and for tumor detection. BRIT, Kolkata, jointly with VECC, Kolkata has successfully achieved to produce ^{201}Tl (half life: 73 h) on 21.01.2021 from enriched ^{203}Tl electroplated target (97%) irradiated with 28 MeV proton of 57 µAh integrated beam current (Nuclear reaction ^{203}Tl(p,3n) ^{201}Pb (decays in 34 hour) ^{201}Tl. At first chemical separation of ^{201}Pb from ^{203}Tl was done within one hour after end of bombardment (EOB). Then after 34 hours of decay of ^{201}Pb to ^{201}Tl, second and the final separation was carried out and formulation of [^{201}Tl] Thallous chloride radiopharmaceutical was prepared. It is a first-time production in India. The ^{201}Tl chloride was evaluated by performing physicochemical tests such as Radionuclidic purity (RNP) and Radiochemical purity (RCP) determination. The R.N. Purity of ^{201}Tl-chloride was found to be >99%. The R.C. Purity of ^{201}TlCl was 100%.

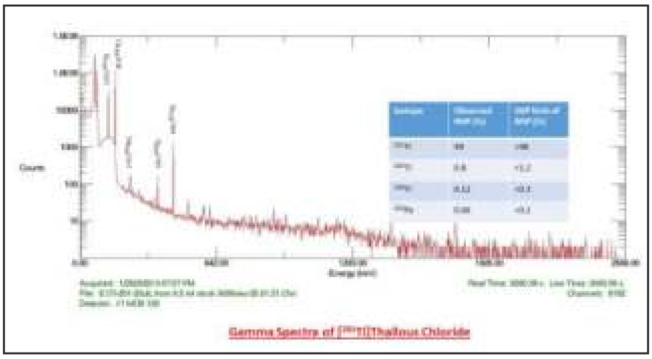


Fig. 32: Gamma Spectrum of [^{201}Tl] Thallous Chloride

(h) Development of radioactive waste management system (LIQUID WASTE) at MCF, Kolkata

Solid Waste, liquid waste from radioactive and biological sinks from laboratories and emergency showers will be collected in the waste room located in the basement of the facility. This room is under access control and entry is restricted. After survey of the area by Health Physics Unit, entry will be permitted under close supervision. Radioactive and nonradioactive wastes, received from controlled areas, are collected into tanks located in the underground level of the building. Secure storage of the liquid waste in tanks allows the radioactivity to decay down to a level where the waste will then be legally discharged into the sewerage. Liquid wastes are classified as High Activity Liquid Waste (HALW) and Low Activity Liquid Waste (LALW). All the liquid waste is collected at waste room. LALW from all the areas (generated during washing of the glassware, tools, instruments etc. used in radioactive laboratory, from emergency showers, accidental release of water in vault areas, bathing of personnel in decontamination room, etc.) will be collected in 6 HDPE tanks of 500 litre capacity, each connected to each other and located in two layers [One layer kept as reserve (Fig..33)]. Once the liquid level in the tanks reaches 80% of the capacity, the pump installed in the waste room will discharge the liquid to dilution tank. The pump will be activated through liquid level sensor (Fig. 34). Provision of level monitoring and discharge from the control panel is made available. Discharge at regular interval is done after monitoring the activity level. LALW waste will run in auto-mode and discharge the water when tank is full. All the tanks have an overflow point clearing the high-level sensor point of the tank. In case the sensor malfunctions, the liquid will overflow to the pump located at waste room. This pump will also collect liquid from spill over, maintenance and cleaning of the room.

Fig. 33: LALW transfer System

Fig. 34: LALW storage tanks with level sensor

HALW generated from SPECT hot cells (less than 30ml per day) will be collected in HALW tank. Three HDPE tanks of 25 litre capacity each for inorganic (acid), inorganic (alkalis) and organic wastes are installed for this (Fig. 35). After decay of the radioactivity decay to an acceptable level, liquid will be transferred to LALW waste tank in manual mode, via remote controlled solenoid valve from control panel. The entire operation would be carried out from the control panel (Fig. 36). Discharge is required once in a year after checking of sample by Health Physics. High level threshold of HALW will be displayed at the control panel. Dilution tank is located outside the building. Liquid from dilution tank will be discharged to municipal sewerage through a pump. This pump will be activated through a radioactivity level sensor, which has been already installed and commissioned. If the activity level is above the permissible limit, the pump will not operate. Commissioning of both, LALW and HALW (Fig. 34 & Fig. 35), have been completed as per design with level sensors.

Fig. 35: High Activity Liquid [Inorganic (acidic & basic) & amp; Organic] Waste Storage system

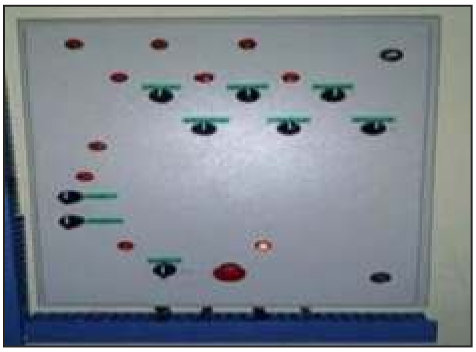


Fig. 36: Control Panel for Low Activity Liquid and High Activity Liquid waste discharge

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

In-house Design, Fabrication and Development of Prototype Vehicle tracking systems that includes portable Vehicle tracking units as well as receiving Base station tracking server. This system enables BRIT to track Class-I radioactive sources as per IAEA and AERB guidelines for tracking of Radioactive source assets. The units may also be used to track expensive BRIT and bulkier products and equipment's/machineries if required, like Gamma Chambers, Blood Irradiator etc.

Fig. 1: Portable Vehicle Tracking unit measuring

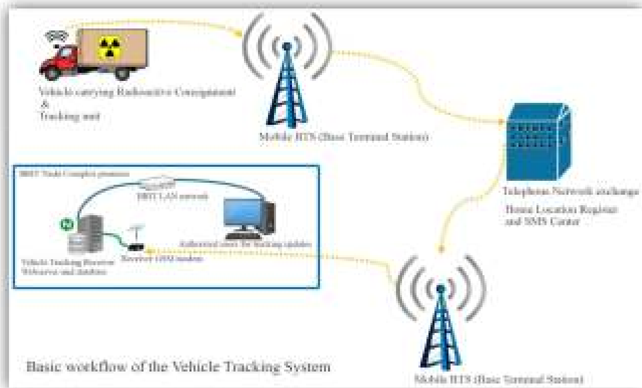


Fig. 2: Scheme of Tracking system service.

D. RCR, Kota (RAPPCOF)

(I) Development and Commissioning of Laundry Monitor at RAPPCOF

Protective clothes and PPEs are used by employees at RAPPCOF during normal operation and maintenance work. The processing of ^{60}Co and sealed source fabrications work carried out at RAPPCOF have increased many folds. Hence, the use of protective clothing also has increased substantially. These protective clothes are washable and reusable. But the clothes need to be checked for the level of radioactive contamination, before sending them for washing, to avoid contamination spread. Highly contaminated clothes need to be disposed off, so as to prevent cross contamination of protective clothing and laundry facility. Segregation of clothes using Teletector was the method adopted, which is time consuming and requires skilled human manpower. The requirement of a laundry monitor was an inevitable demand at the facility since last few years and hence a laundry Monitor consisting of six numbers of Scintillation Detectors was developed from an obsolete Beta Gamma Hand and Foot contamination monitor in the facility.

The Scintillation detector probe was made light proof, electronics circuit was modified and mechanical jobs were done as per the requirement of laundry monitor. The table top structure was fabricated in-house and six numbers of scintillation detectors were installed in it. A wire mesh cover was provided on the table top for protection of scintillation detectors and a frisker was also mounted on the side for frisking of tools. The existing electronics was modified and wiring of detectors was replaced to suit requirements of laundry monitor and to improve reliability of the monitor. After some iterations and modifications, laundry monitor was made ready. The background, alarm level settings and testing the monitor with check sources was carried out successfully. The laundry was checked using this laundry monitor and verified with old method using teletector and survey meter, results were well within the acceptable range.

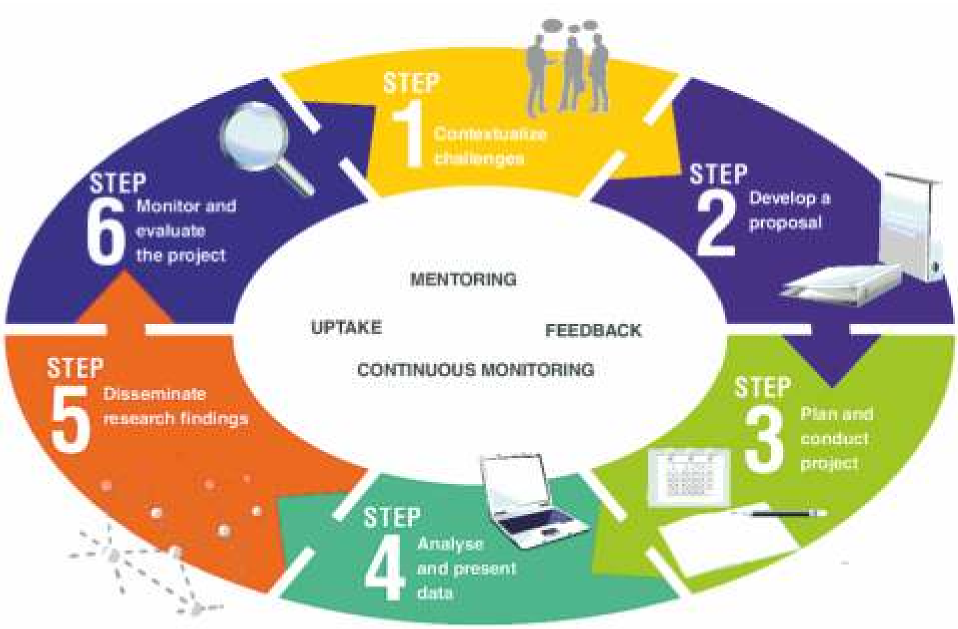
This in-house developed laundry monitor was commissioned and is in use at RAPPCOF, since September 2020. The experience gained while developing laundry monitor was further used for repair and maintenance of scintillation-based hand and foot contamination monitor.

Laundry Monitor developed from a scintillation based Beta Gamma Contamination Monitor at RAPPCOF

Fig. 1: In-house developed Laundry Monitor at RAPPCOF

CHAPTER 3

HUMAN RESOURCES DEVELOPMENT ACTIVITIES



Training Courses/ Lectures/ Workshops/ Seminars/Conferences

1. One M.Sc. student of Nuclear Medicine Technology, BBA University, Lucknow, successfully completed his research project internship under Smt. Teena Goel, OIC, RC, Delhi.

2. Smt. Teena Goel, OIC, RC, Delhi, in collaboration with Shri Aseem Bhatnagar, INMAS, has written a Chapter on "Understanding Nuclear and Radiological Threats“ and (Late) Shri. Hukum Singh, RC, Delhi, has written another Chapter on 'Diagnostic and Forensic Tools in Nuclear and Radiological Attack', which got Published for "Medical Management“ Course, conducted by IGNOU, Delhi.

3. Regional Centre, Delhi, BRIT, has been involved as board members in the preparation of inputs for establishing "Radiation Emergency Medical Centre (REMC)“ for Indian Navy, through INMAS, Delhi.

4. Dr (Smt) Jain Reji George was involved as the Co-ordinator and Convener of CAT-I and CAT-II Training course, conducted by BRIT for the first-time, which started since January, 2021 onwards. The Course structure is planned for 2 years duration and being executed as per the schedule. Lectures were given on 'Nuclear Science & its applications' by Smt. Raksha Rajput and Smt. Jyoti of Medical Physics Section, BRIT.

5. **Shri Abhishek Kumar Sharma, Manager, FMP, was awarded PhD degree in Chemistry by Homi Bhabha National University (HBNI) in 2020. The title of the thesis was, "Radiochemical Separation and Purification of Molybdenum-99 for Medical and industrial Applications". This work was completed under the guidance of Dr. B.S. Tomar, Chair Professor, HBNI, and Ex-Director, Radiochemistry & Isotope Group, BARC.**

6. Officers of RC, Kota (RAPPCOF) were involved in Training and Awareness lectures for various Training Programmes conducted by "Nuclear Training Centre (NTC) of Nuclear Power Corporation of India Ltd. (NPCIL), Rawatbhata, Rajasthan Site. These lectures were regarding the commercial production of high intensity ^{60}Co sealed sources, their applications and the role of Board of Radiation & Isotope Technology (BRIT) for the various uses of Atomic Energy for societal benefits.

7. Two students of M.Sc and M. Tech (Biotechnology) successfully completed their research project work at Microbiology Laboratory, RPP.

8. Officers of RPP laboratory, Vashi, conducted internal quality audits for Quality Management Systems (QMS/FSMS/MDQMS) of RPP Facility which included recertification of medical devices to obtain Quality Management System (MDQMS), ISO 13485:2016 Certification.

9. Dr. Sankha Chattopadhyay, OIC, RC, BRIT, Kolkata, had delivered a lecture titled, "Medical Cyclotron: An Overview“ at the Online Faculty Develiopment Programme on "Quest Abound with Radiation Around: A Webinar on Cross Disciplinary Endeavours in Radiation Science“, Organized by Department of Physics, Central University of Jharkhand, Cheri-Manatu, Ranchi, Jharkhand, India, during December 2020.

10. Initiative was taken by Dr. (Smt) Tarveen Karir, Sr. Manager, SIR&P, for organizing Scientific and Technical lectures from various Sections/Divisions of BRIT, under "Continuous Education Programme (CEP)“. Guest lectures from different Divisions of DAE may also be arranged. The lectures were arranged (monthly once) since January 2020, with the approval of Chief Executve, BRIT. Physical gatherings were dissuaded due to the COVID-19 pandemic, and hence, post-lockdown 'virtual lectures' were scheduled, with the support of IT Section of BRIT. These lectures have proved to be a treasure trove of knowledge pertaining to the activities carried out by BRIT, and have immensely benefitted BRIT employees.

11. Radiation Technology Division (RTD), BRIT, has launched the indigenously developed Co-60 based Industrial Radiography Device, "COCAM-120“ for the NDT industry. **This was inaugurated by Director, BARC, and the first unit of COCAM-120 was handed over to Head, CDM, BARC by Director, BARC.**

Publications in Peer Reviewed Journals

1. **Development of ^{99}Mo-alfa-benzoin oxime complex as industrial radiotracer for identification of leaky heat exchanger and its validation with ^{99m}Tc**

   Abhishek K. Sharma, Gaurav Agrahari, C. B. Tiwari, B. S. Tomar & V. N. Yelgaonkar

   Journal of Radioanalytical and Nuclear Chemistry 323 (2020) 143 – 149.

2. **Monte Carlo estimation of radiation fields and radio activations in the ^{64}Ni solid target irradiation for ^{64}Cu production and its validation with experimental findings.**

   K. Kushwaha, K. Biju, A. Shanbag, S. C. Sharma, J. Haider, Sharmila Banerjee

   Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 479 (2020) 180-186.

3. **Clinical efficacy of Sodium (^{99m}Tc) Pertechnetate from low-specific activity ^{99}Mo/^{99m}Tc Autosolex Generator in hospital radiopharmacy centre.**

   Arpit Mitra, Sankha Chattopadhyay, Ashok Chandak, Sangita Lad, Luna Barua, Anirban De, Umesh Kumar, Rajesh Chinagandham, Trupti Upadhyay, Kamaldeep Koundal, Sharmila Banerjee, Ramakrishna Rajan

   Nucl. Med. Rev. 23/1 (2020) 1-14.

4. **Lopinavir loaded spray dried liposomes with penetration enhancers for cytotoxic activity.**

   Mithun Maniyar, Ashok Chandak, Chandrakant Kokare

   Infec. Dis-Drug Targets 20/5 (2020) 724-736.

5. **One decade of 'Bench-to-Bedside' peptide receptor radionuclide therapy with indigenous [^{177}Lu] Lu-DOTA-TATE obtained through 'Direct' neutron activation route: lessons learnt through including practice evolution in an Indian setting.**

   Sandip Basu, Sudipta Chakraborty, Ramesh V. Asopa, G. Sonawane, S. Nabar, Hemant Shimpi, Ashok Chandak, Vimalnath K.V., Sharmila Banerjee

   Am. J. Nucl. Med. & Mol. Imaging 10/4 (2020) 178-211.

6. **Technetium labelled doxorubicin loaded silk fibroin nanoparticles: Optimization, Characterization and *in-vitro* Evaluation.**

   Vikas Pandey, Tanweer Haider, Ashok Chandak, Avik Chakraborty, Sharmila Banerjee, Vandana Soni

   Journal of Drug Del Sci. Tech. 56 A (2020) 1773-2247.

7. **Development of ^{99m}Tc labelled ultrafine gold bioconjugates for targeted imaging of folate receptor positive cancers.**

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

   Nuclear Medicine & Biology 93 (2021) 1-10.

8. **Development of radioimmunoassay for estimation of C-peptide in human serum.**

   Rajan Radha Rasmi, V.B. Kadwad, Jayula Sarnaik, K. Bhaskar Shenoy, H.M. Somashekarappa

   Journal of Radioanalytical and Nuclear Chemistry 327(2021) 923 – 928

9. **Development of two-step radioimmunoassay (RIA) for the measurement of free trioiodothyronine in human serum based on antibody coated tubes.**

   Rani Gnanasekar, Jayula Sarnaik, N.C. Joseph, V.B. Kadwad, Anupam Mathur

   Journal of Radioanalytical and Nuclear Chemistry 329/1(2021) 71 – 76.

10. **Revision of discharge limit of gross beta activity to the aquatic environment based on public dose estimation: An operational study.**

    Hukum Singh, Teena Goel, Vijay B. Kadwad, Pradip Mukherjee

    Radiation Protection & Environment 44 (2021) 42-46.

11. **Multifunctional core-shell glyconanoparticles for Galectin-3-targeted, trigger-responsive combination chemotherapy.**

    Biji Balakrishnan, Suresh Subramanian, Madhava B. Mallia, Krishnamohan Repaka, Shahdeep Kaur, Rajeet Chandan, Prateek Bhardwaj, Ashutosh Dash, Rinti Banerjee

    Biomacromolecules 21/7 (2020) 2645-2660.

Conference Proceedings and Abstract Publication

1. **Production and supply of high dose ^{131}I-NaI Therapeutic Capsules: Intricate technological aspects.**

   Pooja Kale, Navin Sakhare, Anand Gaurav, Sariah Sundilla, Anupam Mathur, Usha Pandey

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 44.

2. **An improved ^{99m}Tc-TRODAT kit formulation suitable for regular production and supply.**

   Dheeraj Kumar, Soumen Das, Anupam Mathur, Usha Pandey, Archana Mukherjee

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 50.

3. **Bio-evaluation of ^{68}Ga-DOTATATE formulation for *in-vivo* diagnosis of Neuroendocrine tumours (NET): Board of Radiation & Isotope Technology, India Perspective.**

   Krishna Mohan, Anupam Mathur

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 78.

4. **A novel ^{99m}Tc-labelled folic acid derivative exhibiting *in-vivo* affinity towards folate receptors.**

   Soumen Das, Navin Sakhare, Dheeraj Kumar, Anupam Mathur, Shubhangi Mirapurkar, Sheela M., Pradip Chaudhari

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 101.

5. **Real time stability studies on the shelf-life of kit for the preparation of ^{99m}Tc-Sulphur Colloid injection.**

   Uma Sheri Kumar, R. Krishna Mohan, Archana S.G., Vijay B. Kadwad, A.C. Dey

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 47.

6. **Large scale production of ^{68}Ga from solid ^{68}Zn target in Cyclone-30 and preparation of $^{68}GaCl_3$, ^{68}Ga-PSMA & ^{68}Ga-DOTA-TATE.**

   Shayantani Ash, Sankha Chattopadhyay, Sujata Saha Das, Luna Barua, Umesh Kumar, Asit Kumar Pal, D.G. Mahesh, Arup Kumar Hudait, Sumita Chattopadhyay, Md. Nayer Alam, R. Pal, A. Mitra, D. Ghosh, M. Ghorul, S. Pathak, U. Pada, S. Roy, A.De, P. Dhang, A. Mandal, S. Kumar

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 36.

7. **Preparation, stability evaluation and *in-vivo* biodistribution study of ^{99m}Tc-MAA for gastric emptying time and compare with ^{99m}Tc-Sulphur Colloid.**

   Ashok Chandak, Sutapa Rakshit, Yogita Pawar, Mukti Kanta Ray, Sharmila Banerjee

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 24.

8. ***In-vitro* evaluation of copper transporter CTR and ATP-7 for predicting efficacy of $^{64}CuCl_2$ in Cancer Therapeutics.**

   Megha Tawate, K. Kushwaha, A. Chakraborty, S. Rakshit, A. Mitra, S. Lad, S. Tervankar, A. Damle, S. Kulkarni, S. Banerjee

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 92.

9. **Preparation of pharmaceutical grade Na[^{18}F]F injection, a bone imaging radiopharmaceutical using modified integrated fluidic processor in IBA Synthera module.**

   Sujata Saha Das, Sankha. Chattopadhyay, Umesh Kumar, Shayantani Ash, Asit Kumar Pal, Arpit Mitra, Luna Barua, Arup Kumar Hudait, D.G. Mahesh, Sumita Chattopadhyay, Ad. Nayer Alam, R. Pal, P. Dhang, A. De

   Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 46.

10. **Comparison of ^{68}Ga Prostate Specific Membrane Antigen-11 (PSMA-11) PET/CT with multiparametric MRI (mp-MRI) for the staging of Prostate Cancer.**

    Priyanka Verma, Brijesh K. Soni, Sunita Sonawane, Ashok Chandak, R.V. Asopa

    Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 9.

11. **Production of Clinical Grade $^{64}CuCl_2$ in 16.5MeV Medical Cyclotron using indigenously developed solid target assembly.**

    Kanchan Kushwaha, A. Chakraborty, M. Tawate, S. Rakshit, A. Mitra, S. Lad, R. Bhoite, S. Banerjee

    Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 87.

12. **Cost-effective & rapid Gel-clot BET assay for PET and SPECT radiopharmaceuticals hospital radiopharmacy.**

    Sangita Lad, Arpit Mitra, Savita Kulkarni

    Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 57.

13. **Polyethylene Glycol mediated Gel-clot BET assay for radiopharmaceuticals containing colloid & macroaggregates.**

    Sangita Lad, Arpit Mitra, Savita Kulkarni

    Book of Abstracts of 52nd Annual Conference of Society of Nuclear Medicine, India, (Virtual) Abstract # 58.

14. **A comprehensive analysis of cetuximab polymeric nanocomplexes with potent radionuclide to combat metastatic liver cancer.**

    R. Poojari, B. Mohanty, V. Kadwad, D. Suryawanshi, P. Chaudhari, B. Khadke, R. Srivastava, S. Gupta, D. Panda

    Eur. J. Nucl. Med. 138 (2020) S123.

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

Printed by
M/S Sundaram Art Printing Press
Wadala, Mumbai