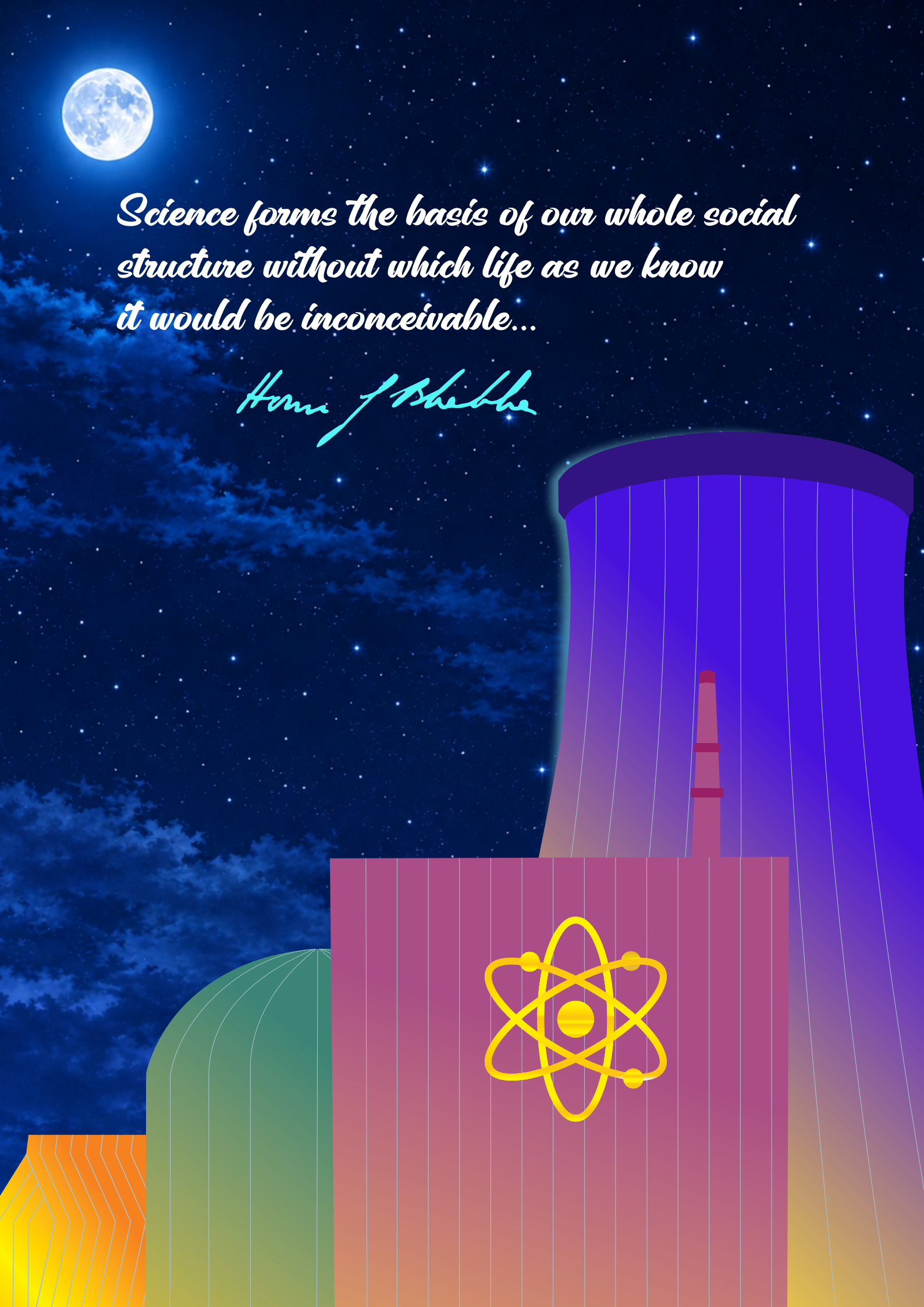

Science forms the basis of our whole social
structure without which life as we know
it would be inconceivable...

BASIC Sciences

Expanding Frontiers in Fundamental Research

आधारभूत विज्ञान: मौलिक अनुसंधान के विस्तृत क्षितिज

Radiation-Induced Mutation Breeding: BARC has developed 17 improved Trombay Groundnut (TG) varieties through radiation-induced mutation breeding, contributing to groundnut improvement, seed dissemination and agricultural production across India. Initiated in 1957, the programme generated genetic variations for desirable agronomic and economic traits, leading to the release of varieties for commercial cultivation in different agro-ecological regions of the country.

The programme began with X-ray treatment of seeds of the groundnut cultivar Spanish Improved, followed by the use of gamma rays. Repeated cycles of mutation, selection and evaluation generated diverse plant types with desirable characteristics. These mutants were used both for direct selection and as parents in recombination breeding, in collaboration with the ICAR and State Agricultural Universities.

TG-1, the first induced mutant variety developed by BARC, was released in 1973. Subsequently, 16 additional TG varieties were developed and released. Their traits include early maturity, moisture-stress tolerance, compact plant architecture, fresh-seed dormancy and large seeds. These characteristics support cultivation under





▲ *Dispatch of breeder seed of Trombay (TG) variety groundnut.*

▶ *A farmer from interior Maharshtra region proudly holds a bunch of freshly harvested Trombay (TG-88) variety groundnut pods.*

different growing conditions, while selected varieties are suitable for confectionery, export and oil-quality requirements.

The varieties have also contributed significantly to national groundnut breeding. Ten TG varieties served as national, zonal or local check varieties in ICAR-All India Coordinated Groundnut Research Project trials since 1997. TAG 24 served as a check variety for 30 years, while TG 26 and TG 37A have each served for 22 years. Their continued use reflects their role as benchmarks for evaluating newly developed groundnut breeding lines.

Beyond their direct cultivation, TG varieties have served as valuable genetic resources. Twenty-one TG varieties and lines have been used as parents by 20 research stations associated with SAUs, contributing to the development of 128 superior breeding lines. Another 15 groundnut varieties have been released through breeding programmes that used TG lines as parents. TAG 24 has been the most preferred TG parent for developing new lines and varieties.

BARC has also supported large-scale seed dissemination. During 2004-2026, it supplied 8,362 quintals of breeder seed from 13 TG varieties to seed agencies and agricultural institutions across 20 states. Gujarat, Odisha and Maharashtra, alongside the National Seeds Corporation and other public and private organisations were the major recipients. TG 37A accounted for 31% of the supplied seed, followed by TAG 24 at 16%, TPG 41 at 15% and TG 51 at 12%.

Based on breeder-seed supply and estimated seed multiplication, BARC's contribution is projected to support an average annual cultivation area of 24,239 hectares and production of approximately 360,319 quintals of groundnut. At the stated market price of Rs. 6,942 per quintal, this production represents an estimated annual value of around Rs. 250 crore.

Additionally, ICAR institutes and SAUs supplied 31,641 quintals of TG breeder seed during the same period. The resulting seed multiplication is estimated to support a further 90,000 hectares and annual production of approximately 13,83,300 quintals, valued at around Rs. 960 crore.



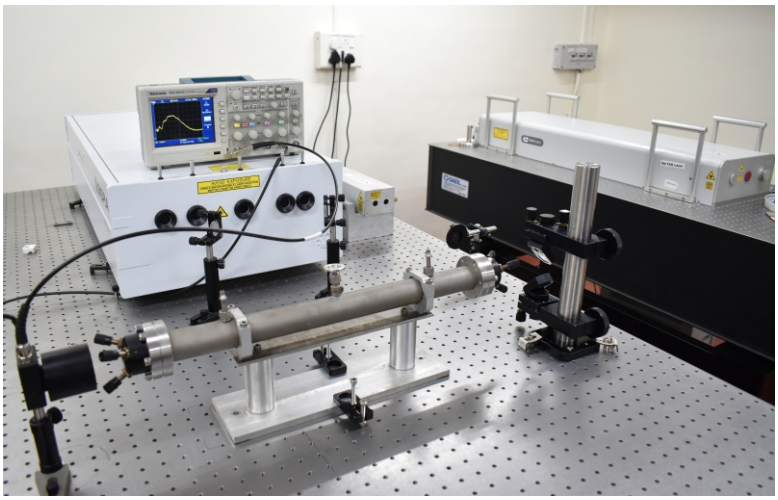
Fumigation-free preservation protocol developed in BARC implemented at a makhana (fox nuts) processing facility near Patna, Bihar.

The programme demonstrates the progression of radiation-induced genetic variation into released varieties, breeding resources, seed distribution and estimated agricultural production, with groundnut farmers across India among its beneficiaries.

Trade of Chemical-Free Makhana Using Radiation Technology: A radiation-based protocol for fumigation-free preservation of makhana (fox nuts) was developed in BARC. The technology was implemented at the recently commissioned food irradiation facility near Patna in Bihar, established by the Government of Bihar and operated under an operations and maintenance (O&M) arrangement. On 8 August 2026, an 18-tonne consignment of irradiated makhana was exported from Bihar to Australia by sea in seven containers. This achievement demonstrates the potential of radiation technology as an alternative to conventional chemical fumigation, supporting phytosanitary compliance, international market access, value addition, and agricultural trade.

Mushroom Preservation Technology: The technology of shelf-life extension of mushroom by combining gamma irradiation with complementary treatment was developed in BARC. The technology know-how was transferred to the industry partner M/s. Jitban Supply Chain Pvt. Ltd. A commercial-scale trial involving approximately 1.5 tonnes of mushrooms resulted in successful export to Thimphu, Bhutan. The mushrooms retained good quality for up to 21 days under chilled storage and received positive consumer responses. Interest in larger-volume procurement highlights the technology's commercial potential for reducing post-harvest losses, extending distribution networks, and facilitating the international marketing of fresh mushrooms.

Enriched Lutetium-176 & Nickel-62 using an in-house Electromagnetic Isotope Separator: BARC has developed an Electromagnetic Isotope Separator through in-house efforts and successfully produced Lutetium-176 and Nickel-62 with



Laser Cavity Ring-Down set-up for measurement of reflectivity of high reflection mirrors.

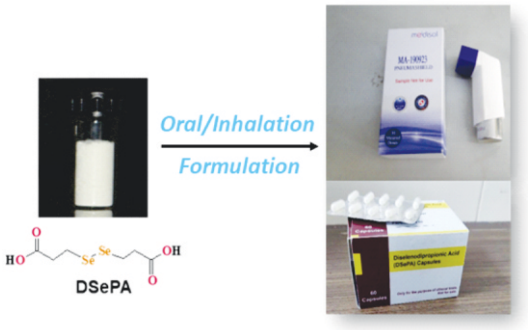
enrichment exceeding 99.5%. Lutetium-176 is an important precursor for producing Lutetium-177, widely used in targeted radionuclide therapy. Highly enriched Nickel-62 is required to produce Nickel-63, a long-lived beta emitter used in nuclear batteries, gas chromatography electron-capture detectors, and ion mobility spectrometers. The EMIS comprises a high-current metal-vapour/sputter ion source, beam extraction and transport optics, a 90° sector electromagnet, and dedicated collectors. The system can produce approximately 1 mg of enriched Nickel-62 every two days, strengthening domestic capabilities in isotope production.

Proton Beamline at the Medical Cyclotron Facility in Kolkata: A new 30 MeV proton beamline has been installed at the Medical Cyclotron Facility, Kolkata, to support Accelerator Driven System research, target-window development, and fast-neutron spectrometry. The beamline includes horizontal transport optics, diagnostic and control systems, and a 90° bending magnet directing the beam to a shielded target cave eight metres underground. Its EPICS-based control system enables remote operation and monitoring. The facility is designed for proton currents up to 350 μA to irradiate target materials, generate fast neutrons and gamma rays, and produce radioisotopes for physics studies and computational-code validation. A semi-automated irradiation module supports beam qualification, neutron-yield measurements, and safe handling of irradiated targets. A key milestone has been achieved by transporting a 30 MeV, 10 μA proton beam to the beam dump, with a beam spot size of 35-55 mm at the target location.

Laser Cavity Ring-Down Facility for High-Reflectivity Mirrors: A Cavity Ring-Down (CRD) facility was setup in BARC to measure the reflectivity of high-reflectivity optical mirrors at 1064 nm, including mirrors relevant to Laser Interferometer Gravitational-Wave Observatory (LIGO) applications. The technique measures the exponential decay of laser light trapped between two mirrors to determine reflectivity with high precision. The facility was validated using a commercial reference mirror. An indigenously developed 33-layer Ta_2O_5/SiO_2 multilayer mirror



Horizontal section of the ADS beamline at Medical Cyclotron Facility, Kolkata.



Prototype formulations of DsePA.

demonstrated a reflectivity of 99.930 ± 0.002% at 1064 nm. This capability supports the development of advanced optical thin-film coatings for high-performance mirrors.

Indigenous Technology for Large Single-Crystal Growth: The technology for growing Germanium and Silicon single crystals up to 50 mm in diameter and 150 mm in length using the Czochralski technique was developed in BARC. The development includes hot-zone and system design, along with optimization of material-specific crystal-growth parameters. These semiconductors are essential for microelectronics and radiation detectors. To facilitate technology transfer and commercialization, an incubation agreement was signed in March 2025 between Rana Semiconductor Pvt. Ltd. and the Atal Incubation Centre, Anushakti Nagar, under the Atal Innovation Mission. This initiative advances indigenous semiconductor technology under the Atmanirbhar Bharat vision.

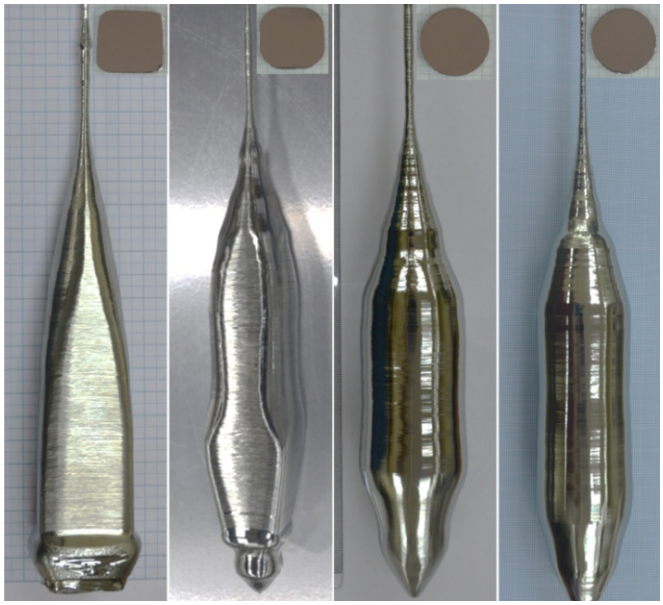
Condensed Matter Research Using Neutrons and Synchrotron Radiation: Advanced materials were extensively investigated in BARC using neutrons at Dhruva and synchrotron radiation at Indus-2. Research covers quantum materials, including topological insulators and low-dimensional magnets; functional materials, such as battery materials, molecular magnets, and thermoelectrics; and soft matter, including polymer membranes, hydrogels, and biomaterials. These studies establish structure–function relationships and support materials development. Both national facilities also serve researchers from universities, IITs, national laboratories, and industry across India, strengthening collaborative research and scientific capacity.

Clinical Translation of DSePA (Organo-selenium) as a Radiotherapy Adjuvant: Radiation pneumonitis (RP), a serious complication of thoracic radiotherapy, compromises treatment intensity and the therapeutic ratio, resulting in poorer clinical outcomes. Steroids are the current standard of care for RP; however, prolonged administration can cause associated complications, necessitating the development of specific therapeutic agents.

Systematic chemico-biological evaluation of organoselenium compounds at Chemistry Group (CG), BARC, has identified 3,3'-diselenodipropionic acid (DSePA) as a potent candidate, with efficacy against RP validated in cellular and murine models. For clinical translation, prototype oral and inhalation formulations have been indigenously developed using FDA-approved excipients. Bioequivalence studies in murine models confirmed DSePA absorption in lung tissue within the desired concentration range.

An intellectual property rights proposal covering DSePA formulations, methods of use, and associated devices was filed in India (TEMP/E-1/123701/2025-MUM, dated 14-Nov-2025). Detailed toxicity studies were completed in rodent models at a GLP-compliant laboratory in accordance with CDSCO guidelines. Licences for manufacturing GMP-grade DSePA and its formulation were subsequently secured from CDSCO (SW/IND/CT-15/2025/000002072, dated 31-Dec-2025; FDA/MFG/SR-2072/2025-2026, dated 04-Apr-2026).

The Institutional Human Ethics Committee of Tata Memorial Centre and CDSCO reviewed the investigational new drug (IND) dossier for DSePA as a radiotherapy adjuvant and granted in-principle approval for a Phase I single-ascending-dose (SAD) trial, subject to minor protocol amendments and completion of GMP manufacturing



Germanium single crystal growth.



Curcumin loaded Pickering emulsion

Prototype formulation

Development of curcumin formulation for higher cellular uptake.

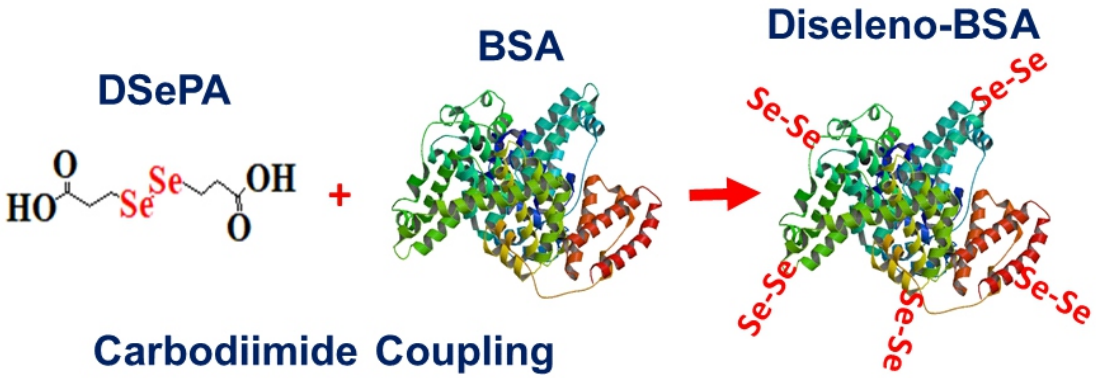
(OIEC/4346/2026/00001, dated 10-Feb-2026). GMP manufacturing of DSePA and its tablet formulation is currently underway. The GMP batches will be used for the Phase I safety study in humans at TMC.

Protein-Based Oral Curcumin Formulations for Improved Cellular Uptake: Curcumin, the active ingredient of turmeric (_Curcuma longa_), has recognized health benefits, but its therapeutic use is limited by poor aqueous solubility, chemical stability, and cellular uptake. An in-house methodology to prepare curcumin-loaded gels/Pickering emulsions was developed in BARC using FDA-approved proteins and lipids for oral and/or buccal delivery. The formulations significantly improved curcumin solubility and stability and enhanced cellular uptake by approximately threefold.

The methodology know-how has been transferred to an industry partner, where successful scale-up and prototype manufacturing have been completed. Administrative procedures for obtaining regulatory and commercialization licences from the competent authority, FSSAI, are currently underway.

Synthetic Selenoproteins for Healthcare Applications: Protein-based bioconjugates offer potential pharmacokinetic advantages over small molecules for therapeutic applications. Building on research at in BARC, for establishing organoselenium compounds as promising chemo-radiotherapeutic agents, an in-house method was developed to synthesize diselenide-functionalized gelatin and albumin for anti-cancer applications.

The bioconjugates demonstrated potent anticancer activity in the A549 lung cancer cellular model, retaining selenium's therapeutic potential. Mechanistic studies established that their anticancer activity involves targeting Ero1α-driven protein folding, leading to lethal endoplasmic reticulum (ER) stress and mitochondrial oxidation. Pharmacokinetic studies in mice demonstrated an approximately fourfold longer circulation half-life of selenium compared with the free diselenide. In vivo efficacy studies using xenograft tumour models are currently underway.



Design of selenium- functionalized bovine serum albumin (BSA).