Science Reporter

A CSIR Publication

September 2022 • ₹ 30/-

Council of Scientific and Industrial Research (CSIR)

Relentless 80 Years in the Service of the Nation

Special Contributions

- Dr Raghunath Anant Mashelkar, FRS
- Dr Shekhar C. Mande
- Dr Samir K. Brahmachari
- Dr Girish Sahni
- Dr T. Ramasami

Azadi Ka Amrit Mahotsav

Science Reporter
Vol. 59 No. 9 September 2022
ISSN: 2582-6492 (Online) ISSN 0036-8512 (Print)
National Institute of Science Communication and Policy Research (NIScPR)
Council of Scientific & Industrial Research (CSIR), New Delhi

CONTENTS

SPECIAL CONTRIBUTIONS

CSIR THEME DIRECTORATES

EDITORIAL

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Riding on 80 Years Legacy

Looking to the Future

HAVING worked for more than three decades in an organisation that is completing eight decades of its existence, it's a proud feeling to hear and recount stories about this great organisation. And there are stories aplenty that define the Council of Scientific and Industrial Research (CSIR), an organisation that has always been at the helm of Indian science.

There is the oft-repeated story of the 1970s when multinational companies held monopoly over the manufacture of infant baby food derived from cow milk. They refused to set up factories to produce it in India as the milk from buffaloes (consumed majorly in India) had too much fat and it was difficult to develop an easily digestible baby food from it. CSIR's Central Food Technological Research Institute (CFTRI) took up the challenge and developed baby food from buffalo milk, later widely marketed as Amulspray Instant Milk Food. This development was also instrumental in ushering in the milk revolution in the country.

Then there's the story of the 1980s, when the US refused to supply a Cray supercomputer to India because it feared India would use it for military and not research purposes. Not to be cowed down, scientists from CSIR's National Aerospace Laboratories (NAL) created Flosolver, India's first parallel computer, which went on to be used in research in fluid dynamics and aeronautics. Its success triggered other successful parallel computing projects in the country such as PARAM.

In the area of petroleum processing too, a near cartel situation was prevailing worldwide. CSIR, in association with its industrial partners, helped to break the stranglehold, having successfully developed processes that are now commercially adopted by several Indian refineries and plants.

A similar story was repeated in the case of zeolite catalysts, used in producing bulk chemicals and petrochemicals. The technology for manufacturing zeolites was a closely guarded secret of multinationals. But only until scientists from CSIR's National Chemical Laboratory decided to break the cartel. Not only did they develop the technology, the country soon achieved self-sufficiency in this field saving precious foreign exchange. The cheaper, safer, longer-lasting zeolite technology was even transferred out of India…to multinationals!

As CSIR celebrates 80 years of its existence, the CSIR fraternity hopes to be part of many more such exciting stories in the years to come. On this occasion, *Science Reporter* is proud to put together this special issue which brings to our readers an overview of the immense contributions of the Council of Scientific and Industrial Research during the past 80 years.

Science Reporter is indeed honoured and highly encouraged by a special message by Dr N. Kalaiselvi, the Director General, CSIR. We also thank all the former Director Generals of CSIR who have recounted their experiences in this issue and also offered valuable insights into the path that CSIR should tread in its quest to provide innovative S&T technologies and solutions for the country and the world.

Hasan Jawaid Khan

Science Reporter is published monthly by the National Institute of Science Communication and Policy Research (NIScPR), CSIR
Dr K S Krishnan Marg, New Delhi-110 012. NIScPR assumes no responsibility for statements and opinions advanced by the authors or for any claims made in the advertisements published in *Science Reporter*.
For Editorial Queries: Ph.: 91-011-25848702; **Email:** sr@niscpr.res.in.res.in; **Fax:** 91-011-25847062
For Sales & Subscription Related Queries: Ph.: 91-011-25841647, EPABX: 011-25846301 Extn. 289; **Email:** psmsupport@niscpr.res.in
For Advertisement Related Queries: Ph.: 91-011-25843359, EPABX: 011-25846301 Extn. 291; **Email:** psmsupport@niscpr.res.in;
Website: http://www.niscpr.res.in
Subscription: Inland: 1 yr: Rs 300/-; 2 yrs: Rs 570/-; 3 yrs: Rs 810/- Foreign: 1 yr (Air Mail): US $ 90 (Annual)

डॉ. (श्रीमती) एन. कलैसेल्वी
सचिव
वैज्ञानिक और औद्योगिक अनुसंधान विभाग तथा
महानिदेशक
Dr. (Mrs) N. Kalaiselvi
Secretary
Department of Scientific & Industrial Research and
Director General

भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
वैज्ञानिक और औद्योगिक अनुसंधान विभाग
Government of India
Ministry of Science and Technology
Council of Scientific & Industrial Research
Department of Scientific & Industrial Research

Message

Ever since its inception on 26 September 1942, the laboratories of the Council of Scientific and Industrial Research (CSIR) have planned and strategized to pursue cutting-edge research on the frontiers of science. At the same time, CSIR scientists have put in their might to provide solutions to challenges faced by India and its citizens on several occasions in the country's journey on the path of progress.

In fact, the growth of CSIR can be closely linked to the growth trajectory of the country. Over the years, new laboratories of CSIR were established to cater to sectors that had to be strengthened at certain periods in the progress cycle of the country. Today, 80 years after its foundation, CSIR is a well-knit network of 37 world-class S&T laboratories with a vast portfolio of S&T expertise and catering to a wide range of sectors.

I congratulate *Science Reporter* for bringing out this special issue focused on the activities and S&T achievements of the Council of Scientific and Industrial Research. I am sure readers will get an excellent insight into the vast range of activities of the CSIR.

While I congratulate all the CSIR fraternity for completing 80 years of glorious existence, I can assure on behalf of CSIR that the organization will continue its quest to serve the country with innovative and implementable S&T solutions for many more years to come.

N. Kalaiselvi
(N.Kalaiselvi)

September 23, 2022
New Delhi

Anusandhan Bhawan, 2, Rafi Ahmed Kidwai Marg, New Delhi-110001
Tel: 23710472, 23717053, Fax: (91-11) 23710618, E-mail: secy-dsir@gov.in; dgcsir@csir.res.in; Website: www.csir.res.in

On Realising CSIR's Amazing Potential

Dr Raghunath Anant Mashelkar, FRS
National Research Professor
Former Secretary, Department of Scientific and Industrial Research
Former Director General, Council of Scientific and Industrial Research
Former President, Indian National Science Academy, National Innovation Foundation, & Global Research Alliance

CSIR and Me

I was born on 1^{st} January 1943. I joined CSIR at its National Chemical Laboratory in Pune on 15^{th} November 1976. I took over as the Director General (DG) of CSIR on 1^{st} July 1995. I retired as DG of CSIR on 31^{st} December 2006. CSIR is the only job that I have done in India for 30 years. I am grateful to the nation for giving me the opportunity to serve CSIR. I have tried to give my best. I hope my best was good enough.

Looking back & looking forward

CSIR has great strengths. They range from its huge diversity of world class competencies to its geographical presence in almost every nook and corner of India. It draws its strength from its confidence emanating from its enviable record of accomplishments, which have been acknowledged by many. For instance, Prof. Jayant Narlikar lists top ten achievements of Indian Science and Technology in the 20^{th} century in his book *Scientific Edge*: *The Indian Scientist from Vedic to Modern Times* (Penguin, 2003). He lists CSIR transformation in the 1990s as one of the ten achievements. This is a matter of pride.

CSIR is on the march in the 21^{st} century. *CSIR Vision 2030*, launched recently, has the laudable objective of providing innovative Science and Technology solutions with the aspiration of assuming global leadership. It is an extremely inspiring document. It lays down a clear technology roadmap covering short-term, medium-term, and long-term objectives. I fully agree with the 'why' and 'what' part of it. I would like to add some thoughts on the 'how' part of it.

CSIR Vision 2030 released on the occasion of superannuation of Dr Shekhar C. Mande and joining of Dr Rajesh S. Gokhale as Director General, CSIR (Additional Charge). Also seen in the picture Dr Ashutosh Sharma, former DST Secretary

What is this essay about?

This essay is a view from my personal window, lessons learned from the book of my life. So there are frequent references to my own experience in my own journey of 30 years of CSIR, which was followed by 15 years with corporate boards and also global institutions. The essay is all about some strong fundamental principles, attributes and values that CSIR has to imbibe and enhance in order to manage the challenge of change dynamics and create a new CSIR for new India. Nuts and bolts are not discussed here.

> **"The essay is from one who loves India, adores CSIR but also from one who has given his life for both and wants them to do better to realise their true potential, which is amazingly high.**

The essay is from one who loves India, adores CSIR but also from one, who has given his life for both and wants them to do better to realise their true potential, which is amazingly high.

Creating a STIR in CSIR

What CSIR needs is speed and scale to react to a world that is changing fast not only in nature of doing science, but also in translating it. Also what CSIR needs is a fresh churn and stirring. Churning requires an energetic mixing device. Talent & Technology coupled with Trust can provide a holistic STIR framework for building the CSIR of our dreams. The elements of STIR are the following four.

1. Speed, Scale and Sustainability
2. Talent, Technology and Trust
3. Integration, Innovation & Inclusion
4. Reimagining, Rebuilding and Repositioning

SPEED, SCALE & SUSTAINABILITY

Speed

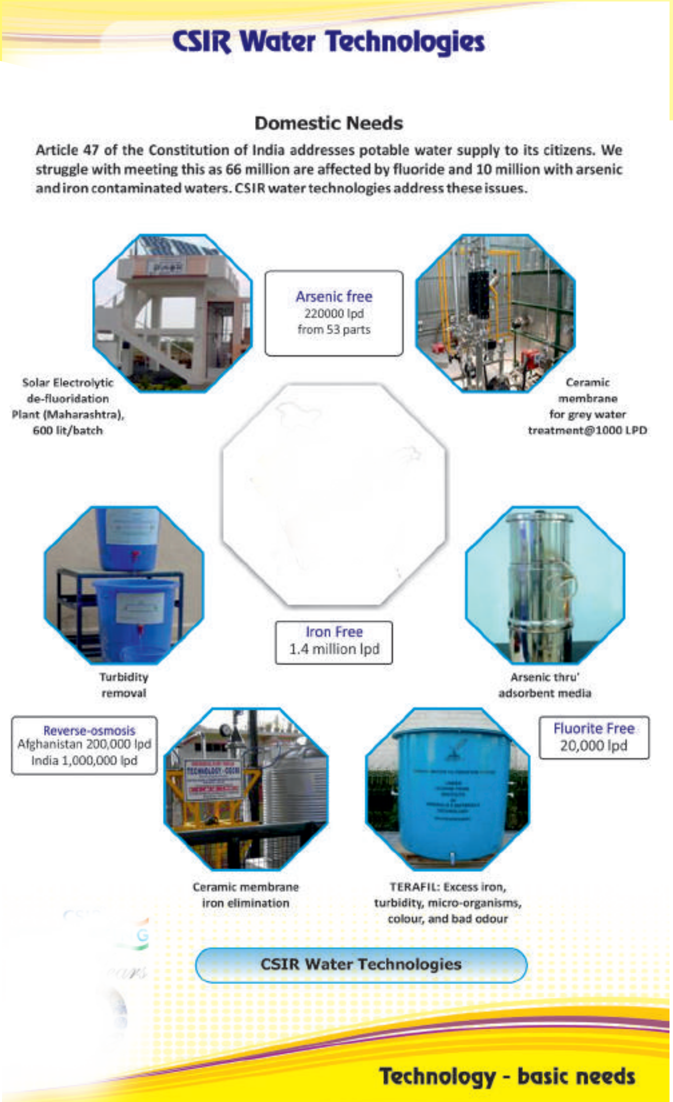
CSIR can be proud of the fact that when it comes to national crisis, it has responded with great speed. The COVID-19 pandemic is a classic example. CSIR responded speedily by reorienting the scientific manpower in providing quick solutions in various domains such as, Digital and Molecular Surveillance; Rapid and Economical Diagnostics; New Drugs & Repurposing of Drugs; Hospital Assistive Devices and PPEs; and Supply Chain and Logistics Support Systems.

And CSIR has done it consistently in the past. Whether it was providing drinking water, food or shelter during the 1999 cyclone in Orissa, or during the 2001 earthquake in Kutch, or during the 2004 Tsunami that hit us hard, CSIR has always responded rapidly.

But CSIR could do much better if it succeeds in removing bureaucracy by creating enabling, dynamic and positive hassle-free systems. The good news is that the nation's topmost leadership fully understands the challenge of bureaucracy. The sad news is that things have not changed despite this. Let me illustrate the point.

STIR

- Speed, Scale and Sustainability
- Talent, Technology and Trust
- Integration, Innovation & Inclusion
- Reimagining, Rebuilding and Repositioning



On 3rd of January every year, thousands of Indian scientists witness the inauguration of the Indian Science Congress by successive Prime Ministers of India. I have attended most of these and among these, the three that I mention below.

- In 2001, Prime Minister Atal Bihari Vajpayee said, "for Indian science to flourish, the administration and government officials should serve as facilitators of science and not as masters of scientists."
- In 2010, Prime Minister Man Mohan Singh lamented "it is unfortunately true that red tape, political interference and lack of proper recognition of good work have all contributed to a regression in Indian science."
- In 2015 Prime Minister Narendra Modi made more specific and pointed suggestions by exactly identifying the pain points while saying "funding proposals must not take too long to clear; meeting application requirement should not become more complex than research; approval process should not become a deterrent for international conferences and our scientific departments must have flexibility of funding decisions based on the uncertainties inherent in research activities."

Sincere attempts have been made to convert these good intentions into bold action. Efforts to take such actions have been thwarted in the past though. Just as an example, there was a proposal to create a different system for procurement and hiring in industry-sponsored projects in CSIR so that there would be a much faster delivery of results. It was rejected.

CSIR is not a university, or an IIT or an IISER or an R&D wing of an industry. Its unique space as a translator, facilitator and co-creator in the journey of 'ideas to impact' is not clear to many.

Let alone fast tracking, at the ground level the bureaucracy has increased over the years. Appearing to be right on paper has become more important than being right in practice. For CSIR to become globally competitive, the challenge of removing bureaucracy has to be on the top of the agenda of the government.

Scale

Reaching massive scales can make massive impact. For this, the CSIR technology must not only be ready for commercialisation but also remain sustainable over a large number of years.

How can CSIR move rapidly from TRL 1 to TRL 9? One way is to start by buying technology, which is already at TRL 3 or TRL 4 level or higher from anywhere around the world, and develop it to the commercial TRL9 level in partnership with Indian industry. This model can lead to enormous cost and time saving besides bringing competitiveness. CSIR has not done it in the past. It needs to do it now. CSIR must move up the ladder of TRL through prototyping, pilot planting, market seeding and evaluation, etc.

But as we move up the ladder at higher scales, factors of safety, effluent treatment, round-the-clock running, etc., come into play, which are difficult to attain and maintain in a research laboratory and industry is the right abode for it. We must set up these 'Innovation Translation Facilities' in partnership with industry in industry itself. Further this has to be financially supported and actively facilitated by the Government. Sector-specific clusters will be most effective. Publicly-owned but privately-managed facilities is the way forward. An interesting model that can be fine-tuned to Indian innovation ecosystem is the highly successful Catapult model (https://catapult.org.uk/wp-content/uploads/2020/12/Catapult-Network-Impact-Brochure-2020-FINAL.pdf).

Sustainability

A sustainable CSIR also means a CSIR that always remains relevant, robust and resilient, especially in a VUCA world, meaning volatile, uncertain, complex and ambiguous.

It is most important that not only CSIR understands its own distinctive identity but also the other stakeholders, like industry, government, politicians & society understand it. CSIR is not a university, or an IIT or an IISER or an R&D wing of an industry. Its unique space as a translator, facilitator and co-creator in the journey of 'ideas to impact' is not clear to many. The failed attempts to shift CSIR labs to user ministries in the past or misconstrued notions by even some well-known industry leaders that CSIR labs should be placed in industry is a result of this lack of sustained communication about the distinctive standing and big purpose of CSIR.

The Kelkar Committee was formed in 2003 to assess and evaluate the outcome of CSIR activities so far. It was formed by CSIR itself for critical self-evaluation. This report titled *Reinventing the CSIR* clearly brought out the big purpose of CSIR, which was to do public good, private good, strategic good and social good. It also created a quantitative matrix (Iyer Nagesh & Vijayalakshmi S., *Research Journal of Applied Sciences, Engineering and Technology,* 2014, 7(15), 3134–3144) to measure the benefit-to-cost ratio and showed how CSIR had always given back to the nation more than the nation invested in CSIR.

> **CSIR should undergo total digital transformation and not just attempt computerisation of some isolated parts of the system in the name of digitalisation. True transformation means a caterpillar changing into butterfly and not becoming a faster caterpillar**

Every now and then a question is asked about what CSIR has done. I suggest that every annual report of CSIR should transparently carry this information on return-on-investment by the nation in CSIR by using the Kelkar committee matrix. That will make CSIR strong and sustainable.

Consistent and resilient leadership is an essential prerequisite for sustainability. CSIR has had five acting director generals in the last 15 years, some for extended periods of time. On many occasions, one director has been put in charge of another laboratory for months together. These are completely avoidable delays in appointments.

How can CSIR remain resilient for ever? I have spelt out ten tenets of resilience in my address to the Indian Institute of Corporate Affairs in their *Power Talk Series Lecture* in 2021. These ten tenets include adaptability, agility, resilient thinking, scenario-based planning, digitalisation, platformisation, creating purpose-driven organisation, self-disruption, climate consciousness and autonomous innovation. CSIR should deep dive into each of these in-depth and prepare a strategy for 'Resilient CSIR'.

Take for instance, one of the key tenets, digitalisation. CSIR should undergo total digital transformation and not just attempt computerisation of some isolated parts of the system in the name of digitalisation. True transformation means a caterpillar changing into butterfly and not becoming a faster caterpillar.

Digital transformation should be accompanied by much needed decentralisation of powers to constituent laboratories as also democratisation across the organisation. There must be sense of empowerment and ownership with each of the family member, both scientists as also those in valuable supporting functions.

Digitization, virtualization, mobilization and personalization are the four new megatrends aided by Web3.0 and emergence of Metaverse. All these will lead to game-changing co-creative, self-organizing, self-correcting, asynchronous, dynamic and open systems that will be borderless and globally distributed. CSIR must totally reinvent itself for benefiting from this mega trend.

TALENT, TECHNOLOGY & TRUST

Talent

CSIR cannot be a global leader if it does not have globally competitive talent. Building a strong brand for CSIR is fundamentally as important as setting up processes that will acquire, nurture, continually reskill, inspire and retain that world class talent.

How can we make CSIR competitive today in terms of talent acquisition? CSIR's recruitment processes need to be much faster. There used to be a quick hire scheme for exceptional talent. It is no more there. We need new recruitment processes that bring speed, flexibility and innovation in terms of not just hiring new NextGen talent but also creating access to such talent. Dual appointments with industry and academia and within CSIR labs themselves, new models in human resource mobility within and outside CSIR are some examples of such innovation.

CSIR must endeavour to provide both psychic and physical income to the newly inducted young talent. The psychic income arises from the possibility of challenging work, from possibility of a great career progression path. But equally important is the inspiring and intellectually stimulating environment that each lab of CSIR should provide. In his inspiring Science Congress inaugural speech in 2015, Prime Minister Narendra Modi had said "We want our scientists and researchers to explore the mysteries of science, not of government procedures." Enabling scientists to fully focus on their research rather than on non-scientific and energy-sapping paperwork is critical for creating that psychic income.

Now about the physical income. When I was DG of CSIR during 1995-2006, we introduced monetary incentives for scientists. Scientists got salary from the government but their income had an additional earning based on rewards for their own distinctive contribution to productive industrial research. This incentive has run aground at the moment. It needs to be re-introduced.

The professional progress allowance has been stopped. That needs to be restored. The Lab Reserve, created from the surpluses from external earnings, gave the labs an operational freedom & flexibility. It was meant to be used for development of physical and human capital for the growth of an individual laboratory. So there was an incentive. Now it is being used for recurring expenses like staff salaries, water & electricity bills. The incentive needs to be restored in its original form.

Technology

CSIR should be the powerhouse of frontier technology for India. The limited view of developing indigenous in-house technology in the laboratories of CSIR from a scratch and then licensing it out to industry is limited to only one option. There are multidimensional possibilities of CSIR contributions to help India build its powerful technology landscape. Let me dwell comprehensively on these.

> **Building a strong brand for CSIR is fundamentally as important as setting up processes that will acquire, nurture, continually reskill, inspire and retain that world class talent.**

> **We at CSIR should fully rise to the clarion call by our Prime Minister Narendra Modi on Atmanirbhar Bharat as also his earlier call of 'Make in India'. However, 'make in India' can't be just 'assembled' in India, it has to be 'invent' in India and make in India.**

Technology Options

- Buy
- Make
- Buy to Make
- Make to Buy
- Make it Together

There are five technology options that I had identified in my C D Deshmukh memorial lecture titled *Economics of Knowledge* (*Current Science,* 77(2), July 1999, 223 – 229):

1. Buy
2. Make
3. Buy to Make
4. Make to Buy
5. Make it Together

Let's examine each one of these and see what our new CSIR can do in each one of these.

The 'Make' option: We at CSIR should fully rise to the clarion call by our Prime Minister Narendra Modi on Atmanirbhar Bharat as also his earlier call of 'Make in India'. However, 'make in India' can't be just 'assembled' in India, it has to be 'invent' in India and make in India. That means not just producing products but even producing underlying technologies that are made in India. Then only can we create Atmanirbhar Bharat with Atmavishwas.

But we must be realistic that no nation makes everything. Also, if one has to reach a high rate of economic growth, we require the most advanced technology 'here and now'. Therefore, in some cases, other alternatives have to be sought.

The 'Buy' option: 'Buying' technology through foreign technology licensing is the second option. However, some technologies are not available for love or for money. And they are not just in strategic sectors; they are also in civilian sector too. My own experience varies from witnessing denial of access to technology for acrylic acid (used in baby diapers) to alpha olefin sulfonates (used in clothes washing) to butyl rubber (used in tyre inner tubes). Further, even when licensing is done, 'buying' the core knowledge embedded in a technology or a machinery is possible, only when the owner is willing to part with it.

India is not necessarily being looked at as a bottomless pit of demand by the firms in the developed world. Technology buyers from India are being seen as potential competitors in the world market. Therefore, technology sales are invariably conditioned with marketing territory restrictions. The age of straightforward technology licensing agreements is giving way to technology-cum-market, technology-cum-stakeholding, technology-cum-product swap, etc. Technology is available to a buyer only if it fits in with the supplier's global scheme.

Again my own experience has been that when Mark III technologies have been developed by the owner, he invariably offers only Mark II and one is finally lucky to get Mark I. How do we deal with this challenge? CSIR can provide a solution.

CSIR must have an active and formal participation with the industry to help it in negotiating the acquisition of the best possible technology based on its deep domain knowledge. I remember my Guru Professor Sharma and me participating in technology selection for public sector petrochemical companies in the 80s, thanks to a visionary Shri Lovraj Kumar, who was then Secretary to Government of India. Helping industry to get the best technology has to be also counted as CSIR's contribution to technology.

The 'Buying to make better' option: Smart countries like Japan opted for the third option of 'buying to make better' route. They acquired knowledge through technology licensing (e.g. Sony buying the transistor patents from US), absorbed it and developed superior products, which competed with the best in the world. In recent years, China has taken to this option. Technology absorption strategy was interwoven (explicitly not just implicitly) by China, into its policy right at the time the foreign investor came in. So China would say, 'we only import once'. India did not do that so well through a strong policy framework. We kept on buying and buying. This needs to change.

The 'Making to buy better' option: The fourth option of 'making to buy better' means moving up the curve on technology development and positioning oneself at high enough TRL level, if not at commercial level. That positioning itself can create a doubt in the minds of the technology licenser. Cray denied high performance supercomputer technology to India but as soon as higher levels of Param series of supercomputers were unveiled, they offered the technology. After all, strength respects strength.

Deep specialized domain knowledge acquired while oneself doing indigenous technology development leads to a mastery of a technology domain and a clear ability to deep dive into technology options. It then gives one an advantage in negotiations, strategic positioning and so on. It is only then that one can negotiate for Mark III and get Mark III from a position of strength, not just Mark II or Mark I. CSIR can lead such an effort in areas that are critical for India. It has not done it so far. It should do it now.

The 'Making it together' option: The fifth option is 'making it together', when different actors and stakeholders across the nation come together to build a new technology. This involves public-private partnerships. CSIR has done well here. New Millennium Indian Technology Leadership Initiative (NMITLI) launched by CSIR in the year 2000 is an example. CSIR's successful post-COVID 19 effort would not have been possible without this 'making it together' approach. The newly launched green hydrogen mission by CSIR is a brilliant example of 'making it together'.

India must have a short, medium and long term plan on what is the dynamic mix that it will create of the five options, namely buy, make, buy to make better, make to buy better, and making it together. CSIR can help India in designing such strategic plans and then partnering in all the five options with all the stakeholders to deliver it.

Startups

India has rapidly moved from a 'starting-up' nation to the fastest growing 'start-up' nation. It set a new record of producing almost one unicorn (one billion US dollar market cap company) per week in 2021, when 42 unicorns were born that year. Contrast this with one unicorn being born every year in the pre-2019 era.

My own analysis showed that close to 50% of the unicorn start-ups have come from elite institutions like IITs and IIMs and the rest of them from tier 2 or tier 3 cities. That is very satisfying news for India, of real democratisation of innovation.

However, the proportion of deep tech start-ups is very small. The way to build a conducive innovation ecosystem for cutting-edge science-led innovation has been explained in my contribution to a SAC-PM strategy document (http://www.mashelkar.com/index.php/work/articles/item/377-science-led-innovation).

CSIR, with its huge scientific prowess, can show the way here. For instance, the Venture Centre at NCL, setup in 2006

is dedicated fully to high-science led start-ups. It won the best national incubator award at the hands of the President in the year 2015 and numerous other honours. With CSIR's amazing geographic reach across India, it can replicate such Venture Centres across the length and breadth of the country.

CSIR as a Technology Leader

CSIR needs to be a leading powerhouse of cutting-edge technology, not only creating the technology itself, but also helping India create an ecosystem through bold public private partnerships to fuel the creation of breakthrough technology. Let's illustrate this with an example.

India recently showcased the first ever invented and made in India hydrogen fuel cell bus using cutting edge technology. This was achieved thanks to a bold and unique Public Private Partnership initiative, namely New Millennium Indian Technology Leadership Initiative (NMITLI) that was launched way back in the year 2000.

NMITLI was bold and unique in many ways. First, it was about leading, and not fast following, in which India prided itself till then. Second, NMITLI took major risks in identifying and funding technologies, where success was uncertain, as these were tomorrow's technologies, and where markets were uncertain too. Third, the funding itself was innovative. The industry got a very low interest loan with very easy payback terms. Fourth, the programme focused on current grand challenges of India and disruptive innovations that could bring in radical yet sustainable transformation.

NMITLI became the largest public private partnership with around 120 plus industry partners and 200 plus public institutional partners. There were several success stories as also failures since risk taking was a built-in component of the programme.

Trust

I have often said that India's challenge is not budget deficit but trust deficit. That shows up in our daily life in various forms. But it affects many things in institutions such as CSIR, starting with recruitment itself.

I was recruited as Scientist E (Assistant Director position then) based simply on a one-hour interaction (and that's all!) that I had in London in 1974 with the then DG of CSIR, Dr Nayudamma, who came on a mission to do quick hire of exceptional talent by doing away with long bureaucratic procedures. I was then barely a 31-year-old lecturer in a university in UK. My Guru, Professor Sharma became full professor at the age of 27 in Bombay University. No ten-year experience clause for him. Both our appointments were based on trust in our potential by someone, whose judgement was trusted. And both of us justified that trust. We both became recipients of one of the highest scientific honours in the world, namely Fellow of Royal Society (FRS). In fact we are only two out of three Indian residents who have become FRS in engineering science in 360 plus years of the history of the Royal Society!

Need for trust transcends in so many areas. Take start-ups. CSIR cannot become a leader in generating start-ups without backing its talent and technology with trust. It was painful to see the kind of harassments that one of the early start-ups in the CSIR set up by a very eminent scientist had to go through because of the 'perceived' conflict of interest. Subsequently committees took years to prove that there was nothing wrong!

We have to trust industries with a reputation. We still treat industries (listed public companies) with suspicion, the way we draft agreements, mostly one sided. As soon as I had taken over as DG of CSIR in 1995, I had argued that both Public and Private sector companies act in national interest. Why is it that CSIR scientists are not allowed to be on boards of private sector companies, of course, after weighing the conflict of interest considerations carefully? Our Governing Body approved a process by which scientists in CSIR can be on the Boards of private listed companies. This had immense intangible value for our CSIR scientists, in terms of their understanding the industry's way

India's first ever indigenous hydrogen fuel cell bus developed by CSIR of strategic thinking and planning, systems and processes, risk assessment, corporate governance, etc.

This provision has gone into a limbo as one sees CSIR being increasingly averse to giving such approvals. Trust must, of course, be accompanied by accountability by those who are trusted. And those violating the trust must be dealt with exemplary punishment.

Let us remind ourselves that when there is no trust at all, paper becomes more important than people. Bureaucracy overrides meritocracy. Guidelines become rulebooks, which become more important than the objectives. Decision making time cycles become longer than the product life cycles.

In summary, for CSIR to become a world class institution, it must balance the trio of Talent, Technology and Trust.

INTEGRATION, INNOVATION & INCLUSION

Integration

Integration has multiple dimensions. The first is the integration of CSIR's purpose with the national purpose, with total alignment. What is good for India is good for CSIR. In CSIR Vision 2030, there is a powerful statement on CSIR alignment with all the national missions, etc. That augurs well.

Second is that CSIR must integrate itself with a diversity of partners – with industry ranging from large to MSMEs, academia, NGOs, start-ups, social entrepreneurs, policy think tanks and so on.

The third is the integration across disciplines. Breakthroughs in research take place at the interface of disciplines. Advances are generally the sum total of numerous creative ideas and interdisciplinary co-operation.

The fourth is the integration within and across national boundaries. Nationally, CSIR has not only created Team CSIR programmes, but also Team India programmes.

CSIR started partnering with leading corporates from around the world, NCL being a pioneer in the early 90s, with its partnership with General Electric, which inspired it to set up the Jack Welch R&D Centre in India, and then others followed. Indeed, seeds of India's emergence as a global R&D platform were sowed by CSIR (Mashelkar, R.A. & Chinchure A., *India Now Business and Economy,* 03(03) Aug-Sep 2016, 28-33).

CSIR also was a pioneer in forging global partnerships in research and innovation. A prime example was taking a leadership position in formation of a global network of CSIR-like institutions, namely Global Research Alliance (GRA), of which I was the President for a decade. In GRA, CSIR-like organisations from the Asia Pacific, Australia, South Africa, Europe and USA had come together to solve global challenges with integrated global science and technology capability for creating global good.

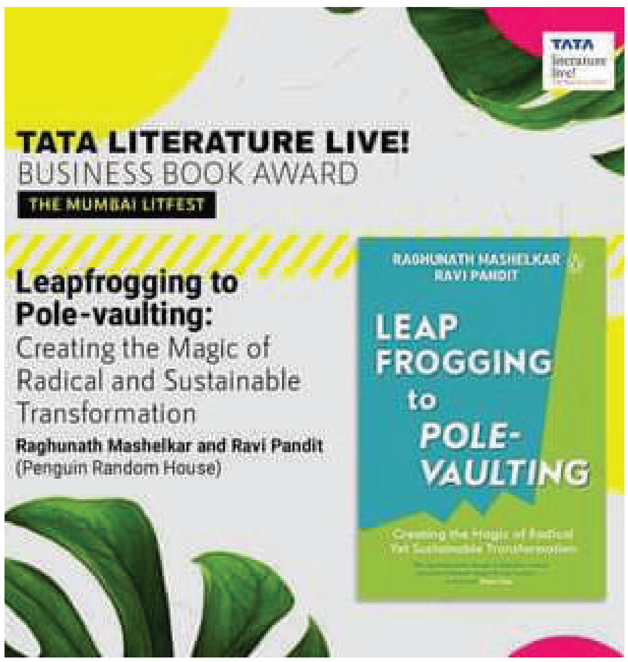
Innovation

Innovation is successful conversion of a new idea into practice. It comprises the journey from mind to market place, from ideas to impact. This journey is rather difficult and over 95% of ideas do not succeed as shown by Burnley and Steven (Greg A. Stevens & James Burley (1997), "3,000 Raw Ideas = 1 Commercial Success!", *Research-Technology Management*, 40:3, 16-27). CSIR must find a mantra to assure maximum level success in its innovation journey.

I propose a new framework, which, if used proactively, can potentially increase the chance of converting an idea into a business, and then remaining a successful business for a prolonged period. I co-authored a book *From Leapfrogging to Pole-vaulting: Creating the Magic of Radical yet Sustainable Transformation,* in 2018, which won the Tata Literature Live! Business Book Award in the same year (Penguin Random House, Gurugram).

In the book, we emphasised the shift from reactive leapfrogging to proactive pole-vaulting to create rapid, radical and yet sustainable transformation. For assuring successful innovation we proposed using the ASSURED Innovation framework. ASSURED comprises seven important attributes, namely, being Affordable, Scalable, Sustainable, Universal, Rapid, Excellent and Distinctive.

- *Affordable:* An affordable solution creates access for everyone across the economic pyramid. Affordability is achieved by not only creating an affordable product, but also implementing extremely efficient operation, production and distribution systems.
- *Scalable:* Scaling the solution to the largest number of addressable beneficiaries makes the largest impact. In-depth understanding of the market addressability is as important as identification of Blue Ocean (unexplored and vast market place for the offering with the entry barriers).
- *Sustainable:* The solutions have to be environmentally sustainable, economically feasible (with robust business and revenue models), socially acceptable and also adaptable to sudden or radical policy and regulatory



changes. Proactive planning for obsolescence of skills, capabilities and processes by being agile and nimble is important. Good governance is essential for sustainability. PESTEL analysis which focuses on Political, Economic, Social, Technological factors and also includes additional assessment of the Environmental and Legal factors that can impact a business, is fundamentally important.

- *Universal:* Universal means user-friendly, simple and maintenance-free products and services. Standardisation of design, supplies, inputs, processes, customer needs, quality of supplies and resources contribute towards universality.
- *Rapid:* The journey from mind to marketplace has to be rapid, and so is the rapid adaptability to changing market conditions (or even sudden policy or regulatory changes) after entry into the market.
- *Excellent:* The endeavour has to be to use the state-of-the-art technological or novel non-technological solutions. But, that is not enough. We need business excellence, including leadership, strategy, customer focus, information management, people and processes.
- *Distinctive:* There is no use creating 'me too' products and services. Solutions must be protected by robust intellectual property portfolio raising entry barriers for the competitors.

In the book, we have done an analysis of several technologies and businesses, which met the ASSURED criteria at one time, but failed later because they failed some part of the ASSURED criteria.

Three important points about the factors in the ASSURED framework. First, all the seven factors are dependent on each other. Better A (affordability) can lead to bigger S (scalability). Second, since the factors within ASSURED are time variant, once ASSURED does not mean always ASSURED. Third, either fully quantitative, semi quantitative or qualitative value can be attached to all the seven factors. Weightage given to each factor depends upon the type of business.

I was the chairman of the standing committee on selection of the best in class technologies for drinking water and sanitation created by the Department of Drinking Water and Sanitation during 2004-19. I am proud to say that NEERI of CSIR created an outstanding ASSURED framework, which has been institutionalised by the ministry for selection of technologies today. I have separately discussed how this framework is being used globally now for diverse applications (Mashelkar, R.A., CII STRIDE, *Journal of Technology Leadership and Innovation,* 01(01), Dec 2021, 17-24).

The productivity, efficiency and success rate of CSIR innovations can go up dramatically if CSIR uses ASSURED matrix for project selection, funding, monitoring, delivering and also keeping track of post-delivery performance in Industry. This will create a new CSIR, whose outcome will not be just the amount of license fee that it earned from industry but the continued profitability of the licensee industry.

Inclusion

India needs accelerated inclusive growth, where no Indian is left behind. Inclusive innovation can act as an inspiring accelerator. The need for this is even more urgent today. Why?

India reduced the number of poor people from 340 million in 2011 to 78 million in 2019. This number was expected to decline further to 59 million in 2020 but ended up increasing to 134 million. This represents the biggest reversal in India's fight against extreme poverty (https://ceda.ashoka.edu.in/covid-19-setback-the-strongest-reversal-in-indias-battle-against-extreme-poverty/).

CSIR has had a rich history of inclusive innovation. High quality affordable generic drugs for the whole world based on CSIR technologies, is just one powerful example. Most recent is the Aroma mission which has been a huge success. CSIR 800 was a model programme on inclusive innovation.

CSIR should be a global leader in inclusive innovation that creates the world's most affordable products and services with the highest quality. That will certainly create the magic of access equality despite income inequality and bring social harmony in the world.

REINVENTING, REPOSITIONING AND REBUILDING

The new India will need a new CSIR. And therefore, CSIR must continuously reimagine, rebuild and reposition itself so that it always remains relevant to India. We have done that regularly.

- In 1996, we had 'CSIR 2001: Vision and Strategy'.
- In 2011, we had 'CSIR@80: Vision and Strategy 2022'.
- In 2022, we had 'CSIR Vision 2030'.

Each of these has played a key role in direction setting for CSIR in the emerging context.

CSIR can rise to its true potential, if full autonomy is given to it. CSIR is registered under the Societies Registration Act 1860 as an autonomous body. It has hardly functioned, however, as a fully autonomous body. CSIR should be provided full autonomy on the pattern of the Department of Atomic Energy (DAE) and Department of Space (DoS). Using this model, a Scientific & Industrial Research Commission should be created, with an eminent scientist/technocrat becoming the Chairman of the Commission.

In times to come, CSIR has to show the way to the nation, and provide leadership.

There have been instances when CSIR has shown the way. Whether it was the first creation of buffalo milk leading to Amul baby food, the first once-a-week oral contraceptive non-steroidal pill Saheli, the first drug EMAL for resistant malaria, first institution to introduce DNA fingerprinting in India, first to create a Traditional Knowledge Digital Library (TKDL), which prevented unethical exploitation of Indian traditional knowledge, first to convert India from an industrial catalyst importing country to an exporting country. And the list goes on.

My Dream...a CSIR...

- that does research that creates new markets, not only in India but in the world.
- that creates and leads new missions just as it did in the leather technology mission.
- that does game-changing disruptive innovation to create radical yet sustainable transformation.
- that creates technologies that are first in the world.
- that creates next practices that others will follow as their best practices.
- that does not leapfrog but pole-vaults to new unimaginable heights and distances.

CSIR has not just been a leader in technology but also a thought leader, action leader, trend setter and a game changer too. The challenge has been maintaining that leadership. Let me illustrate it with just two examples.

CSIR brought patenting culture to India with the slogan of 'patent, publish and prosper'. CSIR was the top leader in the number of US patents granted to India for years together. In 2003, CSIR topped the WIPO published list of prestigious Patents Cooperation Treaty filings in Asia. CSIR was ahead of the leading South Korean companies like LG and Samsung with Huawei from China being in the fourth place. The same Huawei became the top filers of patents among all the industrial enterprises in the world in 2019. We are not amongst the top anymore.

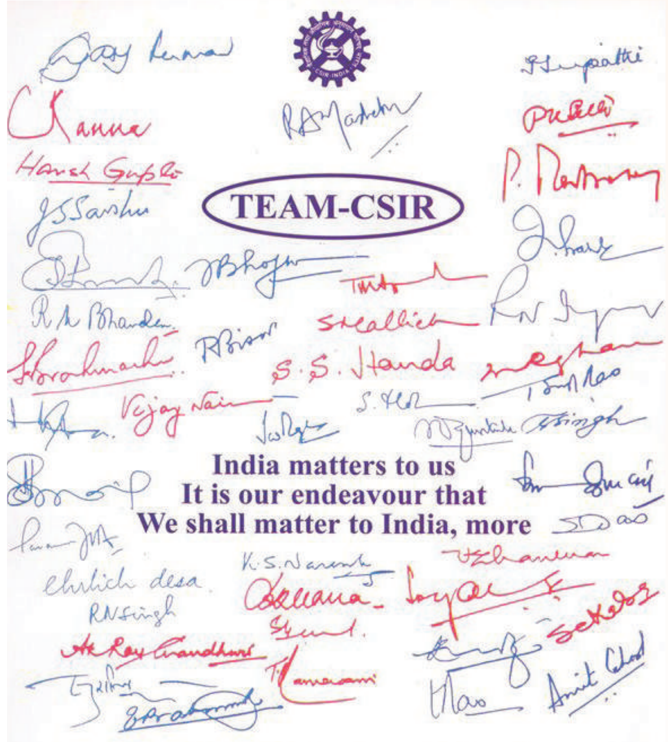
Yet another was Open Source Drug Discovery (OSDD), which was a pioneering CSIR-led team India consortium with a vision to provide affordable healthcare to the developing world by providing a global open platform. OSDD brought together the power of genomics, computational technologies and participation of young and brilliant talent from Universities and industrial partners. It had over 7900 participants from 130 countries across the world. It set waves around the world but due to several reasons it lost momentum in India.

CSIR has demonstrated its capability to lead but not consistently. The challenge is to make global leadership a way of life and not just a flash in the pan. New CSIR should have the potential to do it.

MY DREAM OF CSIR

The CSIR of my dream is one that just doesn't do market-driven research but does research that creates new markets, not only in India but in the world.

- A CSIR that just does not help the national missions but creates and leads new missions just as it did in the leather technology mission.
- A CSIR that just does not do incremental innovation but game-changing disruptive innovation that helps in creating a radical yet sustainable transformation.



CSIR Director's Conference, Bangalore
May 11-12, 1998

- A CSIR that creates technologies that are not just first to India but first to the world.
- A CSIR that just does not follow the best practices of others but creates next practices that others will follow as their best practices.
- A CSIR that just does not leapfrog but pole-vaults to new unimaginable heights and distances.

FINAL WORDS

One might ask as to what is the most memorable day of my life in CSIR. Well there have been many in this long career, but if I were to go for just one day, it will be 11 May 1998.

On 11 May 1998, we had a CSIR Directors' conference in Bangalore, the entire family of 40 directors of CSIR was present. At the end of the meeting, there was an amazing spontaneous gesture by CSIR Directors. All the 40 Directors signed the Bangalore Declaration. They said 'India matters to us. We want to matter to India, more.' And the headline of the declaration was Team CSIR.

This Team CSIR spirit was spontaneous, it was sincere, it came from the heart of everyone. And it is this Team CSIR spirit that will catapult it to great heights. It is this Team CSIR that should integrate itself deeply and indeed inspire the creation of a New India of our dreams, a nation that will do us proud by assuming its rightful position at the top of the comity of nations.

CSIR Firsts
Marking Milestones

- First to produce the indelible ink used in elections in the country.
- First ever baby food from buffalo milk.
- First parallel processing computer Flosolver in India.
- Helped India become the first Pioneer Investor under the United Nations Convention on the Law of the Sea.
- First ever once a week non-steroidal family planning pill in the world - Centchroman - marketed by the name Saheli.
- First to introduce DNA fingerprinting in India.
- First breakthrough of flowering of Bamboo within weeks as against twenty years in nature.
- First all-composite aircraft Hansa.
- First 14-seater plane 'SARAS'
- First to analyze genetic diversity of the indigenous tribes of Andaman and to establish their origin out of Africa 60,000 years ago.
- First to pioneer convenience food technology in the country.
- First transgenic Drosophila model for drug screening for cancer in humans.
- First time anywhere in the world established 'Traditional Knowledge Digital Library' - accessible in five languages - English, German, French, Japanese and Spanish.
- First complete Genome Sequencing of an Indian.
- First indigenous civilian aircraft, NAL NM5 made in association with Mahindra Aerospace.
- First Micro Air Vehicle Aerodynamics Research Tunnel (MART), jointly coordinated by CSIR, DRDO and DST.
- First time in the history of the Republic Day parade, CSIR's journey of drug development from generic to genomic medicine showcased in 2011.
- First ever indigenously built research ship "Sindhu Sadhana".
- First Indian Gyrotron in collaboration with DST.
- First indigenous vaccine against Johne's disease affecting ruminants.
- First four-door "Electric Car" developed in collaboration with Mahindra.
- First biofuel-powered flight with bio-aviation fuel developed by CSIR.
- First-ever high-temperature indigenous fuel cell.
- First pilot plant in India operated with clean and cost-efficient fuel DME (Dimethyl Ether).
- First time in India, introduced Asafoetida or Heeng for cultivation in India.
- First indigenously developed Hydrogen Fuel Cell (HFC) Prototype Car.
- First "Footwear Sizing System" for Indian feet.

The Ethos of CSIR

Dr Shekhar C. Mande

Former Secretary, Department of Scientific and Industrial Research

Former Director General, Council of Scientific and Industrial Research

THE Council of Scientific and Industrial Research (CSIR) was founded in 1942 as the first publicly funded S&T organization in the country. At that time a few specialized Institutions existed to work in identified areas of Science and Technology. However, support to the larger base of S&T in the country did not exist.

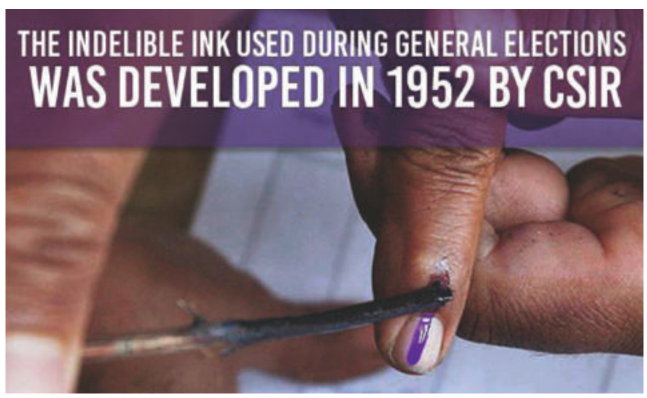
The mantle to develop and expand the Science and Technology landscape in the country therefore fell upon CSIR from the initial years of India's independence. This included establishing the National Laboratories in niche areas, supporting large S&T programmes, initiating formation of other scientific Departments in Government of India, undertaking work related to societal applications of S&T and training manpower required to carry out state-of-art and futuristic programs.

For instance, the Tata Institute of Fundamental Research was founded in 1945 through support from Sir Dorabji Tata trust, but soon a tripartite understanding among Sir Dorabji Tata trusts, Bombay Government and the Central Government was reached. Financial support to TIFR was committed by the Central Government through grants from CSIR in the initial years. Similarly, the formation of the atomic energy programme was also seeded in CSIR, not just initiating the activity but also sending scientists abroad to train themselves in areas of Atomic Energy.

Supporting high quality human resources has continued to be a flagship programme of CSIR and indeed it ranks among its most cherished programmes over the years. A large body of Indian scientists and many others have recognized the support they have received in their formative years through these programmes.

Challenges for Independent India

The initial years of independent India saw enormous challenges being encountered as India was coming out of the economically oppressive colonial rule. This has been acknowledged as among the most difficult time periods in her social history. The challenges included those related to implementation of democracy as the model of governance, growing sufficient food for her population, ensuring appropriate healthcare for all, and developing industries for her progress. The footprint of CSIR's contributions can be seen in almost all of such



activities. One of the prime and widely known examples of the work emerging out of CSIR included development of the indelible ink used in all elections, which continues to be used even today.

An interesting example from the early years of independent India's journey was to resolve the apparent difficulties created by following different calendar systems in diverse parts of India. When it was observed that many states of India were using different calendars leading to confusion even in fixing specific holidays across the nation/states, the responsibility of harmonizing the calendar system was given to CSIR, by setting up a committee of well-known Scientists under the Chairmanship of M.N. Saha. The committee with members of scientific distinction, recommended implementation of two calendar systems – Gregorian calendar, which is used in most parts of the world, and the Saka system. The latter has been used for centuries in India and is based on solid foundations of scientific principles using the solar cycle of 365 days, and with equinox, i.e. March 21/22 as the first day of the year. Eventually, the Saka calendar was adopted on 22 March 1957 as the National Calendar and now occupies a place of pride as one of the national identity elements. CSIR's contributions through such initiatives highlight adoption of scientific approach to all problems faced by the society from the early years of independence.

When the country faced major challenges due to consecutive years of drought and an imminent famine in the mid 1960s, a grim situation eventually leading to the unfolding of the green revolution, CSIR participated in this endeavor by mechanizing agriculture and developing agri-pesticides. The Government of India commissioned a study to CSIR for indigenization of tractors, which led to the Swaraj tractors and consequently a successful industry was able to spin-off from a CSIR laboratory for manufacturing of tractors. Similarly, many agri-pesticides were made in the Chemical laboratories of CSIR partly facilitating the success of the green revolution. Thus, CSIR left its imprint on Indian society at every such stage of societal development.

CSIR – Rising up to the challenge

Similar success stories abound, especially during periods of acute challenges faced by the Indian society. In recent times, the unfolding of the purple revolution in the UT of J&K, the Indian footwear sizing, the automated sewage cleaning robot, making India a net exporter of lemon grass oil, mapping of underground resources through heliborne techniques, making indigenous passenger aircrafts, BioJet fuels from agri residues and waste cooking oil, the first indigenous cultivation of Asafoetida (Heeng), disaster resilient civil structures, etc. have etched CSIR's name in the peoples' memory.

It was therefore not surprising that during the period of global emergency of during COVID-19 pandemic CSIR rose

> **The footprint of CSIR's contributions can be seen in almost all challenges that India faced during the initial years of its independence.**

> **A large body of Indian scientists and many others have recognized the support they have received in their formative years through these programmes.**

to the occasion and presented several innovative solutions. COVID-19 has indeed been an awakening time for the entire S&T community across the world. It taught several lessons to all, but specially brought forth the value of collaborations among diverse groups in the mitigation of the pandemic.

In CSIR, many examples can be seen in multiple laboratories collaborating with each other despite their diverse specializations. Besides, collaborations with industry, although recognized for many years, were strengthened during this time. Indeed, the COVID-19 episode made the entire S&T community, especially that in CSIR, realize the enormous challenges confronting humanity and commitment required to address them resolutely.

In part due to the large breadth of its laboratories, and largely due to the talented trained scientific manpower that it harnesses, CSIR has been able to rise to every challenge in the post-independent era. Much of the innovative work carried out in CSIR laboratories has been translated to the industry, much more needs to be done in this direction.

CSIR India
Fight Against COVID-19

Ethos of CSIR

As India completes its 75 years of independent journey, and CSIR its 80 years of existence, it is important to introspect the ethos of CSIR. When CSIR was established, Shanti Swarup Bhatnagar and other founding figures laid down the vision of CSIR: "*The scope of work in each laboratory (of CSIR) could perhaps be best described to be of the form of a continuous spectrum, at one end of which research work of the purest academic type and of the highest quality is carried out and at the other, the technical development of processes and equipment proceeds by stages.*"

The time is now set to address some of the most difficult challenges faced by humanity in its entire history. The role of CSIR will define how the Indian S&T community responds to these challenges. Enabling creative academic discoveries, their translation for the benefit of all, deep innovations along with industry, addressing all aspects of human development, and integrating humanity with its natural environment will therefore remain the ethos of CSIR.

Council of Scientific and Industrial Research

Legacy and the Path Forward

Dr T. Ramasami
Former Secretary to the Government of India, Ministry of Science and Technology
Distinguished Professor of Eminence, Anna University, Chennai
Former Director, CSIR-CLRI, Chennai

CSIR was founded on 26 September 1942. The agency was to play a role in catalysing technology-led industrial progress and contribute to the socio-economic development of India. Autonomy was considered necessary even at the stages of establishment by the forefathers of the organisation. From a group of five laboratories conceived in 1945, CSIR has grown into a network of 37 laboratories. This has been feasible on account of support of strong political will, committed actions and record of performance by the agency.

Here's a broad look at the evolution and growth of CSIR as an organisation.

Early Period (1942-56)**:** At its early stages, CSIR was needed to mobilise resources and support from both Government and private sectors. Donations from private players were solicited and obtained in the form of cash, land and physical infrastructure from state Governments and philanthropists. During the first 15 years, the number of CSIR laboratories grew to 17. CSIR, then, was the only major Research and Development agency of India. It participated in the development of R&D manpower through Extra Mural Research support as well as in addressing national problems through tools of science as an intramural research body.

Period of Growth (1957-71): Further expansion of the network of CSIR laboratories continued during the next 15 years. Dual roles of Extra- and Intra-Mural Research Function as National laboratories network continued and prospered. Those were times when India had to gain food security. CSIR played a strong support function in India's food security drive. Swaraj tractor and several other agricultural implements to suit India's culture-based agricultural systems and technologies for agrochemicals were delivered through coordinated intra-mural research programmes. Technology for Amul powder from buffalo milk is a case in point of CSIR's effort in providing technology solutions to national problems. CSIR's role in nation-building was evident.

Period of Consolidation (1972-86): With the formation of the Ministry of Science and Technology, promotion of research through Extra Mural Research support became feasible. CSIR could focus on intra-mural industrial research and development and in establishing linkages with the industrial sector. Technological self-reliance had become the national priority. Reverse engineering in critical areas became a CSIR action.

Research in the development of drugs through process innovations for rendering the Indian health care system affordable became a priority. R&D work of CSIR had led to a share of as many as 12 of the 16 drugs introduced in the Indian market during that time. Direct relationships between the R&D priorities of CSIR laboratories in commodity oriented sectors like food, ceramics and leather could be traced and expanded.

Yet, concerns were expressed on financial self-sustainability of CSIR. The Abid Hussain Committee ("Towards a New Perspective", Report of the CSIR Review Committee, Abid Hussain *et al.,* 1986) made some recommendations with game-changing potential. Forward engineering thrust was emphasised. Capitalisation of intellectual outputs was accorded high priority.

Period of Reinvention (1987-2001): Concept of External Cash Flow (ECF) was introduced. During 1987-95, there were steady increases in ECF. Change of leadership at CSIR brought a new found dynamism within the system. CSIR 2001 was revealed in 1995. New paths were paved. With economic globalisation and liberalisation of economy at the National level, agencies like CSIR reinvented themselves for entering into the dynamic market competition in non-strategic technology space.

The Kelkar Committee ("Reinventing the CSIR", Report of CSIR Review Committee, Vijay Kelkar *et al.,* 2004) reviewed CSIR and yardsticks for R&D performance measurements in terms of public-, private-, strategic- and social- goods were drawn up. Efficiency and performance indicators became an internal norm. CSIR implemented a Technology Mission on leather sector successfully and catalysedthe technology-led development of the Indian leather industry. The motto of "CSIR would like to matter to India more" became the doctrine internally.

Period of paving a way for new CSIR (2002-16): Corporate culture in ways of working was emphasised. Physical and R&D infrastructure of all CSIR laboratories were updated and modernised. CSIR academy was established through an Act of Parliament. CSIR focused on emerging as a major global leader in innovation space. CSIR was poised for second-stage reinvention and renaissance. Changes in the external environment forced the concept of New CSIR. Tools of the past could hardly help CSIR in paving paths of the future. Paving the way for New CSIR became the priority.

***Period of transition (2016-2030) towards New CSIR for New India*:** The world view on industrial research in public-funded systems is undergoing seismic changes. In-house research and development which affords first-mover advantages in the marketplace for the inventor and the investor in a competitive market environment is the global norm. World view of industrial research is tilted in favour of R&D for private and strategic good in the current IPR regime. Sustainability of public funded and open ended industrial research is challenged globally. CSIR as one of the largest Public funded agencies engaged in industrial research and development needs to innovate for sustainability in the new millennium. Sustainability is the new mantra.

Uniqueness of CSIR

With a few exceptions, CSIR-India is a unique intramural research agency on a global platform with widely differing sectoral interests. CSIR remains the intellectual leader in creating Intellectual Properties with potential commercial interests. Industrial research leads to national outcomes only when connected seamlessly to wealth or value creation. Generation of intellectual properties from industrial research without market connectivity is inadequate.

Conversion of intellectual properties into wealth and/or value needs interface with other players in the mind-to-market chain. CSIR could well lead the formation of a vibrant industrial research ecosystem by engaging in gainful partnerships. Capitalisation of the IPRs and other industrial research outputs in the form of sustained revenue flow from business processes is a priority.

New paths forward

India is undergoing major internal transitions. The Government of India has launched some important national flagships for the creation of demand pull for products of industrial research and development. Technology-based innovations are in demand. Make in India, Invest in India, Digital India, etc. are all indicators of the transition happening in India.

> **"It is desired that CSIR chooses a sustainable path for delivering values for an aspiring Nation in technology-enabled creation of jobs and increasing her share in Global High Technology Trade. Mindset change from project implementation to nation building is a way forward for the New CSIR of new India."**

SWOT Analysis of Current CSIR

Strength	Weakness	Opportunity	Threat
Build-up of physical assets	Ageing of physical assets created	Emerging National priority and flagships	Outdated intellectual infrastructure
Expertise-base in diverse R&D areas of industrial interest and brand image	Critical gaps inconverting knowledge Into wealth/value creation	To emerge as reliable source of game-changing technologies and lead Atmanirbhar Bharat	Competition from R&D systems of MNCs in India for R&D for India
Strong IPR base and patenting work culture	Inadequate capitalisation of IPR assets for royalty flow	Leveraging first mover advantages in IPR world	Flight of talent base of CSIR in favour of other S&T systems
Proven record of past performance in technology delivery in planned economy	Weak record of performance in areas where technology assets are mobile	Scope for entering into dynamic global competition in global technology market	Competition shake out in globalised knowledge economy in select R&D areas
Linkage capital with some core industrial sectors and academy	Excessive reliance on transaction model & poor cash inflow outside R&D services	Scope for building relationship model with some select industrial sectors with IPR sharing provisions	Horizontal transfer of technologies into manufacturing base and import of high technology products
Corporate work approach for non-strategic research and development with networking capacity	Excessive dependence on public funds with low revenues from IPR and royalty accrual	To gain leadership in catalysis of technology and innovation-led manufacturing in non-strategic sector	Changing world view of industrial research in favour of outsourcing to small companies and non-corporate systems
Ability to create technology-leads in time scales aligned to industrial partners	Low share of sustained incomes from private sector	Leveraging intellectual assets for moving towards financial self-sustainability	Internal complacencies and imbalances in open to targeted R&D priorities

> **CSIR may like to seek a New CSIR Act of Parliament with enabling provisions of rules and regulations for moving towards financial self-reliance.**

> **Success of CSIR laboratories has been higher in commercialisation of technologies when CSIR adopted technology pull and relationship models.**

Quantum increases in technology-led employment in the manufacturing sector are desired by the Government of India. Unprecedented opportunities of indigenous industrial research and development are being opened up. Atmanirbhar provides a base of capitalisation of intellectual assetsof CSIR. At these times, return from past investments into CSIR and to the Nation in the form of deliverables in the near future is expected.

New positions and paths for emerging as a leader: Industrial research does not permit open-ended research models. Time-bound and value appraised strategies are critical. Portfolio management of research priorities for each industrial sector of importance might differ. It might be necessary to identify and select industrial sectors of importance based on analysis of gaps in technology pipeline and positioning of CSIR as a dependable partner for the chosen sector. An organisational strategy to invest intellectual and financial resources judiciously on time-bound and focused industrial and translational research could be a priority.

New models for connecting knowledge to value creation: CSIR has relied on supply side and technology push and transfer model for long. Success of CSIR laboratories has been higher in commercialisation of technologies when CSIR adopted technology pull and relationship models. Relationship models call for approaches for joint identification of R&D goals, co-investment and co-generation along with industrial partners. Long term partnerships among CSIR and industrial stakeholders are crucial.

Definition of roles and sharp focusing of goals: Public funded models for industrial research have not succeeded globally. Industrial research demands high levels of contextualisation and demand-driven approaches complete with sensitivity analysis of technological gaps and unmet needs. Direct coupling between development and deployment of technologies with commercialisation links are necessary. Evidence-based decision-making for partnering industrial sector is a good starting-point. Sector-specific business models with shared objectives based on co-investments and generation of values for both CSIR and stakeholders may seem a need.

> **The Government of India has launched some important national flagships for the creation of demand pull for products of industrial research and development.**

New models for partnerships and alliances: New models for Public Private Partnerships for R&D are called for. CSIR may like to seek a New CSIR Act of Parliament with enabling provisions of rules and regulations for moving towards financial self-reliance. Many small economies of the world which are innovation leaders in high technology arena, are suffering negative balance of trade. Innovation ranking of a country and her performance in global trade do not seem strongly coupled. CSIR could forge alliances with innovation leaders from small economies and leverage its capacity to drive the costs of manufacture down through R&D innovations and enter global market for technology supply.This would call for innovations in designer partnerships and strategic alliances for mutual benefits.

New governance models for changing growth trajectories in times of transition: Current governance model suits public funded research for only social and public good with high reliance on budgetary grants from the Government. New CSIR needs to embrace R&D for private good for mobilisation of at least 50% of its annual financial needs through revenue-generating mechanisms. Currently, a large share of revenue flow into CSIR is from technical and R&D services. CSIR might review its own governance model for moving towards financial self-sustenance within the next five years. New business models without diluting core objectives are essential.

Right Positioning of CSIR in the Mind-to-Market Chain

Social capital in the form of trust between the industrial sectors of choice and the CSIR laboratories isnecessary. Right positioning of CSIR in the mind-to-market chain, building social capital and financing R&D through a mix of hard and soft money are crucial.

Several historic contributions of CSIR are recalled. Shaping the future of CSIR in the current world view of industrial research demands innovative measures. It is desired that CSIR chooses a sustainable path for delivering values for an aspiring Nation in technology-enabled creation of jobs and increasing her share in Global High Technology Trade. Mindset change from project implementation to nation building is a way forward for the New CSIR of new India.

CSIR@105 NOT OUT

Dr Samir K. Brahmachari

Academy Professor, AcSIR

Former Secretary, Department of Scientific and Industrial Research

Former Director General, Council of Scientific and Industrial Research

Founder Director, CSIR–Institute of Genomics & Integrative Biology, Delhi

HOW do we keep CSIR relevant as the nation marches ahead from its 75th year of independence to the centenary year 2047? When I was in the Indian Institute of Science (IISc) as a PhD student in 1976 my first exposure to CSIR was a visit to CSIR-Central Food Technology Research Institute (CFTRI), Mysore to do some experiments on analytical ultracentrifuge. As a faculty in IISc I also participated in 1987 in the grand opening of CSIR-Centre for Cellular & Molecular Biology (CCMB), Hyderabad, then the best equipped laboratory for biological research in India – "a jewel in the crown".

Prior to the open market economy in 1990 the industry and other institutions depended on CSIR's facilities to do R&D. Centre for Biochemical Technology (CBT) was responsible for supply of biochemicals across the nation when import was restricted due to governmental regulation. This helped me to do competitive research in molecular structural biology at IISc, for which I received the Shanti Swarup Bhatnagar award in 1990. But for CBT, it would not have been possible. Little did I imagine that one day I would head this laboratory to establish genomic sciences in India.

In the early 90s, India as well as CSIR faced major financial difficulties and many CSIR laboratories had to reorient themselves to generate external funds with industrial collaborations. By the turn of the century, Indian industries' dependency on CSIR for R&D facilities significantly decreased as most of the industrial labs, especially pharmaceutical companies, could import equipments freely. Hence CSIR had to focus on the generation of new knowledge and intellectual property.

When I moved to CSIR from IISc in 1997 as director of CBT to establish genomics technology in India, it was a sunrise science then. But I was unaware of the vastness of the CSIR skill base in every area of science and technology and its contribution in making India self-sufficient. After establishing the Institute of Genomics and Integrative Biology (IGIB) in New Delhi, a globally competitive institute in genome science, I took over as Director General of CSIR in 2007.

CSIR – Contributions that touch every Indian

Although over the past decade as a CSIR director I had been exposed by my predecessor Dr R.A. Mashelkar to the biological and chemical sciences laboratories (about 50% of the 40 laboratories of the CSIR family), still I was ignorant of CSIR's many contributions of the past. I recall a journalist from Singapore once told me, "CSIR is the most guarded secret of India." I realized as a CSIR DG then that there is some truth in the statement.

Let me illustrate how unknowingly every citizen of India uses the outcomes of CSIR technologies:

- Indelible ink when you cast your vote
- Amul baby food you drink as a child
- Pesticides and tractors (Swaraj and Sonalika) of the green revolution
- Every generic drug you take and the drugs we export as a pharmacy of the world
- Every porcelain sink and toilet "Made in India" that you use
- Every low-cost spartek tile that you stand on in your home
- Most of the petroleum products that you use
- The safety assurance of roads and bridges on which you travel

> "CSIR is like 'Intel inside' for innumerable strategic sector technologies from sensors of missiles to radiation safety glasses of atomic reactors and head-up display of our indigenous supersonic jet "tejas" to five-seater aircrafts for training."

- Technology of fly ash to waste plastic that we use to build roads
- Concrete slippers that keep the Indian rails on track when you travel by train
- Every leather product developed through non-polluting technologies that you use in India and export abroad
- Endorsement of environmental safety of all major infrastructure projects in India that benefit us
- Safety for coal mine workers and enhanced production
- packaged food to aromas from lavender to rose water
- Rice bran oil we consume
- Even the *Science Reporter* that you hold in your hand is a publication of CSIR since 1964.

CSIR is like "Intel inside" for innumerable strategic sector technologies from sensors of missiles to radiation safety glasses of atomic reactors and head-up display of our indigenous supersonic jet "tejas" to five-seater aircrafts for training. It is also the timekeeper of the nation (IST) and maintains all the standards that we use daily. Identification of the extent of the continental shelf of India gave access to larger marine resources for people of India. Protection of our Indian traditional knowledge by developing TKDL, the traditional knowledge digital library, is a hallmark. The list can go on and on.

CSIR always stood up to meet the challenges that the nation faced. Prime Minister and President CSIR on 14th November 2007 during my first meeting after taking up the office of DG, CSIR said, "CSIR is 65 years old and was built by Dr Bhatnagar to meet the challenges of that time. I would like you to build a new CSIR that would fulfil the aspirations of modern India."

Till that time, I managed an old laboratory of CSIR (CBT) for 10 years to transform it into a leading genomics institute. But the size and budget of IGIB in 2007 was 1% of CSIR. Scaling up is a different ball game well known to chemists. What works at the laboratory level does not work at the industrial scale. It is important to look back in order to look forward. This demand from the President CSIR led to a series of actions over the next 10–12 quarters with the support of an amazing group of champions drawn from outside CSIR. To name a few, Mr Dipankar Basu (Retd. Secretary, Coordination, GOI); Late Dr P.K. Biswas (Retd. Advisor S&T, Planning Commission) and Mr Zakir Thomas (IRS) with multifaceted experience including IPR. This team was specifically strengthened by the late Mr V.K. Gupta, architect of TKDL and Dr S. Sivaram (Director, CSIR-NCL) with support from Dr V.S. Ramamurthy (ex-secretary DST, GOI) and illustrious Prof. M.M. Sharma. CSIR and I would ever remain indebted to them.

Gathering this expertise was a key step towards building a new CSIR for new India the seed of which was sown more than a decade ago by creating a position paper in 2011 with the younger colleagues in CSIR family — the *CSIR Vision and Strategy 2022*.

Learnings from the past

So, what have we learnt from the past to arrive at the present CSIR@80?

1. Gather the best minds from diverse fields who would be committed to CSIR and the nation beyond promoting themselves.
2. Recruit the best potential leaders and give them freedom to operate.
3. Commission projects much ahead of time than be a part of the bandwagon.
4. Traverse a path not trodden by others.
5. Give scientists respect and treat them as valuable national assets, through creation of outstanding scientists, distinguished scientist positions and giving respectable designations.
6. Empower scientists to create startups by creating incubators in national laboratories.

In fact, Prime Minister Shri Narendra Modi, also President of CSIR, gave a clarion call for "Stand up India and Start up India", a mission that CSIR as an organization is most equipped to fulfil.

To give an identity and brand to CSIR laboratories spread through the length and breadth of the country, we made CSIR one family by prefixing CSIR to all laboratory names. We organised CSIR Techfest 2010 at Pragati Maidan to make the public aware of the contributions of CSIR. The CSIR 800 programme was launched to create initiatives that would make a difference to the life of people at the bottom of the economic pyramid. One example of the outcome of the CSIR-800 programme is the electrical rickshaw nucleated by CSIR in 2008. The Soleckshaw or E-rickshaw replaced conventional cycle rickshaws to a great extent.

The AcSIR (Academy of Scientific and Innovative Research) was established in 2012 by an Act of Parliament to create human resource in transdisciplinary areas. Today, AcSIR, a virtual networked university, established without any additional funding from the consolidated fund of India, is producing nearly a thousand PhDs a year. Currently more than 5500 students are pursuing PhD in S&T.

CSIR became the first public funded organization to establish internet and video connectivity across its 38 laboratories way back in 2010 from Srinagar to Trivandrum and from Goa to Arunachal Pradesh. This became the backbone of project planning in 2012 and implementation during the XIIth plan 2012-17. This infrastructure was instantly available for daily consultation among the scientific leaders much before Zoom or MS Teams was available.

Most recently, CSIR's role as a frontline S&T organisation was clearly visible during the COVID-19 pandemic. CSIR played a major role in developing PPEs and ventilators, genomic surveillance and diagnostics (FELUDA), and Covaxin adjuvant, all in record time.

Fifteen years back, CSIR initiated the open source drug discovery (OSDD) movement for neglected diseases, an approach that was embraced by the world during the COVID-19 pandemic. CSIR-IGIB, established two decades ago, developed the genetic landscape of India, a basal data for development of genomic medicine ahead of time. This positioning allowed India, through the INSACOG – a multi-laboratory, multi-agency, Pan-India network to monitor genomic variations in the SARS-CoV-2 – to carry out genomic surveillance during the COVID-19 pandemic.

> CSIR needs several disruptive thought leaders. It needs to work on creating thousands of startups to create wealth and to go in for major organizational restructuring to participate in India's start-up ecosystem as an enabler.

The way forward

Although much of what was envisioned in *CSIR@80: Vision and Strategy 2022* has been achieved, many targets remain relevant today. What is the way forward?

CSIR needs several disruptive thought leaders. It needs to work on creating thousands of startups to create wealth and to go in for major organizational restructuring to participate in India's start-up ecosystem as an enabler. CSIR also needs to put in place a mechanism to reward risk taking and even celebrate failure in high-risk projects. Young scientists need to be empowered much more to dream of the impossible and to make it happen.

What do I dream of for the nation?

- An innovative and developed India in 2047, with average life expectancy of 80 years;
- None left behind for a lack of opportunity;
- Skill India making hundreds of millions of youth employable;
- Affordable healthcare as a right for all;
- Rural India with urban infrastructure;
- Robodoctors in public health centres & robotic surgery in rural settings;
- Application of metaverse in education and commerce;
- India leading the world in digital health and AI applications;
- Functional food-based personalized genomics and traditional knowledge to tackle life style disorders.

I believe, CSIR can play a role in each of these aspirations. The question is how CSIR's future leaderships will prepare CSIR for India @2047 ahead of time and will contribute to the Indian growth trajectory to make CSIR matter to people of India more.

80 Years of CSIR The Best is Yet to Come

Dr Girish Sahni

Former Secretary, Department of Scientific and Industrial Research

Former Director General, Council of Scientific and Industrial Research

THE Council of Scientific and Industrial Research (CSIR) stands at an important crossroads today. Its history is a saga of triumphs, struggles, and reinventions.

This is a time of profound change for India. From post-independence struggles to establish our own science and technology base, and find industrial solutions to enable import substitutions, there followed an era of globalization. This remarkable organization, one of the largest chains of scientific institutions in the world, successfully delivered many of society's expectations to meet emergent national needs in various sectors. It has also established without any doubt its solid credentials of fundamental research quality in diverse areas as evidenced by high global ratings like the Scimago Institute world ratings.

One foresees a far greater change brought about by the dark shadows of pandemic, political turmoil, and perhaps international conflicts. Certainly, developing countries face challenging times with their vast multitude of aspiring populations looking for peace, stability and economic redemption. As India marches forward confidently, our scientific vision and the roadmap ahead should be consonant with this endeavour.

In the past decades, CSIR's laboratories have contributed to the national cause in areas as diverse as the strategic sector, metallurgy, chemical and leather industries, pharma and biopharma, food technology, biotechnology, Earth Sciences and agriculture, to name just a few. When other academic and research institutions in the country were in their infancy, CSIR's many contributions stood out as shining examples of science serving society.

As the country opened up in the early 90s and the patent protection era came to an end, CSIR rapidly upgraded its fundamental scientific capabilities to not only publish outstanding studies and research papers in fundamental science, but also transformed these into intellectual property rights. In both these arenas, namely high quality scientific publications as well as numbers of patents, this organization has a lot to be proud of. Thus, we became primed to not only generate excellent science, but also take the first important steps (in the form of patents) towards its conversion into market potential.

Beyond a certain point past its infancy, the growth of any entity – be it an individual or organization – is significantly dependent on its ability and willingness to participate in critical self-reflection. While it may be a painful exercise, learning from one's past shortcomings and putting in efforts to transform one's perceived weaknesses into strengths is just as important as finding new avenues for success. This momentous occasion presents one such opportunity.

Especially considering the wealth of publicly available knowledge that emanates from the collective ingenuity of the human intellect, the main objective for not just CSIR, but all aspiring organizations working towards societal uplift, is to develop a practical culture of addressing societal/industrial problems and commercializing the scientific solutions to benefit the masses. In other words, taking science from the lab to the homes and lives of our people is the only way to keep a publicly supported R&D organisation like CSIR continually relevant much in the future. Indeed, such an aspiration is an integral part of the mandate of the Council of Scientific and *Industrial* Research, as handed down from its foundational days, 80 years ago.

The entire value-chain/functional steps involved in the lab-to-market pathway can be identified somewhat simply as: observation and ideation, hypothesis-driven investigations, findings/discovery, innovation wherever applicable, prototype creation and testing, productisation/iterative cycles of improvement, as well as marketing.

It is a fact that the first steps dealing with the discovery process and publications, are vastly more exciting to scientists in general, and can also be defined as the honeymoon phase of S&T. The hardships and investments required in the longer term for the latter steps towards commercialization have also been fostered and institutionalized in CSIR over the years, even as individual scientists and laboratories exhibit proudly long lists of patents and publications, the more 'upstream' end of the value chain. But all these stages have to be assiduously strengthened if we are to realize our full potential. The 'downstream' stage of converting innovation into products and services depends not just on creating synergy between lab and industry, but also huge amounts of investment. Vital to this is also the requirement of a fundamental change in the mind-set of the scientists themselves, and industry's respect for national research and development.

We are fortunate that CSIR can proudly claim many commercial products ranging from generic pharma and biopharma medicines, several new molecular drug entities, agriculturally relevant traditional as well as medicinal plants – as under the aroma programme – new medical devices, innovations and technological solutions for minerals and underground discoveries, etc.

Despite this great progress, a formidable challenge still remains to be overcome in utilizing the rich knowledge base of national R&D labs (as indeed all fundamental knowledge available to humankind), and converting these into products and services with the help of industry on scales commensurate with our national needs. Fortunately, there are many successful examples even from within CSIR which provide a learning of the best-case scenarios possible.

By and large, these success stories have come about because of the tireless and undoubtedly painful efforts of the dedicated scientists and support structures in local leadership to coalesce all the stakeholders in this value chain, namely, scientists, businesses, investors, marketing specialists, etc. Indeed whenever such a convergence has happened, although rare, one has invariably seen the spectacle of success.

To make this process institutionalized and more consistent, I propose that CSIR develops an integratory digital platform (much like Uber and Amazon) where demands and needs of industry, capabilities of laboratories, funding and investment offerings and all other enablers in the lab-to-market value chain are visible and approachable at a mouse-click. Of course, to enable such a platform to function, policy changes in CSIR and attitudinal changes in strategic leadership are vital. This will catalyse CSIR's greatest need, namely to create organization-wide support structures that enable more successful integration with industry.

Today, with the digital technologies that we possess, extremely powerful platforms for integrating diverse stakeholders to engender capabilities beyond our wildest expectations can be realised. This would be operationalised by creating a network, or Grid, of national labs with their scientific prowess and formidable analytical and process facilities, and their linkage with on-ground demands and needs of specific industries (whether heavy industries or MSMEs), potential investors, Govt Line ministries, NGOs, etc. – indeed, all stakeholders on the unpredictable highway from lab-to-market – can be visualized and put firmly in place. The potential of such an integrated network or Enabling Platform that CSIR needs to engender can easily be imagined with the phenomenal success that well-known platforms such as Amazon and Uber have brought to the business environment worldwide.

The often unseen and unpredictable human biases and other weak links in delivering workable, affordable and assimilable technological end products for the real, everyday life – that often delay and thwart potentially beneficial projects being successful – could be minimised by such Smart digital platforms for covering the whole spectrum of technology development, right until the last stages of commercialisation.

Although at first sight this appears quite straight forward and logical, fundamental policy changes would be required in initiating and carrying forward such an endeavour, as changes in ingrained attitudes in the organisation, and top-to-bottom institutional inclusion are required for successful completion of multi-competence and multi-tiered technological development and commercialisation projects. For this, a rebalancing between the multitude of stand-alone early-stage investigations (fundamental or discovery science) on the one hand, and supra developmental projects with ones straddling lab-to-market ends will be required.

For many years, a majority of the research funding within CSIR has been towards early-stage discovery. This is more akin to the university research model where individual investigators carry out research with graduate and post-graduate students where most of the outputs are mostly publications and sometimes patents. On the other hand, both industrial R&D as well as publicly supported technology-oriented laboratory chains (such as ISRO and DRDO in India, CSIR South Africa and Australia, German Research Foundation institutions, NASA, etc.) predominantly support late-stage highly targeted developmental activities that lead to industrial and commercial/societal value outcomes.

There has been a conscious tilt along these lines in recent times. The FTT and FTC (Fast Track Technology and Fast Track Commercialisation) programmes started in 2015-16 have been effective in harnessing and developing, on a high priority basis, the "low-hanging fruits" from intra-mural CSIR research to higher levels of technology readiness that is more attractive for industrial licensing and development and minimal take-off periods to market.

Through the envisaged National R&D Mega Grid initiated and led by CSIR, and then partnered across all other agencies and stakeholders, a dynamic and constant engagement between R&D teams (representing the so-called last mile in the lab) on one hand, and the development and marketing teams in industry (the first miles leading to market) would be streamlined, strengthened and nurtured. This would help, in my view, to identify, engage and reinforce the weakest links in the lab-to-market journey on a fast-response time scale.

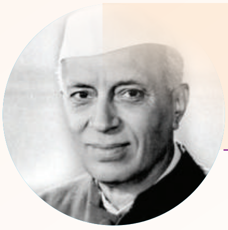
The creation of this platform will automatically foster transparency and time-bound corrective measures, where all stakeholders could potentially get a ringside view of obstacles and address them without needless time delays. These are often the steps that need to be taken after the initial scientific breakthroughs, and require troubleshooting of team formations, funding hurdles, process scale-up and/or prototype generation issues, and of course the myriad administrative bottlenecks or leadership issues which often cripple the onward march of projects to fruition.

Creation of Downstream Prototype and Process Completion Centres across the CSIR laboratories chain will also be extremely effective if run in a thoroughly professional and transparent manner, shielded from negative interference and in a mode where all stakeholders, especially from small scale industry, are welcomed and helped.

With its vast infrastructure, outstanding scientists in diverse disciplines, and the need and hunger of the Indian industry – especially micro and small scale industry – CSIR is now positioned optimally for such a transformation.

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR)

80 Years in the Service of the Nation



"It is science alone that can solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people."
Pandit Jawaharlal Nehru, India's First Prime Minister

"The Council of Scientific and Industrial Research is a national institution in the building of which every section of the Indian community has contributed."
Shri C. Rajagopalachari, First Indian Governor General

"...science has no future in India unless our agriculture and our industries are fully developed; more food and more health are dependent upon these factors. Scientific and Industrial Research thrives best when it is applied to material benefit."
Dr Shanti Swarup Bhatnagar, First Director General of CSIR

"CSIR is at the forefront of furthering scientific research and innovation in India. Starting with indelible ink which is the hallmark of our democratic fabric, CSIR has left an indelible mark on every sphere of life."
Shri Narendra Modi, Prime Minister of India

"CSIR is certainly the finest institution in the country. That is why today it is the only institution in the whole of India that is a part of the first 100 best institutions in the world."
Dr Harsh Vardhan, Former S&T Minister

"It is heartening to see the evolution of CSIR from developing India's first Indelible Ink used in elections to providing Indian Standard Time using Atomic Clocks. From the development of Swaraj Tractor to the recent test flying of HANSA-NG is a testament to the growth of CSIR in the last eight decades."
Dr Jitendra Singh, S&T Minister

Established in September 1942, the year 2022 marks 80 years of CSIR's service to science and the nation. During the past eight decades, CSIR has grown into one of the largest R&D networks in the world – an action-oriented network of scientific laboratories with activities ranging from agriculture & aerospace to buildings & chemicals, drugs & earthquakes to environment & leather, molecular biology & mining to medicinal plants & mechanical engineering, metrology & petroleum to roads and buildings.

Here's a glimpse into the establishment of the country's largest S&T organisation and some of the most significant technologies, products and processes that have rolled out from the precincts of the CSIR laboratories during the past eight decades.

1940s – The Foundational Decade

- April 1940, Board of Scientific and Industrial Research established with office at the Government Test House, Alipore, Kolkata
- Illustrious members of BSIR – Dr J.C. Bose, Dr Nazir Ahmed, Dr Meghnad Saha, Sir H.P. Mody, Sir Syed Sultan Ahmed, Mr Kasturbhai Lalbhai, Lala Shri Ram, Mr P.F.G. Warren and Dr N.N. Law.
- 1941, Lord Linlithgow, Viceroy of India, invites Dr S.S. Bhatnagar to be first Director of the Board.
- 14 November 1941, Sir A. Ramaswamy Mudaliar's resolution for creation of Industrial Research Fund with annual grant of Rs 10 lakh for a period of five years adopted by Central Assembly.
- 21 March 1942, BSIR reconstituted as Council of Scientific and Industrial Research to administer the Fund.
- 26 September 1942, Council of Scientific and Industrial Research is born as an autonomous body.
- Dr S.S. Bhatnagar, first Director General of CSIR.
- Plans drawn up for science in post-Independent India, to meet the immediate requirements of the country:
  - Laboratories to be set up in 11 areas in the first phase (known as the Bhatnagar Eleven): Physical, Chemical, Metallurgical, Glass, Fuel, Building, Road, Leather, Electrochemical, Drug, and Food Technology.
  - Foundation stones laid for 6 national laboratories: National Chemical Laboratory, National Physical Laboratory, National Metallurgical Laboratory, Central Fuel Research Institute, Central Glass & Ceramics Research Institute and Central Food Technological Research Institute.
  - In second phase, plans to establish laboratories to cater to the growing needs of dissemination of scientific information, electrochemical research, drug research, road research and leather research.
- In next phase, plans to establish institutes geared to the conservation and exploitation of plants of economic value, salt research, treatment of water and industrial wastes, aerospace and petroleum research.

1950s

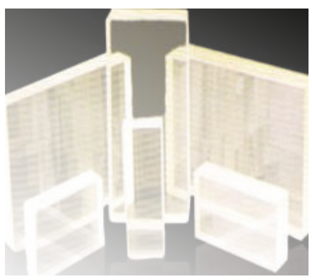
- **Indelible Ink — Mark of Elections in India**

The indelible ink has become the mark of elections in India. Developed in 1952 by the CSIR-National Physical Laboratory (CSIR-NPL), it was licensed to Mysore Paints and Varnish Limited, the sole supplier of indelible ink to the Election Commission of India. The indelible ink developed by CSIR is also exported to countries like Nepal, Cambodia, Turkey, South Africa, Nigeria and others.

1960s

- **Optical glass**

The manufacture of optical glass used in lenses and prisms in a wide range of scientific, photographic and survey instruments was a closely guarded secret and India had to import it at expensive prices. CSIR-Central Glass and Ceramic Research Institute (CSIR-CGCRI) succeeded in developing a process for the production of optical glass.



- **Trisonic Wind Tunnel**

A wind tunnel is used in aircraft design to study the effects of air moving past solid objects. It comprises a closed tubular passage, in which the aircraft fitted with appropriate sensors is subjected to airflow. CSIR-National Aerospace Laboratories (CSIR-NAL) established a trisonic wind tunnel in the 1960s to catalyze aerospace research and development. Every Indian aerospace vehicle, from satellite launchers to aircrafts, has graduated out of this wind tunnel.

1970s

- **Amulspray Instant Milk Baby Food**
  During the 1970s, milk-based food for infants was imported. International companies refused to set up a manufacturing facility to produce it in India as the milk from buffaloes, readily available in India, had too much fat and it was difficult to develop an easily digestible baby food from it. CSIR-Central Food Technological Research Institute (CSIR-CFTRI) took up the challenge and developed baby food from buffalo milk, breaking the international monopoly.

- **SWARAJ**
  Mechanisation of agriculture played an important role in making India self-sufficient in food grains. CSIR-Central Mechanical Engineering Research Institute (CSIR-CMERI) developed the Swaraj, a 20 HP tractor, and licensed it to Punjab Tractor Limited in 1974.

- **Nutan — Smokeless Cooking**
  Sooty kerosene wick-based stoves, which were energy inefficient and hazardous to health, were once the only option for cooking food in rural Indian homes. The CSIR-Indian Institute of Petroleum (CSIR-IIP) developed Nutan, a smokeless cooking stove, with funding and marketing support from Indian Oil Corporation (IOC). Launched in the Indian market in 1977, it reduced fuel requirement by 25%.

- **India Mark II pump**
  The CSIR-Central Mechanical Engineering Research Institute (CSIR-CMERI) came up with a solution to providing water in villages with technology that was simple, easy to operate and maintain with the India Mark II pump. Made of non-corrosive non-metallic parts, the low-cost pump has been successful not only in rural India but in several other nations.

1980s

- **Flosolver — India's First Parallel Computer**
  In the 1980s, India was importing computing power from other nations. In 1986, when the US government refused to supply a Cray supercomputer to India, scientists from the CSIR-National Aerospace Laboratories (CSIR-NAL) built their own supercomputer – India's first. They connected several computers in parallel to create Flosolver; its success triggered other successful parallel computing projects in the country such as PARAM.

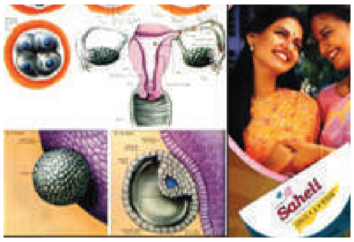
- In 1983-84, CSIR-NAL started a project to fabricate an all-composite aircraft. The aircraft, called the Light Canard Research Aircraft (LCRA), was ready by the end of 1986 and made its maiden flight on 26 February 1987.

- **Nalgonda Technique — Flouride Removal from Water**
  The CSIR-National Environmental Engineering Research Institute (CSIR-NEERI) pioneered the Nalgonda technique to remove fluoride from water in 1988. The Nalgonda technique is named after the village in India where the method was pioneered and employs the flocculation principle.

- **Pioneer Investor**
  In the 1980s, the CSIR-National Institute of Oceanography (CSIR-NIO) played an important role in exploring the oceans for its resources. Ocean waters are a source for strategic metals like Nickel, Cobalt and Copper at water depths of 4-6 km. India was the first nation to get "Pioneer Investor" status from the United Nations, which gave it mining rights of over 1.5 million square kilometres area. On 26 January 1981, CSIR-NIO hauled up polymetallic

nodules from the depth of 4,800 m in the western Indian Ocean. The NIO has also found several marine organisms that could give important drug leads.

- **Saheli**



Birth control pills based on female hormones progestogen and estrogen had many undesirable effects due to their interference with other actions of the endocrine system. Scientists at the CSIR-Central Drug Research Institute (CSIR-CDRI) came upon a solution by developing an agent that would prevent pregnancy by interfering with the implantation of the fertilized ovum in the uterus without disturbing the hypothalamus-pituitary-ovarian hormone axis. The once-a-week pill Centchroman – marketed as Saheli – reached the masses by the end of the 1980s.

1990s

- **Hansa**

CSIR's National Aerospace Laboratories designed and developed *Hansa,* India's first all-composite two-seater trainer aircraft. The aircraft could also be deployed for surveillance, aerial photography, coast guard and environmental monitoring roles.

- **Asmon — Non-toxic to Liver**

Herbal medicine for the management of bronchial asthma christened Asmon, was developed by the CSIR-Indian Institute of Chemical Biology (CSIR-IICB).

- **Bamboo Flowering**

Bamboo flowers only once during their lifetime and that too just once in seven to a hundred years depending on the species. The plants die after flowering. In 1990, CSIR scientists created history when they made bamboo flowering within weeks possible by using tissue culture technologies.

- **Convenient Mixes of Food Items**

Convenience foods like dosa, idli, vada, gulab jamun and many other crispies and snacks are very popular today. It was CSIR-Central Food Technological Research Institute (CSIR-CFTRI) that conceived and developed convenient mixes for these popular Indian dishes. Scientists at CSIR-CFTRI have also successfully designed machineries for the bulk manufacturing of popular cuisines. Today, 90% of the annual production of convenience food products worth several millions of rupees is based on CFTRI technologies.

- Scientists at CSIR-CFTRI have also successfully designed machineries for the bulk manufacturing of popular cuisines like idli, dosa and chapati. Some of the other machineries the institute has devised include vada frying, coffee roaster, infrared drying of cashew nuts, continuous popping machine, laddu making and chikki making machineries. Bioplates from agri-horti wastes, sunflower dehuller and papad making units have become popular with the farming community and Small Scale Industrial units.


- **Turmeric Patent Revoked — Landmark Case**

CSIR challenged the US patent granted to the wound healing properties of turmeric in 1995. In 1997, India won the patent battle and the turmeric patent was revoked. This landmark case set a precedent for challenging patents based on traditional knowledge. In a pioneering initiative, CSIR developed a digital archive of Indian traditional knowledge — the Traditional Knowledge Digital Library (TKDL) to prevent misappropriation of Indian traditional knowledge in International Patent Offices. Till date, in more than 250 cases, patent applications have either been withdrawn/ cancelled/declared dead/terminated or have had claims amended by applicants or rejected by the Examiner(s) on the basis of TKDL submissions.

- **Centre for DNA Fingerprinting and Diagnostics (CDFD)**

The CSIR-Centre for Cellular and Molecular Biology (CSIR-CCMB) developed a Bkm-derived probe for DNA fingerprinting, which is extensively used for forensic investigation, paternity determination and seed stock verification. This indigenous technique has been used as evidence in many cases in the judiciary. The direct result of this work was the formation of an autonomous institution, the Centre for DNA Fingerprinting and Diagnostics (CDFD) in 1995.

- **Leather Processing**
  The CSIR-Central Leather Research Institute (CSIR-CLRI) has always had an active role in supporting leather processing and retail units. This was momentous in 1996, when CLRI prevented the shutting down of 570 tanneries in Tamil Nadu as per Supreme Court orders. CLRI's cleaner leather process technologies solved the problem of the highly polluting nature of the tanning effluents, thus saving 250000 jobs.

- CSIR-CLRI's technologies have also added a touch of class to the world of fashion in leather. With novel technologies, tie-and-dye leathers and printed leathers were introduced for the first time in the western market known for their fastidiousness for fancy leather goods such as colourful handbags, wallets leather cases and several other utility articles. Designing fashionable footwear is also CLRI's forte. In 1986, the first Computer-Aided Design (CAD) facility in India for footwear was established at CLRI.

- **Arteether — Fast-acting Agent**
  In 1995, scientists at the CSIR-CDRI developed a drug to treat malaria – Arteether. Arteether is a semi synthetic derivative of artemisinine, the active constituent of the plant *Artemisia annua*. Clinical trials showed excellent responses. Arteether is being prescribed to the patients as second line of treatment for chloroquine-resistant *P. falciparum* malaria including cerebral malaria.

- **Plantation Revival in Kangra**
  CSIR-Institute of Himalayan Bioresource Technology (CSIR-IHBT) devised techniques to revive the plantations in Kangra, Himachal Pradesh. Agro and harvestry practices were developed to suit specific conditions. Processing innovations reduced the withering time from 16 to 5 hours. These measures boosted premium tea production in the region.

- **Drug Development at Cheaper Costs**
  CSIR-Indian Institute of Chemical Technology (CSIR-IICT) developed a cheaper process for the manufacture of anti-HIV cocktail of drugs. The anti-AIDS drug Zidovudine (commonly known as AZT) had to be imported at a prohibitive cost. At a time when the price of anti-AIDS drugs produced abroad was about $10,000 per AIDS victim for a year's treatment, Indian pharmaceutical Cipla, created a stir by offering the same for just $350! This innovation ushered in an era of drug development at cheaper costs.

2000s

- **Tejas — India's Light Combat Aircraft**
  CSIR-NAL took a bow when the Light Combat Aircraft (LCA) soared onto the skies for the first time in 2001. When the LCA engages in combat, the pilot carries out split-second manoeuvres using the head-up cockpit display and the sophisticated control software.

- **Saras — India's First Civilian Plane**
  CSIR-NAL also developed SARAS, the 14-seater twin-engine turboprop aircraft with a maximum speed of over 600 km/hour, which made its maiden flight on 22 August

2004. Saras has state-of-the-art avionics, electrical and environmental control systems.

- **LaCONES — Conserving Endagered Animals**
  Project LaCONES is aimed at the conservation of endangered animals through the use of the biotechnological intervention. This initiative of unmatched scale anywhere in the world was proposed by CSIR with the help of the Department of Biotechnology (DBT) and the Central Zoo Authority of India (CZA). It has a wide range of objectives including monitoring of genetic variation using modern techniques. Through assisted reproductive technologies, scientists at LaCONES have already achieved pregnancy in blackbuck, chital and blue rock pigeon. In 2007, LaCONES announced the birth of "Spotty," a baby spotted deer by using artificial insemination.

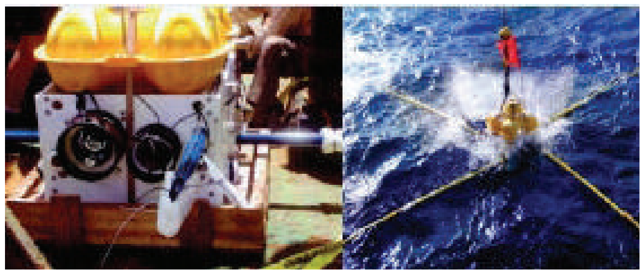
- **Exploring Gas Hydrates**
  CSIR-National Geophysical Research Institute (CSIR-NGRI) has made inroads into an area of frontier research that may offer solutions to our energy crises. Gas hydrates are methane molecules, locked in a cage of ice, whose reserves alone could meet international gas requirements for the next 300 years! CSIR-NGRI is involved in explorations of gas hydrate reserves off Indian coasts and preliminary studies are encouraging.

- **Livelihood through Mint Cultivation**
  CSIR-Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP) provided farmers with pest-resistant and high oil-yielding varieties of Menthol mint (*Mentha arvensis*). Thousands of farmers are earning their livelihood through mint cultivation and India has now become the largest exporter of menthol mint and its oil.

- **First Indian Gyrotron**
  Gyrotron, a very high power millimetre wave source is one of the most important components of controlled thermonuclear fusion. A CSIR-CEERI-led consortium of five institutions has designed and developed the country's first Gyrotron device for application in Nuclear Fusion Power Research at Institute for Plasma Research (IPR), Gandhinagar. India has now joined an elite group of five countries to have this kind of technology.

- **ERBIUM doped Fibre Amplifier**
  CSIR-Central Glass & Ceramic Research Institute (CSIR-CGCRI) in collaboration with Network Systems Technology (NeST), developed the ERBIUM doped Fibre Amplifier (EDFA), a key component of cable TV networks and which restores energy loss during transmission and ensures high-quality picture, sound and connectivity.

- **Marine Magnetotellurics — Geophysical Technique**
  CSIR-National Geophysical Research Institute (CSIR-NGRI) and the CSIR-National Institute of Oceanography (CSIR-NIO) pioneered the use of a novel geophysical technique called marine magnetotellurics for exploration of the Gulf of Kutch and the Saurashtra region.



- **Complete Genome Sequencing**
  The CSIR-Institute of Genomics and Integrative Biology (CSIR-IGIB) completed the first ever Human Genome Sequencing of a healthy Indian citizen. India is now in the league of countries that have demonstrated the capability to sequence and assemble complete human genomes like the United States, China, Canada, United Kingdom, and Korea. The breakthrough paves the way for predictive healthcare.

2010s

- **CSIR Science Tableau**
  In 2011, for the first time in the history of the Republic Day parade, a science tableau of the Council of Scientific and Industrial Research (CSIR) showcased the journey of drug development from generic to genomic medicines.

- **C-NM5 Aircraft**
  CSIR-NAL and Mahindra Aerospace announced the successful maiden flight of their jointly developed C-NM5 aircraft on 14 September 2011. This is India's first public-private partnership in the development of aircraft. The aircraft has been designed using cutting-edge technology and design and analysis tools.

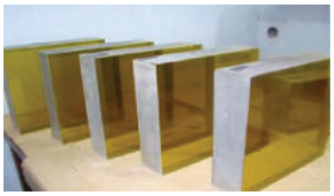
- **Micro Air Vehicle Aerodynamics Research Tunnel**
  India's first Micro Air Vehicle Aerodynamics Research Tunnel (MART) for testing the fixed-wing, flapping-wing and rotary-wing MAVs in the 500 mm wingspan category was set up at NAL. The project was jointly coordinated by CSIR, DRDO and DST. This advanced tunnel can address all the aerodynamic, propulsion and aeroelastic issues related to MAVs.

- **Drishti Transmissometer**
  Drishti Transmissometer facilitates aircraft landing and take-off at all civilian airports of the nation even in low visibility conditions. The sophisticated instrument was designed and developed by CSIR-NAL.

- **Sindhu Sadhana**
  India's first ever indigenously built research ship "Sindhu Sadhana" was launched by CSIR-NIO to enhance the capabilities of Indian oceanographers to understand the multidisciplinary observations and oceanographic processes in the seas around the nation and to translate this knowledge to benefit the country.

- **Acoustic Test Facility**
  The Facility designed and developed by CSIR-NAL has been used for acoustic tests of Chandrayaan-1, Mars Orbiter Mission, GSLV, and India's Reusable Launch Vehicle-Technology Demonstrator.

- **RSW glass blocks**
  Radiation Shielding Windows (RSW) used in nuclear installations are viewing devices that allow direct viewing into radioactive areas while still providing adequate protection to the operating personnel. CSIR-Central Glass & Ceramics Research Institute (CGCRI) has developed homogeneous and defect-free high-density RSW glass blocks.



- **Pure Tungsten Powder**
  Tungsten is fully imported for ordnance applications. It is irreplaceable due to its high density. Global tungsten supply is dominated by the Chinese monopoly. CSIR-National Metallurgical Laboratory (NML) has developed the cheapest and shortest route to produce high pure tungsten powder from a variety of tungsten carbide (WC) hard metal scraps.

- **Lightweight Composite Components**
  Light weight metallic materials are required for the manufacturing of light tanks. CSIR-National Institute for Interdisciplinary Science & Technology (CSIR-NIIST) has developed and supplied such lightweight composite components for India's light combat battle tanks being manufactured by DRDO. CSIR-NIIST has also developed microwave low loss materials usable for strategic establishments such as DRDO and ISRO.

- **Earthquake Warning System (EqWS)**
  This technological intervention and the first of its kind initiative in the country to avert the huge loss of life and infrastructure during an earthquake. This system was developed by CSIR-Central Scientific Instruments Organisation (CSIO), Chandigarh, to activate appropriate actions for safety during a tremor. The EqWS has been deployed in Delhi Metro at five different locations including Mundka, Botanical Garden, Huda City Centre, Metro Bhawan and Faridabad, which helps metro stop services during the disaster.

- **DHVANI**
  Detection and Hit Visualisation using Acoustic N-wave Identification system (DHVANI), an indigenous marksmanship training device that informs the trainer and shooter the accuracy of shots within seconds. It was developed by CSIR-NAL, and after rigorous field trials at Army ranges in Bengaluru, Secunderabad, and Infantry School Mhow, the well-validated training system was approved for induction into the Indian Army in July 2014.

- **Reflectance Confocal Microscope**
  CSIR-CGCRI successfully developed a "Reflectance Confocal Microscope", which is based on Supercontinuum

Light Source. This innovation paved the way for India's position in global photonics research.

- **VIHBRA**

Virtual Intelligence in Home Based Rehabilitation (VIBHRA) developed by CSIR-CSIO is a virtual intelligent platform for motor rehabilitation which combines experience from virtual reality and knowledge from machine intelligence to enhance neural reorganisation that optimises the physical rehabilitation outcomes in patients with disability.

- **First Indigenous Vaccine for Johne's Disease**

Johne's Disease (JD), a progressive granulomatous enteritis of ruminants characterised by untreatable, profuse, chronic diarrhoea, weight loss, and emaciation. The CSIR-New Millennium Indian Technology Leadership Initiative (NMITLI) scheme with M/s Biovet Private Limited, Bengaluru, developed the vaccine against Johne's Disease i.e. JD Oil and JD Gel. The vaccine is the first indigenous vaccine against Johne's disease affecting ruminants.

- **Streptokinase — Life-saver Injectable Protein Drug**

The drug saves up to 40% of human lives after heart attacks if given within few hours of the onset of chest pain. CSIR-IMTECH has developed a portfolio of Streptokinase technology. Cadila is manufacturing the drug indigenously, a first in India.

- **Mercury-free Plasma (MFP) UV-lamp**

CSIR-Central Electronics Engineering Research Institute (CEERI), Pilani, developed a Mercury-free Plasma (MFP) UV lamp for water disinfection systems which would provide water free of hazardous mercury. The technology can also be used for sterilisation of food, medical equipment, surfaces, ill-skin conditions, air conditioners and air fresheners for hospitals, etc.

- **NEERI-ZAR**

To meet drinking and cooking water requirements on an emergency basis, CSIR-NEERI developed NEERI-ZAR which serves as a disaster management tool for drinking water supply under flood affected situations.

- **TERAFIL Filter**

CSIR-Institute of Minerals and Materials Technology (IMMT), Bhubaneswar, developed the 'TERAFIL' filter which is a highly efficient low-cost device for supply of clean drinking water. The filter is especially useful when the water is rich in sediments, suspended particles, iron and certain micro-organisms causing water borne diseases.

- **Solar Power Tree**

Developed by CSIR-CMERI, this is a uniquely designed vertical array of solar panels that can generate 5 kWh of electricity from just four square feet area. The energy is enough to light up five homes.

- **Soleckshaw — green solution to urban transport**

Soleckshaw is a pollution-free, safe and economical electric three-wheeler, designed and developed under the CSIR-New Millennium Indian Technology Leadership Initiative (NMITLI) scheme to meet the need for short to medium distance transport within cities.

- **Electric Car**

World's lightest and lowest cost, 4-door, 4-seater battery-operated "Electric Car" was developed under CSIR-NMITLI, Mahindra Reva launched the car for use as a city car. It is the first four-door electric vehicle with some "trans-city" capabilities regarding range and speed.

- **Green Aviation**

Jet fuel derived from biomass is an initiative towards Green Aviation. CSIR-Indian Institute of Petroleum, Dehradun, developed the technology as well as a catalyst to produce jet fuel based on biomass-derived non-edible oils such as jatropha oil.

- **Electronic Nose**

The E-Nose for monitoring obnoxious odours generated from industries has been developed jointly by the CSIR-National Environmental Engineering Research Institute, Nagpur, and the Centre for Development of Advanced Computing (C-DAC). It can sniff out Volatile Organic Compounds (VOCs) potentially harmful to human life in a very short time.

- **Multi-Fuel Portable Cook Stoves**

For efficient cooking with reduced fuel consumption and pollution, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, designed Energy Efficient Multi-Fuel Portable Cook Stoves. These stoves are used for cooking in smokeless conditions with reduced fuel consumption and pollution. A variety of solid fuels like wood, twig, leaf, dung cake, agricultural waste, raw coal, briquettes, etc., can be burnt in the stoves at high thermal efficiency (30% to 50%).

- **Neerdhur — Improved Domestic Cookstove**
In rural and remote areas where cooking often becomes a messy affair and hunting for fuel is a pain, Neerdhur gives a quick solution. The improved cooking stove designed and developed by the CSIR-National Environmental Engineering Research Institute, Nagpur, is efficient and can run on multi-fuels (biomass pellets, charcoal, agro residue, wood chips, wood logs, cow dung cakes, etc.).

- **Krishishakti Tractor**
CSIR-CMERI has developed a small range (11.2 hp) diesel engine tractor enabling mechanised agriculture for small farmers.

- **Ksheer-Scanner**
Ksheer-Scanner, an electronic system for the detection of adulteration in milk, was launched by CSIR-Central Electronics Engineering Research Institute (CEERI), Pilani. Another device, Ksheer Tester, has also been developed for testing adulteration in milk for domestic usage.

- **Release of New Varieties of Plants**
During CSIR Platinum Jubilee Function, Hon'ble Prime Minister Shri NarendraModireleasednew varieties of turmeric, khus, RosescentedGeranium, aromatic grassCitronella, Lemongrass, flowering plantLily and ornamental flower plant Gerberadeveloped by CSIR labs. These were also handed over to farmersat five different locations – Hyderabad,Cuddalore, Palampur, Jorhat and Jammu.

- **Pottery Kiln**
"Queen" Coal/Wood Fired Pottery Kiln for efficient sintering/baking of all kinds of potteries or terracotta items such as handicrafts, domestic earthenware, roof tiles, water filters, etc. at a uniform high temperature (800-9000C) to obtain good quality and long life of potteries. It is low-cost coal, or wood-fired furnace, made with red brick & clay. It was developed by the CSIR-Institute of Minerals and Materials Technology (IMMT), Bhubaneswar.

- **Fire Resistant Door**
CSIR-Central Building Research Institute, Roorkee, has developed a Fire Resistant Metallic door. It reduces the spread of fire from one compartment to the other.

- **Boards and Panels**
CSIR-CBRI has also developed know-how for the production of pine needle composite boards/panels using isocyanate adhesive.

- **Herbal Health Drink**
CSIR-National Botanical Research Institute, Lucknow, has formulated a purely natural and non-toxic Herbal Health Drink with a unique blend of modern Nutraceutical concepts with traditional knowledge. Herbal Ointment for wounds and cuts, herbal colours and herbal Sindoor, are also some herbal extracts from CSIR-NBRI to keep away people from hazardous chemicals.

- **Smart Device to Monitor, and Detect Cracks**
CSIR-CECRI developed a portable device that can monitor weak structures and send alerts whenever a crack is observed. The device called the Triboluminescence (TL) camera uses a light-emitting compound and a smart camera that allows the detection of cracks — invisible to the naked eye — on structures made of concrete, metal and fibre-reinforced plastic. The compound when coated on a surface will emit light due to excessive pressure and the smart camera is programmed to capture it.

- **A New Energy Storage System**
CSIR-CECRI and CSIR-CSMCRI developed a new eco-friendly recycling process for the widely used Li-ion batteries. They have produced graphene from discarded lithium-ion batteries which could potentially be an ideal material for next-generation high-performance supercapacitors.

- **"Geopolymer Concrete" for Road Construction**
The Indian Roads Congress (IRC) has accredited the construction of the road by "Geopolymer Concrete" developed jointly by NETRA-NTPC Ltd and CSIR-CBRI, Roorkee. The geo-polymer road stretch is unique in India and its replication across the nation can address

environmental problems associated with huge quantities of fly ash being generated by coal-based power plants.

- **Eye Blink can Control Devices**
  CSIR-Central Scientific Instruments Organization (CSIO), Chandigarh, has developed a man-machine interface that can be operated using electric signals generated during the blinking of the eyes – helpful for persons with disabilities. The brain produces signals on blinking the eyes that can be captured from the scalp in the form of Electroencephalography (EEG) signals. These signals can then be processed using a microcontroller and used to run devices to perform desired tasks.

- **India's First Ever Biofuel-Powered Flight**
  

  A bio-aviation fuel developed by CSIR-IIP successfully powered India's first historic biofuel-powered flight on 27 August 2018 from Dehradun airport. The bio-aviation fuel was produced indigenously by the CSIR-IIP from jatropha oil and was based on the patented technology of the institute. India is now one of the few countries in the world to utilise biofuel for planes.

- **Eco-friendly Green Crackers – SWAS, SAFAL and STAR**
  Central Electrochemical Research Institute (CECRI), Tamil Nadu and National Environmental Engineering Research Institute (NEERI), Nagpur, have developed eco-friendly 'Green Crackers' which are 15-20% cheaper than conventional ones. The crackers have been named as safe water releaser (SWAS), safe minimal aluminium (SAFAL) and safe thermite cracker (STAR).

- **Whole Genome Sequencing of 1000 Indians**
  CSIR-CCMB and CSIR-IGIB sequenced the genome of 1000 Indians from different populations. This was achieved as part of the IndiGen initiative undertaken by CSIR in April 2019. The development was a major step towards enabling predictive and preventive medicine.

- **Biodiesel Plant**
  CSIR-CMERI designed and developed a biodiesel plant that can carry out the conversion of Tung oil from Tung Tree (*Aleurites fordii*) into biodiesel. The oil has various industrial applications such as in ceramic, paint, paper and cloth production. Tung oil *(Aleurites fordii*) has been regarded as a promising non-edible source of biodiesel production.

- **"JALDOST" for Flood Rescue & De-Weeding**
  In 2019, CSIR-NAL launched an airboat JALDOST in the Ulsoor Lake in central Bengaluru, which can be used for flood relief as well as for weeding in waterbodies. The boat uses stainless steel cutters that facilitate the cutting of rooted weeds in water bodies. The system uses hydraulic power from the engine to cut weeds and is also fitted with equipment to scoop them up.
  
  The airboat was constructed using technology used in low-cost aircraft. Since there are no moving parts below the water surface, there is no risk of entanglement with objects underwater not easily identifiable. Jalboat can travel in locations where conventional boats are not practicable.

2020s

- Hansa-NG (New Generation) trainer aircraft made its successful maiden flight on 3 September 2021 and has completed all the test flights for certification by DGCA. It has a digital state-of-the art fully glass cockpit display system, economically designed doors for better ingress and egress, increased fuel capacity for higher range and endurance, bubble canopy for excellent aerial view, and is easy to fly with good handling quality and low operations and maintenance cost.

- **Mob Control Vehicle (MCV)**
  To provide technical support to paramilitary forces engaged in maintaining law and order situation, three innovative variants 'Compact, Medium, Heavy' category of Mob Control Vehicles (MCVs) were designed, developed and demonstrated by CSIR-Central Mechanical Engineering Research Institute, (CSIR-CMERI) Durgapur.

- **Technology on Air Pollution Control inGreen Crematoria**
  To address the high localised toxic emissions from crematoria, CSIR-NEERI, Nagpur, has developed technology knowhow to mitigate air pollution from Open Pyre Green Crematoria.

- **Eco-friendly, Efficient and DME Fired "Aditi Urja Sanch" Unit**
  CSIR-NCL developed the nation's first pilot plant operated with clean and cost-efficient fuel DME (Dimethyl Ether) with 20-24 kg/day capacity.

- **Asafoetida (Heeng) for Cultivation for the First Time in India**
  CSIR-IHBT has ensured cultivation of Heeng, or Asafoetida, an essential spice in many Indian dishes, for the first time in India. The first plantation was done on 18 October 2021 at Lahaul and Spiti district in Himachal Pradesh, at an altitude of about 11 thousand feet above sea level. The
  

CSIR's Key Initiatives to Fight against COVID-19

A concerted effort was made by the CSIR laboratories to combat the COVID-19 pandemic that wreaked havoc worldwide. As the Coronavirus pandemic unfolded, CSIR offered a comprehensive, well-coordinated, and integrated approach to mitigating the outbreak, ranging from sanitising and disinfecting solutions to equipping frontline workers with protective gear, and exploring new drugs and vaccines to repurposing existing ones. A look at some interventions.

FELUDA Paper-strip: CSIR-IGIB developed a low-cost FELUDA (FNCAS9 Editor-Limited Uniform Detection Assay) paper-strip coronavirus test which can detect the virus within an hour. The paper-strip test, which utilises CRISPRCas9, is not only cost-effective but also does not need dedicated machinery or specialised skill.

Coverall Suit: The suit by CSIR-NAL was made of certified polypropylene spun laminated multi-layered non-woven fabric-based coverall to ensure the safety of doctors, nurses, paramedical staff and healthcare workers.

Hasta-Suraksha: Foot Operated Hand Washing System by CSIR-IMMT, a compact system mechanically operated by foot which does not require any electricity and can be used at any convenient location.

SwasthVayu – Non-invasive Ventilator: Realising the shortage of ventilators by hospitals, CSIR-NAL came up with a Bi-level Positive Airway Pressure (BiPAP) System Portable Ventilator, SwasthVayu for COVID patients.

Oxygen Enrichment Unit: A startup of CSIR-NCL, Genrich Membranes developed Oxygen Enrichment Unit (OEU) based on innovative, indigenously developed Hollow-fibre Membrane technology.

Karuna Bhawan: Makeshift Hospital for COVID-19, Karuna Bhawan, a portable, prefabricated, foldable steel structure of 30.23 sq mt per module plinth area was designed with adequate insulation and waterproofing features by CSIR-CBRI. The structure is modular and can be constructed at site. Makes use of lightweight prefabricated steel portals that are foldable, easy to erect, reusable, safe, comfortable to the occupants and cost-effective.

eSPRAY & Covid-Spray: Electrostatic Disinfection Machine (eSPRAY & COVID-Spray) by CSIR-CSIO, works based on the electrostatic principle, producing a uniform and fine spray droplets of disinfection material in the range of 10-20 Ã‚Âµm. The machine uses very less disinfection material as compared to conventional methods.

Sanitizer System: UV-C-based Sanitizer System by CSIR-CEERI was developed for disinfecting fomites and other surfaces. It has a unique design as the UV-C lamps maintain uniform intensity throughout the chamber.

Dry Swab: Dry Swab-based RNA Extraction Free Direct RT-PCR Diagnostics was developed by CSIR-CCMB to scale up testing. It was a simple variation of the existing gold standard RT-PCR method that can easily scale up the testing with no new investment of resources.

spice was not being grown in India, and the entire demand was met from imports, mostly from Afghanistan.

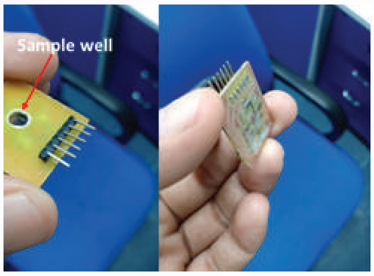
- **Affordable Solar Powered Battery-based Sprayers**
  Due to inappropriate machinery, a major portion of pesticide sprays is wasted, also polluting the soil, water and air. To make spraying efficient, CSIR-CMERI has developed two variants of affordable solar-powered battery-based sprayers – one for "marginal farmers" and the other for "small farmers".

- **Bharatiya Nirdeshak Dravya (BND®)**
  BPCL quality assurance (QA) department and M/s Aashvi Technology LLP (ATL) joined hands with CSIR-NPL for manufacturing and marketing of "Bharatiya Nirdeshak Dravya" (Certified Reference Material) to ensure correct and accurate results of Lab Instruments.

- **Drone-based Geophysical Survey System**
  CSIR-NGRI developed an indigenous unique drone-based geophysical survey system for mineral exploration, mapping of basement topography and also for aquifer mapping of different geological terrains.

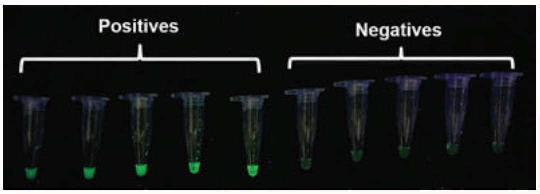
- **Emergency Restoration System for Power Lines**
  CSIR-SERC developed an indigenous technology called Emergency Restoration System (ERS). In case of Transmission Line (TL) tower failures, permanent restoration may take several weeks. The lightweight modular system ERS can be used as a temporary support structure to restore power lines immediately with minimal losses.

- **3D Printed Patient-specific Medical Implants**
  CSIR-CSIO developed a technology for manufacturing



Micro PCR with Disposable Chip: Developed by CSIR-CEERI, a handheld Polymerase Chain Reaction (PCR) system for DNA sequence amplification consisting of a disposable micro-fabricated amplification chip, capable of handling 20-150 Åµl sample volume.

RT-LAMP Diagnosis of COVID-19: CSIR-IIIM and Reliance Industries Limited (Mumbai) together developed a Reverse Transcription Loop-Mediated Isothermal Amplification (RT-LAMP) assay for a much cheaper diagnosis of COVID-19. RT-LAMP assay doesn't require sophisticated and expensive equipments like a real-time PCR machine. It is a simple assay that can be done in a very basic lab setup even with limited expertise.



Hospital Care Assistive Robotic Device (HCARD): The device developed by CSIR-CMERI is a nursing care system that navigates the existing facility without intervention and within the programmed constraints to deliver and transport materials in the ward.

Intubation Hood: The Hood by CSIR-CMERI is suitable for doctors who require a transparent hood when carrying out treatment procedures such as intubation. Can also be used during any oral examination by dentists.

Air Sanitizer: An engineered system developed for disinfecting aerosols by CSIR-NIIST. The unit absorbs aerosols from a distance and exposes them to a combination of germicidal UV radiations and filters and releases out clean and fresh air.

AarogyaPath: Healthcare Supply Chain Solution by CSIR-CRRI is an information management and forecasting database platform at the national level to capture demand-and-supply scenarios for key items that are required to address the national healthcare needs.

Kisan Sabha: The portal was developed by CSIR-CRRI connecting farmers directly to retailers and vice versa. Makes communication between farmers and their stakeholders simpler, quicker, and efficient and provides them with better products at affordable rates.

MUKT: Multi-Wavelength UV Source for Killing Pathogens in Real Time (MUKT) by CSIR-CEERI is a plasma-UV-based electronic easy-to-use pathogen inactivation system designed for its multi-purpose and diverse applications in medical, domestic, food and grocery stores. There are two versions of MUKT -Portable Version and Handheld Version. The systems are easy to operate with a normal AC power supply.

Serological Surveillance through CSIR-Cohort Study by CSIR-IGIB to ascertain the burden of COVID-19 using a serology-based assay that can distinguish SARS-CoV2 from other similar viral infections and to determine the antibody titres at various time intervals.

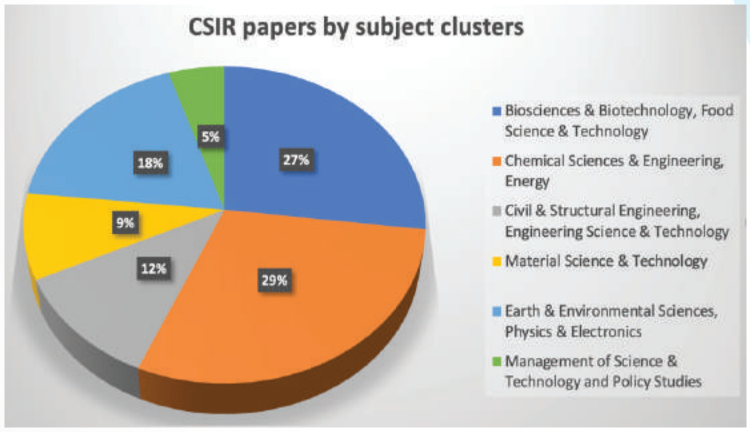
Contactless Auto UV Disinfection Unit: The unit was developed for Biometric Attendance Systems by CSIR-CIMFR. In this, a UV-C germicidal lamp is used for disinfection of surfaces of Biometric Attendance Systems (BAS) placed inside the unit. The unit can be used for placing almost all sizes of available biometric attendance machines on the market. The UV-C lamp inactivates bacteria and viruses on the infected surface of BAS system used by number of persons.

patient-specific medical implants for several human body parts. The technology was transferred to the industry for commercial production and marketing of the product. Since implants made with common specifications don't fit well in different patients, CSIR-CSIO attempted to solve the problem with the help of Computer-Aided Design (CAD) followed by 3D printing of the biocompatible metals, during which the patient's CT-Scan/MRI data is used to design the implant with specifications compatible with patients.

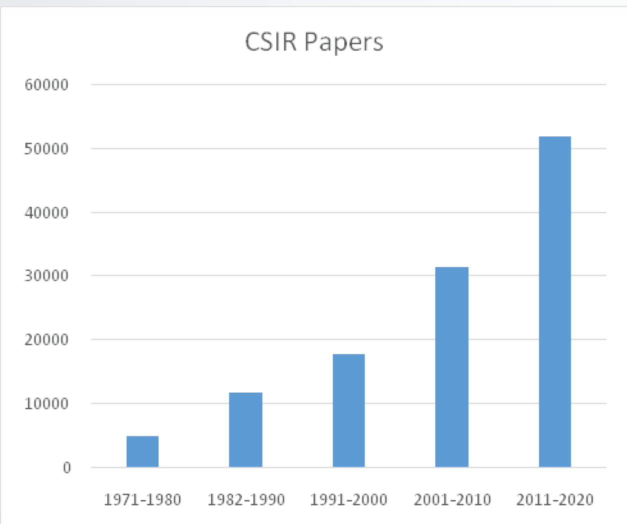
- **India's first Hydrogen Fuel Cell (HFC) Prototype Car**
  CSIR and KPIT, Pune, conducted successful trials of India's first Hydrogen Fuel Cell (HFC) prototype car. CSIR-NCL indigenously developed a low-temperature PEM (Proton Exchange Membrane) type Fuel Cell stack for the car which operates at 65-75 degrees centigrade. With further improvements, this is a way forward to having a cleaner world with reduced air pollution.

- **Footwear Sizing System**
  To establish a foot-sizing system for India, CSIR-CLRI has ventured into collecting foot data throughout India to have a "Footwear Sizing System" for Indian feet for the first time. For a wide Indian population, 3D digital imaging techniques having a three-dimensional foot scanner will be used to scan the characteristics of the foot and will measure over 20-foot measurement parameters *via* an optical laser scanning system.

CSIR – Among Leading Contributors of Research in India



- Over 40,000 research journals publish nearly 4 million research papers annually.
- According to the Web of Science, a prominent scientific database, Indian scientists and researchers published nearly 1.56 lakh research papers in 2021.
- According to different data sources, India stands among the top 10 countries in the world in the number of research papers published.



- In India, the Council of Scientific and Industrial Research (CSIR) has been one of the leading contributors of research papers.
- The Web of Science data shows that CSIR's research output has increased ten-fold, from 5066 research papers during 1971-1980 to 51,989 research papers during 2011-2020.
- CSIR has contributed about 8.2% of the research papers from India in the last five decades.
- The paper with the highest number of citations that has all Indian authors and is published in an Indian journal is from CSIR. The paper, "A modified spectrophotometric assay of superoxide-dismutase", authored by three CSIR researchers, P Kakkar, B Das and PN Viswanathan and published in the CSIR journal, *Indian Journal of Biochemistry and Biophysics,* has received over 2,500 citations till date.
- The 37 CSIR laboratories spread across the country conduct research in six subject clusters. Nearly 56% of research is from the biological sciences and chemical sciences clusters. The remaining 44% of the research is spread across the four clusters.
- CSIR research papers continue to appear in high impact journals such as *Nature, Lancet, Science, New England Journal of Medicine* and many more signifying the high-quality research that has been a hallmark of CSIR.

CSIR Mission Projects *Ushering in Socio-Economic Changes*

Dr Abhishek Kumar
Sr Scientist, CSIR HQ
K. Venkatasubramanian
Chief Scientist, CSIR HQ

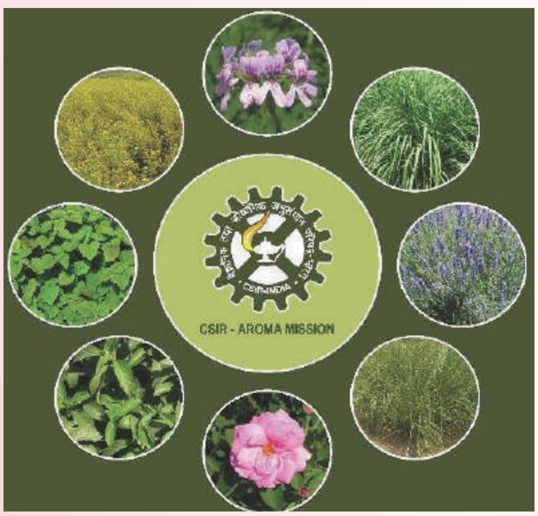
WITH its mission "to build a new CSIR for a new India", CSIR has been an active participant and contributor to various Government of India Missions like Deep Ocean Mission, Waste to Wealth Mission, Electric Vehicle Mission, National Hydrogen Mission, Jal Jeevan Mission, etc.

Besides, CSIR has also formulated and launched numerous ambitious missions to propel the nation forward. These mission mode projects have a perfect blend and potential to contribute towards the public, private, societal and strategic sectors of the nation. CSIR's Mission Projects synergize the best competencies available in CSIR research laboratories and outside institutions.

Some of these CSIR missions that have brought about noticeable techno-socio-economic changes are presented here.

CSIR Aroma Mission

The CSIR Aroma Mission aims to bring transformative change in the aroma sector through interventions in the areas of agriculture, processing and product development for fuelling the growth of the aroma industry and generating rural employment. The most significant achievement under the CSIR Aroma Mission, and one that has been in the news lately, is the "Purple Revolution" in Jammu and Kashmir through introduction and promotion of Lavender cultivation, processing and marketing of its essential oil in Jammu & Kashmir.



Apart from CSIR, the other organisations that were a part of this Mission are Khadi and Village Industries Commission (KVIC), Agricultural and Processed Food Products Export Development Authority (APEDA), Tribal Cooperative Marketing Development Federation of India Ltd. (TRIFED), Fragrance and Flavour Development Centre (FFDC/MSME), Kannauj, Indian Council of Agricultural Research (ICAR), Biotech Park, Lucknow and many State Departments, Universities & Social Organizations.

The Mission covered almost the entire country from tribal areas in Manipur and Odisha to Himachal Pradesh, Kargil, Leh districts and in several other states. The Mission targeted crops such as Salvia, Chamomile, Mints (Spearmint & Peppermint), Mints (*M. arvensis*), Lavender, Patchouli, Geranium, Rose, Citronella, Lemongrass, Palmarosa, Vetiver, Rosagrass, Ocimum, Rosemary, *Artemisia maritima*, *Tagetes minuta*, Jammu monarda and Turmeric for Leaf oil.

The objectives of the Aroma Mission are:

- Provide technical and infrastructural support for distillation and value-addition to farmers/growers.
- Enable effective buy-back mechanism to assure remunerative prices to the farmers/growers.
- Provide inputs for value-addition in essential oils and aroma ingredients for their integration in global trade and economy.
- Facilitate collaborations with Industry to meet their requirement for essential oils.

- Explore international markets for brand 'CSIR Aroma' – essential oils produced under the mission.
- Provide quality certification as per BIS standards.

Some of the significant outcomes of the Mission are:

- About 35,000 ha of additional area brought under captive cultivation of aromatic cash crops particularly targeting rain-fed/degraded land across the country.
- From being one of the importers of Lemongrass oil a few years back, India has now become one of the largest exporters in the world.
- Lemongrass cultivation explored as a viable source of income and alternative to opium cultivation in Manipur.
- More than 2000 Aroma clusters developed of which 18 are in tribal areas generating an alternate source of income for tribal farmers.
- More than 100 entrepreneurs developed including women entrepreneurs, involved in planting material generation and value-added products development.
- High-value aromatic crops including Lavender and Salvia introduced in the higher altitudes of J&K including Ladakh and disturbed areas of J&K and Arunachal Pradesh.
- Introduction and expansion of Lemongrass, Rosagrass & Palmarosa in rain-fed areas of Vidarbha, Bundelkhand and Odisha.
- Popularisation, expansion of aromatic crops like Lemongrass and Mints in Naxalite-affected Bastar and tribal area of Dudhwa, UP and Annamalai Tiger Reserve (ATR) along with installation of improved distillation units for value-addition.
- Deployment of high-yielding varieties of Vetiver in tsunami and cyclone-affected areas of Tamil Nadu and flood-affected areas of UP, Assam and Bihar.
- Barren land producing liquid gold for farmers in Himachal Pradesh: Wild marigold farming opens up new avenues of income for farmers in Himachal Pradesh. Himachal Pradesh cultivates Wild marigold in more than 300 hectares of land.
- Farmers of Nabarangpur and Angul districts in Odisha are producing Tulsi and Lemongrass oils in an eco-friendly manner under CSIR-Aroma Mission.
- Women growing Lemongrass to boost their income in Bokaro district, Jharkhand.

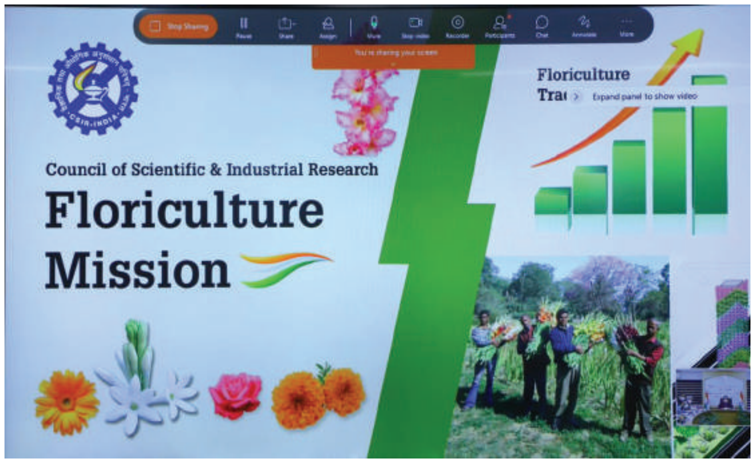
Besides, as the Aroma Mission progresses, some other outcomes envisaged from the CSIR-Aroma Mission are:

- Higher incomes for farmers.
- Generation of ample rural employment (12 lakh man-days).
- Enable Indian farmers and aroma industry to become global leaders in the production and export of at least two (lemongrass and vetiver) essential oils.
- An additional area of about 30,000 hectares will be brought under cultivation of these crops in the next three years to further catalyze cultivation of aromatic crops in about 100,000 hectares.
- Generate 2000 tonnes of essential oil annually for perfumery, cosmetics and pharmaceutical industries, worth Rs. 300 crores and use of these oils in value addition and herbal products to generate a business of at least 500 crores.

CSIR Floriculture Mission

CSIR has been involved in floriculture R&D of novel floricultural varieties for decades. Harnessing ornamental values of wild native plants and their domestication and popularization has a potential to enrich global floriculture crop diversity. The aims of the mission are

- Enhancing farmers' income and entrepreneurship development
- Development of new floral varieties
- Expansion of areas under floricultural crops



- Urban floriculture
- Development of post-harvest and value addition technologies
- Integration of Apiculture and Floriculture
- National level registration and release of existing and new floral varieties, and
- Establishing effective domestic and international market linkages.

The Mission has had a country-wide footprint. Some of the significant achievements of this mission are:

- More than 500 hectares expanded under floriculture crops and 200 ha under integrated apiculture with floriculture.
- Farmers given training in cultivation of floriculture crops.
- New variety of Chrysanthemum released, two species of wild ornamental plants domesticated and 42 species under domestication.
- 5 new post-harvest products developed.
- 12 varieties of floriculture crops are under ICAR-AICRP national trials for registration.
- 75 clusters of floriculture and apiculture created; and
- Fragrance mapping in respect of 6 crops across the country completed.

The mission further aims to bring 2000 ha under floriculture crops during the current year, 25 new varieties are in the process of development, 16 varieties of floriculture crops will be sent shortly under ICAR-AICRP national trials for registration and cultivation of Lily and Tulip in high elevation areas has been initiated.

CSIR Cotton Mission

CSIR initiated the Cotton Mission in 2019 to develop next generation transgenic cotton for broad-spectrum resistance to field pests for yield protection. Apart from CSIR, ICAR-Central Institute of Cotton Research, Nagpur, ICAR-Indian Institute of Vegetable Research, Varanasi, ICAR-Central Institute of Sub-tropical Horticulture, Lucknow and Punjab Agricultural University, Ludhiana are contributing to this mission. The major objectives of this mission are:

- Improvement of cotton varieties for insect tolerance
    - Stacking of promising GM cotton events in cotton varieties for durable and broad-spectrum resistance to field insect pests
    - Deregulation of GM cotton varieties
    - Discovery of new insecticidal genes, promoters, and development of GM cotton varieties
- Use of Pheromone Application Technology as an immediate solution to field insect pest control
- Application of whitefly trap-cum-death-sink cotton to protect vegetable and horticultural crops from whitefly-vectored viral diseases in India Design and development of spindle-type cotton boll-picking machine for Indian conditions.

The significant achievements of this mission are:

- For the control of the devastating cotton insect pest whitefly, CSIR-National Botanical Research Institute, Lucknow has developed 33 GM cotton lines using its patented gene Tma12. These GM cotton lines show significant tolerance to whiteflies.
- Cotton farmers in the country are currently facing the problem of pink bollworm (another major cotton insect pest). It is being addressed by disruption of mating of the insect. For this, female specific pheromones have been synthesized at CSIR-Indian Institute of Chemical Technology, Hyderabad. Composition of pheromones has been optimized to enhance the insect attraction. Pheromone blend is placed in small size lures and installed in field. In field, these lures function like traps, attract male insects, and cause confusion leading to mating disruption. It also helps in insect monitoring for timely spray of pesticides. Mating disruption and judicious use of pesticides will reduce the insect load in the field.
- For the control of whitefly vectored viral diseases in vegetable and horticultural crops, CSIR-National Botanical Research Institute, Lucknow has developed a new GM cotton. This GM cotton attracts whiteflies and kills them. It can guard several crops against viral diseases. The technology will enable farmers to grow crops without application of pesticides.
- Contained field trials of whitefly tolerant cotton and guard cotton under progress for second year. Preliminary findings regarding the whitefly tolerant cotton are promising.

CSIR Seaweed Mission

The CSIR Seaweed Mission was initiated in the year 2019 for sustainable production and utilization of seaweeds. Apart from CSIR, Tamil Nadu State Fisheries Department, GoTN, Andhra Pradesh Skill Development Corporation, Andhra Pradesh, Administration of Andaman Nicobar and Bidhan Chandra Krishi Viswavidyalaya (BCKV), West Bengal are actively participating in this mission.

The major achievements of the Mission are:

- Clonal propagation of *Gracilaria dura* and *Kappaphycus alvarezii* through appropriate treatment of various growth promoting substances.
- Novel seaweed based animal feed additive formulations for animals to enhance their productivity and boost immunity developed and technology transferred.
- Improved method of production of Agar and Alginate developed in terms of efficiency of use of water to reduce the burden of water usage and effluent generation.
- Elite germplasm for commercial exploitation during seaweed farming developed for *Kappaphycus alvarezii*. 5000 elite germlings have been distributed to commercial farmers.
- Pilot-scale seed production of *Kappaphycus alvarezii* for promoting extensive farming along Tamil Nadu coast has been undertaken.

Acknowledgements

The above mentioned societal mission/s are coordinated by Technology Management Directorate (TMD) of CSIR Hqs. The primary source of data for this paper is content provided by TMD.

Civil, Infrastructure and Engineering Three Pillars of Nation's Growth

CSIR THEME DIRECTORATES

Dr N. Anandavalli

Director, CSIR-Structural Engineering Research Centre (CSIR-SERC), Chennai

Theme Director, Civil, Infrastructure & Engineering Theme Directorate of CSIR

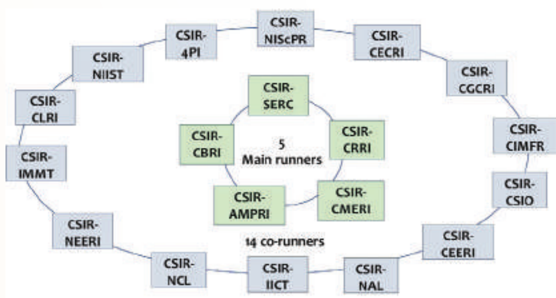
CIVIL engineering plays an important role in nation building. It involves the design, construction and maintenance of the nation's lifelines — roads, railways, bridges, canals, dams, airports, sewage systems, pipelines, tunnels, structural components or buildings and machines. Civil engineering is all about planning and preparing for the unexpected.

The budget of FY 2022-23 earmarked a 35% increase in the capital expenditure as compared to the FY 2021-22, which is 2.9% of Indian GDP. Under the instrument 'PM GatiShakti', there are national master plans to spend much of the capital expenditure for infrastructure development in the seven engines of growth — Roads, Railways, Airports, Mass transport, Ports, Waterways and Logistics. This will be complimented by energy transmission, IT communication, bulk water and sewerage as well as social infrastructure. This is a transformative approach to economic growth of the country through world-class modern infrastructure and logistics. Apart from higher growth, expansion in infrastructure will also create more jobs.

Infrastructure creation played a pivotal role in pulling back the economy from the slowdown caused due to the pandemic situation. The Government has already launched the ambitious Rs.102 lakh crore National Infrastructure Pipeline (NIP). The Government also plans to expand the national highways network by 25000 km in 2022-23, boosting it by 20% of total 136440 km. Towards fast-track railways Kavach indigenously developed signal technology and a Dedicated Freight Corridor (DFC) are proposed by the Government. Under Sagarmala National Perspective Plan six new Mega Ports will be developed. Implementation and execution of these plans for infrastructure is the key to success.

CSIR – Catalysing Infrastructure Growth

Civil, Infrastructure and Engineering (CIE), one of the CSIR's eight themes, concentrates on different aspects of development and maintenance of sustainable infrastructure. The global and national scenario on civil, infrastructure and engineering generates steep demand and thereby provides enough opportunities for making use of the expertise available with the CSIR laboratories to offer solutions based on inter-disciplinary approach. In view of the Government's emphasis on the seven engines of growth, the CIE theme of CSIR plays a key role in each growth engine.



Participating Laboratories of the CIE theme

CSIR-SERC: CSIR-Structural Engineering Research Centre, Chennai
CSIR-CBRI: CSIR-Central Building Research Institute, Roorkee
CSRI-CRRI: CSIR-Central Road Research Institute, New Delhi
CSIR-CMERI: CSIR-Central Mechanical Engineering Research Institute, Durgapur
CSIR-AMPRI: CSIR-Advanced Material Process Research Institute, Bhopal

Focus Areas

- ***Structural Health Monitoring & Life Extension:*** Structural Health Monitoring for high speed railways, aging infrastructure & Smart City infrastructure.
- ***Disaster Mitigation:*** Disaster resilient infrastructure, renewable energy infrastructure, strategic infrastructure, reengineering towards addressing climate action.
- ***Building Physics & Materials:*** Next generation construction materials, self-healing sustainable concrete, circular economy in construction materials, low-cost

carbon sink construction materials, FRP in structural engineering applications.

- ***Rural Infrastructure:*** Solar-powered cold storage for agricultural produce, post-harvesting technologies for high humid environment, agricultural waste-to-value added products, cold mix technology for high volume roads, bamboo reinforced concrete structures for low-cost housing etc.
- ***Mobility Infrastructure & Planning:*** Techniques for road assets management, safe road connectivity for hilly terrain, hill road widening using light weight geofoam blocks, traffic circulation plan around metro stations & impact quantification, Indian Road (Highway) safety manual, folded textile reinforced panels etc.
- ***Automation & Robotics:*** Focus on robotics & automation and Industry 4.0, additive manufacturing, next generation digital manufacturing, next generation electric mobility, etc.
- ***Waste to Wealth:*** Geopolymer concrete for fast-track construction, self-compacting high-strength concrete, polymer/nanocomposite using plastic waste, self-sustainable Integrated Municipal Solid Waste Disposal System (IMSWDS) for bulk waste generator utilization of waste materials, industrial solid wastes, and valorization of sludge in construction.

UNIQUE SOLUTIONS – WIDE IMPACT

Safety assessment of Scherzer span of Pamban Railway Bridge for Southern Railway

Pamban Bridge, India's first ever sea bridge, is a railway bridge connecting the important pilgrim town of Rameswaram on Pamban Island to the mainland of India. More than one hundred years old, cracks developed in structural members of the Scherzer's span, due to which rail services were suspended. To restore the train services in the shortest possible time by the Southern Railway, CSIR-SERC instrumented and measured the responses during static load testing using a special train formation for assessing the structural integrity. Based on the studies, the suggested remedial measures helped the Southern Railway to resume the rail services within a short period. Rameswaram is an important pilgrimage place, and the intervention removed the hindrance to thousands of pilgrims and also to the villagers in Rameswaram.

Instrumentation of the bridge by CSIR-SERC team

LCA Fuel Drop Tank of Tejas

The Aeronautical Development Agency (ADA), Bengaluru has designed and developed the Light Combat Aircraft (LCA) - Tejas, for the Indian Air Force, with HAL as the Principal Partner along with other agencies including CSIR. The 1200 Lt fuel drop tank of Tejas needs to be tested for slosh and vibration loadings simultaneously as a mandatory requirement. CSIR's intervention facilitated 'Final Operation Clearance' for enhancing the drop tank life from 500 to 3000 flying hours and to obtain the full certification.

Test set-up for LCA fuel drop tank under slosh and vibration loading

Evaluation and management of longitudinal force on substructures of railway bridges

CSIR developed an innovative technique for evaluating effect of longitudinal force on bridges. This was adopted in evaluation of various railway bridges for Research Designs and Standards Organisation (RDSO); East Central Railways, Bihar; IRCON International Limited, Patna; East Central Railway, Renukut, and Western Railway, Mumbai.

Safety audit of existing railway bridges under higher axle loads was also carried out. By ensuring the safety and serviceability of older bridges to carry heavier freights, Indian Railways could increase the axle loads of freight wagons. This also helps in rationalizing the existing provisions for the economical and sustainable design of bridges.

Field investigations on a through-type open-web girder bridge

Rail/road underpass construction techniques

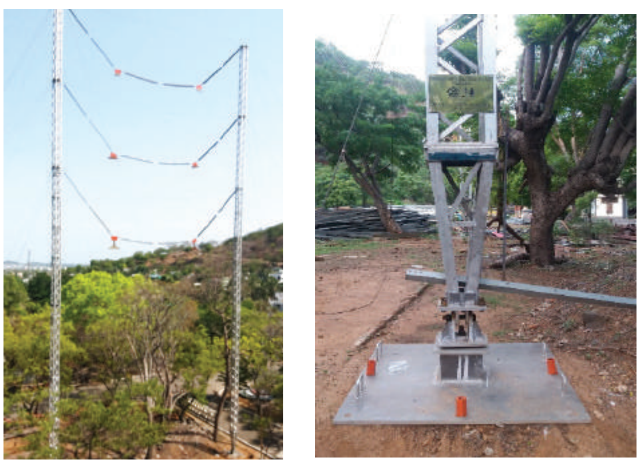
A technique has been invented for reinforcing or strengthening the soil at the box face during box jacking operations for construction of underpasses without disturbing the infrastructure on the ground. The developed technology was named as "Underpass with Box Pushing" which has been patented in five countries (Sri Lanka, Singapore, USA, UK, and India) and it has already been successfully implemented at 7 locations in the country (Yamuna Bazaar, Delhi; Apsara Border, Delhi; Sahibabad, Ghaziabad; Mahipalpur, Delhi; Gurgaon Haryana; Kota, Rajasthan; Pragati Maidan, Delhi).

The technologies being developed are: "Underpass Intersection", "Instant Ground Improvement" and "Multi-Level Underpass". The patents are also being filed for these technologies.

Underpass Constructed at Yamuna Railway Bridge in New Delhi

Emergency Retrieval System (ERS) for Power Lines

Power Transmission Lines (TLs) are infrastructural facilities of National importance, spanning several hundred circuit kilometres in length, transporting electricity from power plant to the distribution sub-station. Failure of TL towers due to natural calamities or manmade damages causes interruption in power transmission, which has severe repercussions. Permanent restoration of towers may take several weeks. Therefore, an indigenous technology has been developed for quick retrieval of the collapsed TL towers. Known as Emergency Retrieval System (ERS), this invention is the first of its kind in India, and forms part of 'Make in India' and Atmanirbhar Bharat initiatives.


Typical ERS for 400 kV Double Circuit Suspension Type TL Tower

The lightweight robust modules, easy to connect connections, easy to construct foundation and scalability features available in the invention enable faster installation of ERS at the site. The cost of the ERS is about 40% less than the available alternate imported systems.

Pre-engineered precast lightweight panels for mass housing

Precast lightweight large wall and roof panels using EPS for affordable housing has been developed. The lightweight panels consist of two reinforcement concrete skins with EPS as a core material. The sandwich panel is cast by pouring self-flowing concrete into the mould to form the bottom skin and EPS is placed as a core. On the top of EPS, self-flowing concrete is poured to form the top skin.

Key features include:

- Sandwich panels have low thermal conductivity, moderate compressive strength and excellent shock absorption ability.
- The lightweight panels cast using self-flowing concrete resulted in faster casting and better quality control.
- Building with sandwich panels results in two third weight reduction compared to the conventional ones (67% weight reduction without compromising structural efficiency).
- Amenable for prefabrication.


Demo building at CSIR-SERC


School building at KV, CLRI


500 houses for Hud-hud cylone victims at Andhra Pradesh

Mobile cold mixer cum paver

Mountainous and hilly areas in India suffer from poor road connectivity, which severely restricts economic progress. An adequate and long lasting road network is necessary for fulfilling strategic needs. However, conventional methods of road construction like hot mix asphalt may not be conducive to ecologically fragile hilly regions.

To alleviate this problem, 'Mobile Cold Mixer cum Paver (MCMP)' for construction of black top layers using bitumen emulsion based technology has been developed. This equipment is capable of onsite mixing and laying of bituminous mixes on prepared granular/old black top pavement surfaces. The prototype of this equipment was tested on site in Uttarakhand and its performance was found very good. The endeavour has effectively resulted in a green technology for construction and maintenance of roads.

Patch Fill – Pothole repair machine

Potholes are one of the most common types of pavement distress. They are a perennial problem for highway maintenance agencies because potholes are geographically spread out and repair work is costly as well as time-consuming. The pothole problem aggravates during the rainy season, and their repair becomes more difficult because of inclement weather and wet pavement surfaces.

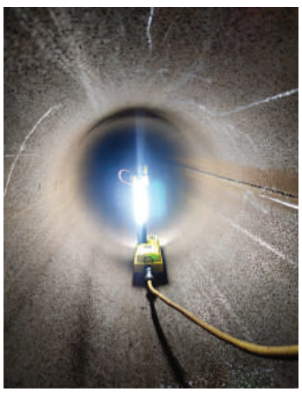
To overcome this problem, a compact and low cost Pothole Repair Machine has been developed indigenously, which uses bitumen emulsion based cold mix technology. This machine is self-propelled and self-contained, and can carry out cleaning of the pothole as well as placing of bituminous cold mix.

Mobile Bridge Inspection Unit (MBIU)

The technology has been indigenously developed to assess the health of bridges and received the Innovation Award (2017) by NRDC. Two licensees are producing commercially in India. Four units have been commercially produced and are serving in the field. The cost saving because of the indigenous MBIU unit is approx. Rs 180 lakhs compared to import cost of Rs. 250-340 lakhs.

Advanced & Smart Boiler Header Inspection Robot

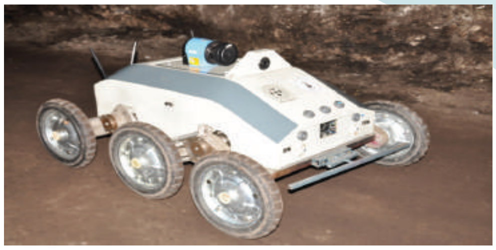
A remotely operated smart and advance robotic system for internal inspection of the boiler headers has been developed. It has provision for wider and 360° planner view. It can transmit data from the robotic system to the control console for real-time monitoring. It can be launched and retrieved safely during a mission or in case of breakdown or failure.



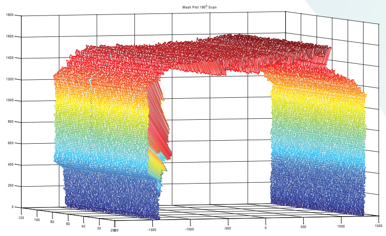
GUI View: Foreign bodies (S - 41/ Right-hand side)

Tele-operated Mining Robot (TMR)

- Six wheeled configuration for stable movement over rugged terrains.
- Obstacle avoidance capability for safe navigation in unstructured mine tunnels.
- Real time data transfer to the command control station for immediate monitoring.
- Multiple command control console for better utility and control by multiple operators.



Field Trial at Khottadih Colliery



Typical 3D Scanning data of Khottadih Colliery

Rural housing designs: PAHAL document

During 2017-28, the Ministry of Rural Development (MoRD) sponsored a project on the development of Rural housing designs. This resulted in the PAHAL Document containing 130 design templates for different geo-climatic and hazard zones of India for a cost effective housing scheme, utilizing locally available materials. The cost per square feet of 7 USD is a global feat worth emulating by many developing nations.

Structural Health Monitoring of Cultural Heritage

SHM of the vital structures and cultural heritage of India validates the role of support system, designed and introduced to take care of additional loads due to settlement and other problems. The Rashtrapati Bhawan is digitally preserved through a cloud data, coming out of a LIDAR study.

The CIE theme of CSIR has a marked presence in the re-engineering of the rich heritage assets of India. Noteworthy are the contributions in Kashi Vishwanath Mandir; Konark; structures of Islamic rulers like Taj Mahal; colonial structures like CST, Mumbai; Rashtrapati Bhawan, etc. A Centre of Excellence in cultural heritage has been established at CSIR-CBRI to conduct specialized testing and experimental activities on the conservation and preservation of cultural heritage of the country, with particular emphasis on stone and masonry structures, arches, and domes.

Landslide control measures

Landslide control measures implemented using CSIR's technology at critical hilly regions and transportation network have enhanced the productivity of mountainous states and have reduced the travel time of both humans and materials at many of the critical locations including those in the pilgrim routes of Chardham.

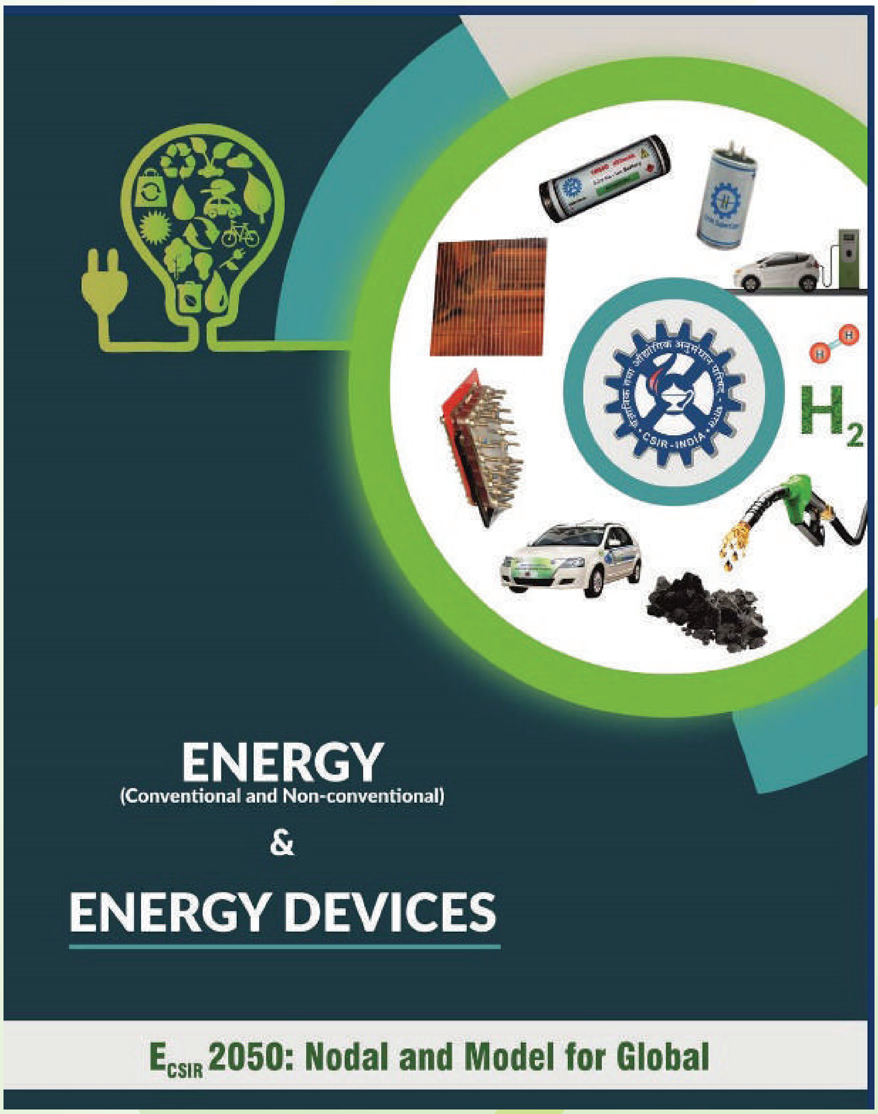
Acknowledgement

Former and present Directors of the CSIR-SERC, CSIR-CBRI, CSIR-CRRI, CSIR-CMERI and CSIR-AMPRI are duly acknowledged. Contributions from the scientists and sub-theme nodal scientists are also duly acknowledged.

CSIR's Mission on "Nodal to Model for Global" in Energy Sector

CSIR THEME DIRECTORATES

Dr N. Kalaiselvi
Director, CSIR-Central Electrochemical Research Institute (CECRI), Karaikudi
Theme Director [Energy (Conventional & Non-conventional) & Energy Devices: E2D]
(Dr N. Kalaiselvi has now taken over as the DG-CSIR)



THE International Energy Agency (IEA) ranks India as the world's third-largest energy-consuming country. The use of energy in India has doubled since 2000 (IEA, 2020). Coal, oil, and solid biomass constitute 80% of the energy supply in meeting the demand. Realising the growing energy demands and environmental concerns, India has made a tremendous effort in expanding renewable sources of energy, mainly solar power. It has set a target to achieve 450 GW of renewable power capacity by 2030 and in particular, solar power is set for drastic growth to match the share of coal in the power mix by 2040.

Today, more than 60% of India's industrial energy demand is met by the direct use of fossil fuels. The country is looking at low-carbon fuels, solid biofuels, and green hydrogen as substitutes for coal in many industrial and transportation sectors.

Green hydrogen can be produced by electrolysing water. There exists a potential market for green and blue hydrogen despite the higher upfront costs and pace of development. Recent years have witnessed the significant growth of fuel cell electric vehicles with hydrogen-based cells (TERI, 2022). Green hydrogen or low-carbon hydrogen will have major impact in reducing the CO_2 emission in the steel industries by adapting the direct reduction using hydrogen to produce green steel (TERI, 2021). Further, electrification of MSMEs that are the backbone of the Indian industry sector will save energy and minimise emissions (TERI, 2021).

The Government of India (GoI) revised and strengthened the commercial building Energy Conservation Building Code and launched Eco-Niwas Samhita, the energy conservation code for residential buildings in 2018 to use energy-saving methods through renewable energy sources. The Green National Highways Corridor project aims to develop eco-friendly National Highways. The Sustainable Alternative towards Affordable Transportation (SATAT) was launched in 2018 to increase the production of compressed biogas from waste/biomass sources as a transportation fuel (TERI, 2022).

As India enters into a dynamic period in energy development, in each of the above energy sectors the contributions of CSIR will play a crucial role in transforming the country into a self-reliant 'Atmanirbhar Bharat'.

CSIR – Energising the Nation

Through its programmes New Millennium Indian Technology Leadership Initiative (NMITLI) and CSIR Innovation Centre for Next Generation Energy Storage Solutions (ICeNGESS), CSIR has been demonstrating its role in the nation's energy sector, particularly on fuel cells and storage batteries. CSIR labs jointly played a major role in the recent launch of fuel cell cars.

Energy (Conventional and Non-conventional) and Energy Devices (EED) is one of the eight themes of CSIR in which 24 labs are working collectively to identify and address issues related to the energy security of the nation. The theme has the following six major sub-verticals:

- Coal Energy (including clean coal technologies/gas/gas hydrate)
- Petroleum/Bioenergy including Bio-waste to Energy
- Hydrogen Energy including Hydrogen Economy
- Energy Conversion and Related Devices
- Energy Materials and Energy Storage Devices
- Energy Management/Energy & Environment

Energy & Energy Devices – Key CSIR Technologies

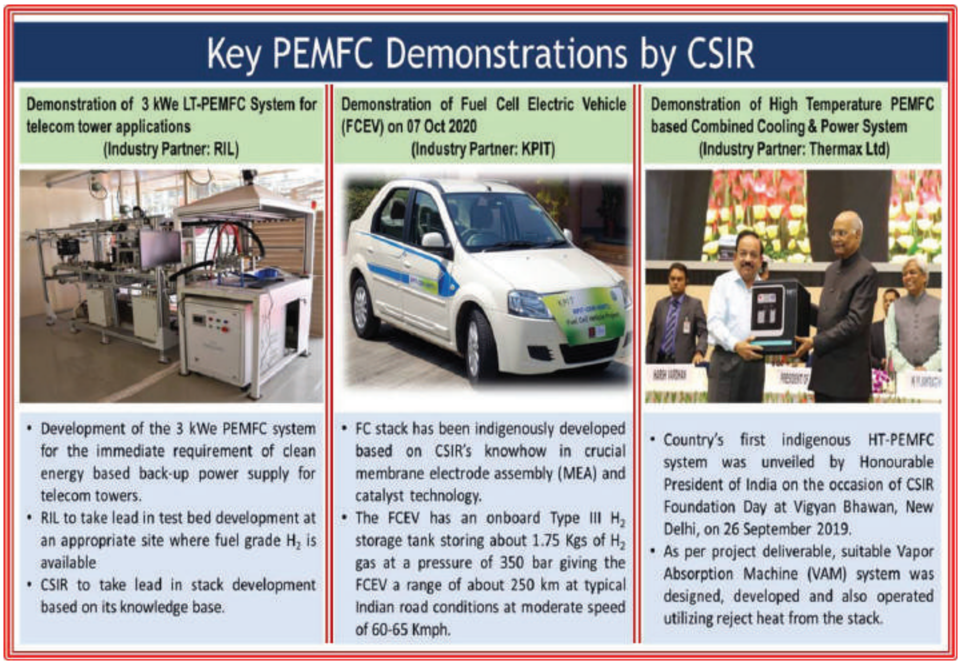
- Specialty optical fibers
- Virtual intelligence techniques for rehabilitation (VEERA)
- Industrial energy management system
- Induction motor and pump efficiency monitoring systems (IMEMS & PEMS)
- Finger gesture-based control module for intelligent patient vehicle
- Building energy management software (BEMS)
- Improved domestic cooking burner for PNG
- Semi-automatic equipment for large area dye-sensitised solar module fabrication
- Carbon composites bipolar plates for hydrogen-based fuel cell applications
- Technology for production of soft coke
- Technology for non-recovery type coke oven
- Drag-type coke oven with stamp charging and coke quenching
- Air conditioning efficiency meter (ACE meter)

The thematic activities focus on materials, methods, and devices for various green energy solutions by adapting energy-efficient processes. Over the years, pan-CSIR efforts have led to the development of various technologies and know-hows under the E2D theme.

Several technologies and know-hows in terms of materials and manufacturing related to lithium ion batteries, lead acid batteries, red-ox flow batteries, supercapacitor devices, etc. have been transferred to various Indian industries. Some of the R&D activities and technologies developed are presented here.

Coal Energy (including clean coal technologies/gas/gas hydrate)

- 1.5 TPD oxy-blown Pressurized Fluidized Bed Gasification (PFBG) pilot plant (TRL-6) for the conversion of coal to syngas; dedicated to the nation on November 17, 2020.
- Indigenous Gasification Technology is a milestone achievement towards the Methanol Economy Program of NITI Aayog.



- Novel membrane-based technology for direct extraction of hydrogen from coal.
- Commercial-scale development of hot stamping charging technology of coal for coke making.
- Mercury emission for coal sector, environmental impact, and its abatement.
- Certified Reference Materials (CRM) and standards for coal and solid biofuels.
- Pilot-scale production of bio-ethanol from food residue biomass (FORBI) and Municipal Solid Waste (MSW).
- Green hydrogen production via blue-green/green microalgae and bacteria by a combined fermentation process using versatile substrates.
- Microbial fuel cell technology.

Petroleum/Bioenergy including Bio-waste to Energy

- Technology for the production of renewable green aviation fuel from non-edible oils and used oils, and the patented catalyst for the production of energy-efficient, economical, and eco-friendly (<10 ppm sulphur, reduced NOx and COx) bio-aviation fuel will avoid the import of crude oil and save foreign exchange reserves.
- Indigenous, room temperature biodiesel process for converting vegetable oil (non-edible and used cooking oils) containing low Free Fatty Acids (FFA) to biodiesel at ambient conditions, which can also be used in high power sources like Gensets, power engines, agriculture-related equipment, etc. for the upliftment of the rural economy. A mobile unit (50 Lit/batch) has been set up at Dehradun. The demand to replicate this unit has been received from various state Biofuel boards, entrepreneurship, and the oil industry (like HPCL).
- Anaerobic Gas lift Reactor (AGR) is a high rate biomethanation technology developed by CSIR to treat organic solid waste for the generation of biogas and bio manure. The scale of operation is 250 kg to 10 tons per day and the technology is patented in India and abroad.
- Technology to convert plastic into petroleum products such as diesel, petrol, and other aromatic compounds. This technology not only helps in disposing of plastic wastes but will also result in generating revenue from it. The diesel produced will be of automotive-grade, meeting BS-VI specifications for use in vehicles.

Hydrogen Energy including Hydrogen Economy

CSIR has developed significant competencies and infrastructure along the hydrogen value chain in its various ongoing programmes. Aligning with the National Green Hydrogen Mission of India, CSIR has launched a green hydrogen technology development mission programme that aims to develop end-to-end technologies across all three parts of the hydrogen value chain – generation, storage, and utilisation.

The key outcomes of CSIR's programmes in this direction include India's first indigenous fuel cell car, first indigenous 5 kW scale PEM and SO electrolyser technologies, indigenous 2.5 kW power generation unit for telecom towers, indigenous hydrogen plasma smelting reduction reactor for steel making, and Indian coal gasification plant for syngas and hydrogen production. The focus of these programs is to develop technologies at a complete system level and to develop vendors in the MSME sector. The programmes have been executed in close collaboration with industries.

Energy Conversion and Related Devices

India is one of the countries with the most significant production of energy from renewable resources. According to the Bureau of Energy Efficiency, the electricity sector alone accounts for 34.6% of the total installed power capacity.

Among the photovoltaics, CSIR focuses on the emerging Dye-Sensitized Solar Cell (DSC) and Perovskite Solar Cell (PSC) for Indoor Photovoltaic (IPV) and Building Integrated Photovoltaic (BIPV) applications. Similarly, the concept of Agrivoltaics (AV) is receiving global attention due to the concept of dual-use for the same land area, i.e., for both agriculture activities and PV installation that increase land-use efficiency. Its implementation benefits farmers with dual income by generating both food and energy.

CSIR has developed competence in building equipment for the fabrication of efficient indoor light harvesting master plates and modules for DSCs. It is also involved in custom design and synthesis of new engineered dyes having a spectral match with artificial light sources, use of alternate cost-effective, earth-abundant, and non-corrosive copper complex electrolytes that can deliver more voltage and unique prototypes/products partnering with industry by integration of DSC indoor PV master plates and modules.

Some of the key technologies include:

- Third generation photovoltaics (DSCs & PSCs) for decentralised and off-grid energy harvesting applications
- Light sharing agrivoltaic technology
- Smart materials, devices, and window prototypes
- Planar optics for low concentration photovoltaics
- Si photovoltaic cells
- Thermoelectric materials and devices
- Conductive inks for photovoltaics and nanogenerators for self-powered electronics.

Energy Materials and Energy Storage Devices

The energy storage sector is a multi-billion dollar industry that provides economic growth for the country. Despite the huge demand for Li-ion batteries in India, the country still relies on import of batteries due to lack of indigenous technologies and commercial manufacturing units. This necessitates R&D to keep pace globally and also in-house battery technologies to meet the criteria for India-specific needs, especially for EV applications and to achieve the ambitious goal of building self-reliant India.

"CSIR Innovation Centre for Next Generation Energy Storage Solutions (ICeNGESS)" has been established as a state-of-the-art pilot plant facility for making cylindrical lithium-ion cells. The country's first-of-its kind facility will serve as a demonstrating platform with a vision to create avenues through Technical Incubation to encourage investors to start-up with new lithium-ion battery enterprises.

The ICeNGESS seeks to nurture and promote indigenous fabrication of lithium-ion cells, imparting training and hand-holding support, promoting indigenous supply chain driven business opportunities to private sector/industries, and offering know-how and transfer of technology. The project strives to make the platform ready for next generation energy storage devices such as sodium-ion batteries, supercapacitors, and the circular economy driven recycling/refurbishing possibilities of spent batteries to ensure their second life too.

Some of the focus areas in this sub-vertical are:

- Development of Li-ion Batteries (LIBs) for India-specific applications
- Development of Na-ion batteries for energy storage
- Design and development of high-performance Li-S battery for EVs & UAVs applications
- Development of rechargeable Zinc-Air batteries
- Development of redox flow batteries for storing large scale electricity
- Battery recycling, efficient recovery of metals from spent batteries, and circular economy
- Indigenous fabrication of supercapacitor device.

Energy Management/Energy & Environment

Energy efficiency and management are recognised as equally important approaches to cleaner energy generation. Energy management is targeted to significantly contribute to India's global commitment to climate change and also to reduce energy intensity.

CSIR is working in the domain of Integrated Energy Audit and Management and this would be further extended to Sustainability Management in the industry. This is being attempted following deep science-based integrated approach encompassing electrical, thermal, process, utilities, waste treatment systems, and other scientific interventions to reduce energy footprints.

Systematic energy audit and management efforts across CSIR labs will lead the team of certified energy auditors to take up industrial projects. Process-Energy-Environmental audit and management will be promoted for industrial energy and sustainability management. Further R&D activities will be explored to reduce the environmental footprint of energy generation as well as energy use by various scientific solutions including DRE applications, emission control, and waste management. The efforts are also in line with the Carbon Capture and Utilisation, and Storage (CCUS) activities.

Impact on Industrial, Economical & Societal Sectors

CSIR's R&D activities under the Energy (Conventional & Non-conventional) and Energy Devices theme have direct and indirect impacts on Indian industries, the country's economy, and on society. A close industrial connection is being established through the active participation of Business Development Groups in all CSIR labs to identify the needs of industries ranging from region-specific MSMEs to large-scale Indian and multinational companies/industries to understand their issues at the grassroot levels and to provide solutions.

India is a growing economy and often has to depend on import of some raw materials and certain products. The R&D activities are thus designed under E2D theme to enhance the effective use of available resources within the country to avoid imports. Such import substitute activities will result in indigenous technologies to address the India-specific and region-specific issues. Also, through nurturing and supporting MSMEs, the overall economy will be supported.

India has the highest percentage of young population in the world. CSIR labs working under the Energy and Energy Devices (E2D) theme are tapping the young and training them to position the country with global competence in various energy sectors. Under CSIR's Skill Development Programme, Jigyasa, Connect with Scientist, etc. the focus is on creating awareness among school and college students about renewable energy resources, environmental impacts, etc. and providing hands-on training in operation and maintenance of various battery technologies, solar cells, etc.

The recent successes realised, the technologies developed and forecast in the Energy and Energy Devices theme show the promising and potential role of CSIR in making India a self-reliant nation and also a model in the energy sector in the global arena.

CSIR THEME DIRECTORATES

Leadership in Mining, Minerals, Metals and Materials @CSIR

Dr I. Chattoraj
Director, CSIR-National Metallurgical Laboratory
Theme Director, Mining, Minerals, Metals & Materials

THE Council of Scientific and Industrial Research (CSIR), was the first to set up domain specific research organizations in the country in various areas. The Central Glass and Ceramic Research Institute (CSIR-CGCRI), Kolkata, was the first of its kind for ceramic research and so was the National Metallurgical Laboratory (CSIR-NML), Jamshedpur, for research in metals. The erstwhile Central Fuel Research Institute (CFRI), Digwadih, and the erstwhile Central Mining Research Station (CMRS), Dhanbad, were pioneers in coal research and mining research, respectively. The latter two institutes have now been merged into one entity known as Central Institute for Mining and Fuel Research (CSIR-CIMFR).

A host of regional research laboratories across the country (in Bhubaneswar, Trivandrum, Bhopal, Jorhat, etc.) which later on evolved as National Institutes, complemented the research efforts in the four areas of Mining, Minerals, Metals and Materials (collectively called 4M).

CSIR had established Indian pioneership in diverse sub-areas and domains of 4M. In the late 50s, optical glass was produced in only a few countries of the world and its production technology was kept a carefully guarded secret. CSIR-CGCRI developed this glass without any foreign collaboration. The Institute's indigenous pilot plant with an annual capacity of 10 tonnes went into production in 1961 and opened up new vistas in the field of optical industries in India.

Since the early sixties, CSIR-NML's contributions to the development of the ferroalloy industry were phenomenal. Calcium-Silicide was produced for the first time in India (1975-76) at CSIR-NML in a 500 kVA submerged arc furnace pilot plant. The first production of sponge magnesium anywhere in India happened in late 60s at NML. The magnesium pilot plant was commissioned in February 1972 and was dedicated to the country by Shri Mohan Kumaramangalam, Union Minister for Steel and Mines, in November 1972. High purity magnesium (99.9%) was successfully produced in tonnage quantities and the sponge magnesium was subsequently melted and alloyed at a pilot scale. The establishment of Asia's largest creep laboratory (at that time) at CSIR-NML, for uninterrupted long term testing at elevated temperatures was a major milestone in the scientific history of India.

In the 80s, CSIR-CGCRI was one of the first Indian entrants in the field of optical fibre for telecommunications, sol-gel processing of glass and ceramic materials, production of glass fibre based composites and application of ceramic materials in electronics.

CSIR-CFRI carried out seminal research in petrography, coal surface chemistry, adsorbents and development of beehive coke oven.

The pioneership and high benchmarks set by the early researchers in the different CSIR institutes and laboratories are being emulated today, and some of the outcomes are presented here.

Mining Research

For more than 70 years, CSIR-CIMFR has been studying mining methods, rock mechanics and ground control issues encountered during mining activities and has developed valuable indigenous norms, formulations, and technologies through laboratory and field investigations, numerical simulations and stability analysis that increase the safety as well as productivity of opencast and underground mines. CSIR-CIMFR has helped almost all large opencast mines in India by designing slopes of benches, highwall and overburden to their optimum levels.

CSIR-CIMFR has contributed significantly to the classification of Indian geo-mining conditions and the introduction of effective ground reinforcement systems leading to significant improvement in the safety, production and productivity of underground mines in India.

Failure criterion for Indian coal and coal measure rocks, and equivalent material mine modelling techniques are some of the classical works developed by CSIR-CIMFR that are widely practised not only in the country but also abroad. The Institute has played a key role in the development/adoption of the wide stall method, underpinning based simultaneous extraction of contiguous seams under fragile parting, and cross-development based extraction, shortwall method and blasting gallery method for optimum extraction of thick seams and locked up coals in pillars in the country.

The Institute has also contributed to the successful implementation of mechanized methods in mining technologies in India. The Institute has recently ventured into the new areas of converting physical mines into 3D virtual mines embedded with sensors, IoT devices, wireless communication, Artificial Intelligence (AI), monitoring and control devices.

CSIR-CIMFR has made pioneering contributions to the fundamental understanding of Indian coals for various fuel and non-fuel applications. Under the leadership of CSIR-CIMFR, various other sister laboratories (CSIR-NML, IMMT, IICT) are involved in coal-core characterization for Indian coals. To increase productivity, quality of coke and use of inferior coal for coke making, CSIR-CIMFR has developed a machine for stamp charging of coal in non-recovery coke ovens with a coke quenching system. CSIR-CIMFR has also developed a 1.5 TPD pilot plant for oxygen enriched Pressurized Fluidized Bed Gasification (PFBG).

Oxygen-enriched air blown pressurized fluidized bed refractory lined gasifier at CSIR-CIMFR

Minerals Research

- A unique 100 tpd pilot plant at CSIR-NML allows large scale piloting of minerals processing protocols.
- In the areas of mineral beneficiation, both CSIR-NML and CSIR-IMMT have carried out extensive campaigns. CSIR-NML has completed more than 800 flow-sheet developments till date which has included almost all minerals of India with an exhaustive Indian clientele as well as foreign sponsors from four different continents.
- CSIR-IMMT has developed a novel indigenous technology to utilize low/lean grade iron ores for steel production.
- CSIR-IMMT and CSIR-NML have developed technologies for the beneficiation of tungsten from Hutti gold mine tailings, containing only about 0.02% WO_3. Li beneficiation, from indigenous sources containing low amounts of Li, has been completed through a CSIR mission mode programme involving several laboratories. The processes developed are not economically viable yet, this was a pre-emptive exercise to establish technology readiness if there are supply chain disruptions, or if higher grade primary resources are imported.
- Water is extensively used in most mineral beneficiations. To reduce or even eliminate the need for water, CSIR-NML has successfully demonstrated dry beneficiation of coals to Coal India Limited. This has so enthused the organization that they are now planning to set-up a large scale pilot plant onsite for the same.
- Ilmenite forms the largest constituent of Indian beach sand deposits (~348MT). The heavy mineral rich deposits in beach sands around the town of Chavara in the southern part of India are characterized by ilmenite with higher TiO_2 contents, often exceeding 60 wt.%. CSIR-NIIST aims to employ microwave energy for heating of ilmenite minerals during their processing and beneficiation. Microwave-assisted reduction has significantly decreased the quantity of acid used in subsequent treatments enabling green process technology.
- Agglomeration of fines and slimes is another important activity where CSIR has contributed significantly. Palletisation of high LOI and high blain iron ore has been established by CSIR-IMMT, while micro-palletisation, pellet-sinter composite, briquetting of fines with alternate binders has been carried out for industrial sponsors by CSIR-NML.
- For mining 10 carats of diamond approximately 100 tons of kimberlite waste/tailing is generated. Kimberlite containing silica and magnesium compounds as major components coexists with iron and titanium oxide. CSIR-CSMCRI has developed a process to recover magnesium as magnesium chloride with silica-rich residues. This silica-rich residue was used to prepare sodium silicate solution, the sodium silicate solution was further used to produce precipitated silica and Zeolite-A. The process was demonstrated to National Mineral Development Corporation (NMDC), using pilot plant facilities at CSIR-CSMCRI.

Metals Research

Metals research, in volume and number, is possibly the most important vertical in 4M. The constituent institutes have addressed all issues of metals research including Extraction, Refining, Casting & Forming, Post-processing and Recycling.

Extraction and Refining of Metals

The three main areas of extraction, namely, Pyrometallurgy, Hydrometallurgy and Electrometallurgy, are all practised with rigour. Production of various ferro-alloys for industrial sponsors including Ferrosilicon, Ferrovanadium and Ferrochrome, have been completed for industrial sponsors at CSIR-NML with its 500 KVa submerged arc furnace.

CSIR-IMMT has developed several protocols for metals recovery from polymetallic sea nodules, a strategic material. The first and only pilot scale production of Sodium was possible through CSIR-NML developed technology.

A wear-resistant steel was developed in-house at CSIR-NML to address the silt erosion problem for hydel power plant components, located in the Himalayas. An abrasion resistant steel was also developed for grinding media and was successfully utilized by the client. The present thrusts are on development of advanced automotive steels including steels for e-vehicles. Quench and partitioned steels, very high strength steels and multi-phase steels are being researched in collaboration with different steel majors. The use of Plasma for steel development has been researched at CSIR-IMMT. The use of hydrogen for DRI steel making has been taken up by the latter.

In the domain of refractories, CSIR-CGCRI is pioneering the development of low carbon MgO-C refractory for clean steel production to minimise the carbon pickup from the refractories during refining. DRI steel making using tunnel kilns was a novel concept proven at plant site by CSIR-NML.

Hydrometallurgical extraction of various costly or strategic metals has been carried out at CSIR-IMMT as well as CSIR-NML. The latter two laboratories have also collaborated to develop a better process for Mn extraction. Extraction of Nd from neodymium oxide using molten salt electrolysis is underway at CSIR-IMMT. Gd, produced through electrolysis by CSIR-NML was supplied to DAE.

Casting and Forming

CSIR-NIIST has established a pilot scale squeeze casting facility for the manufacturing of near-net shape aluminium alloy components for strategic and automotive applications. Squeeze casting technology has wider scope for manufacturing high strength-high integrity aluminium alloy components such as steering knuckle, control arms, hub, brackets, piston, etc. Various industries and user agencies such as WABCO India Limited, Atlas Copco, Belgium, ADE & GTRE (DRDO), VSSC (ISRO), Sivakasi and Roots cast, Coimbatore, are collaborating in the product development for their applications.

Through the use of in-house rolling mills, extrusion press, large forging hammers, in conjunction with simulation devices like the Gleeble, FLD machines and in-house developed annealing simulators, a host of advanced steels have been developed for industrial sponsors, or improved upon, at CSIR-NML in association with industrial partners.

CSIR-AMPRI has been a leader in recent developments on production of metallic foams. These foams are used for a variety of applications especially in the automotive and defence sectors.

Pilot scale Squeeze Casting Facility at CSIR-NIIST

Post processing

CSIR-NML hosts the Hot Dip Processing Simulator (HDPS), possibly the only one active in the country. The instrument simulates galvanising as well as annealing processes, and has been instrumental in the development of automotive grade steels as well as in the development of new coatings. Various CSIR institutes have been working on and have developed advanced coatings including superhard, superhydrophobic and self-healing coatings, for wear and corrosion resistance, and, functional coatings like conductive and anti-bacterial coatings.

Recycling

To address the immediate needs of the country, especially defence needs, CSIR-NML has developed and commercialized a technology for the recovery of tungsten from a large variety of W-bearing scrap. The technology is superior in terms of tungsten recovery (> 90% with co-recovery of associated metals like Co and Ni), process economics and environmental considerations. CSIR-NML is also spearheading Li extraction from secondary resources (end of life batteries) with significant success.

Similarly, in the matter of Rare Earth elements, substantial efforts have been made to exploit secondaries, including a variety of urban ores like discarded computers, cell phones, magnets, CFLs, etc. Additionally, strategic metals valorisation from diverse industrial wastes, like spent catalysts, are being carried out. A dedicated urban ore recycling centre has been created and is in operation. Several technology transfers in valorisation of urban wastes, especially with regards to extraction of Li, Co, Ni, REEs, have happened over the last five years.

Solid wastes and effluents are of major concern in metallurgical industries. Large quantities of solid wastes (slimes and fines during iron ore mining, slags, mill scales) and effluents, like pickle liquor, are generated during iron and steel making operations. CSIR-NML has developed a number of processing options and value added products to address the problems. Some of these have been tested in real plant conditions and include:

- DRI from slimes/mill scale using tunnel kiln;
- Mill scale briquettes as coolant in LD converter usingslimeand Jhama coal; and
- Magnetite for heavy media separation using high purity hematite produced during pickling operation as raw material.

In yet another significant development, technologies have been developed and tested for the production of a wide spectrum of value added iron oxide pigments.

CSIR-IMMT, Bhubaneswar has developed an innovative process of mineral polymerization for effective utilization of various industrial and mining wastes in manufacture of cold setting building bricks. This process has been adopted commercially in MSME sectors and in major industries for the manufacture of cold setting building brick containing up to 70% fly ash.

CSIR-AMPRI has similar programmes on valorisation of fly ash and red mud. Radiation shielding materials have been developed by CSIR-AMPRI using industrial wastes. A Niti Ayog catalysed project with three industrial partners (Hindalco, Nalco and Vedanta) is being executed by CSIR-NML and CSIR-IMMT along with JNARDDC, Nagpur, for holistic utilization of red mud, an aluminium industry waste. CSIR-IMMT has developed the technology for the production of alum crystals/blocks from waste aluminium dross.

Tungsten extraction from scraps: Commercialized CSIR-NML technology

Materials and Devices

While "materials research" is a catchall phrase, the emphasis in the constituent CSIR laboratories in 4M has been on Advanced Functional Materials, Biomaterials, Optical Materials and Device developments. A plethora of materials development and their conversion to applications has happened across CSIR.

- Graphene from natural resources was developed by CSIR-NML and on the basis of that development Tata Steel has been able to make significant impacts in the commercial graphene markets.
- CSIR-CGCRI is involved in the development of tungsten-oxide graphene nano-composite thin films for electrochromic display, white light emitting composites for energy efficient W-LEDs and silicon carbide based materials for direct white light emission applications.
- CSIR-CGCRI has also developed high piezoelectric coefficient composites for application as flank array sensors, which are used for long range passive detection, classification and localization of targets in deep waters.
- The same institute has also indigenously developed Thulium laser for use in surgical instruments.
- Radiation shielding glasses for nuclear installation as well as for hospitals have been developed and licensed by CSIR-CGCRI as well as CSIR-AMPRI.

Test bed system for generating 500W CW power lasers

Thulium fibre laser module

Thulium Laser development at CSIR-CGCRI

- CSIR-NAL has been an Indian pioneer in shape memory alloy developments.
- Special ceramic materials for radomes have been developed at a pilot scale by CSIR-CGCRI.
- CSIR-CSMCRI has developed a process using Wollastonite to manufacture lightweight thermal insulation blocks and pipes for the steam pipeline. CSIR-IMMT has developed electrolytic-membrane technologies for the recovery of value-added products.
- CSIR-CGCRI is an Indian leader in developing medical instruments and devices. The institute has contributed towards designing, developing and manufacturing biomaterials and implants for patients at an affordable cost, through fabrication of osteoconductive PAEK composites by reinforcing bioactive ceramic/ glass fillers; evaluation of mechanical properties of developed PAEK composites; evaluation of vitro biological properties of selected optimized composites and preclinical evaluation-of osteoconduction and osteointegration properties of developed composites.
- Structural Health Monitoring (SHM) is an area of expertise for CSIR, both for infrastructures as well as for industrial components. Having one of the best mechanical testing capabilities in the world as well as one of the most comprehensive non-destructive evaluation capabilities has made CSIR-NML a leader in industrial structural health monitoring and component integrity evaluation. In addition to providing critical inputs to industries, the failure investigation and rejuvenation programmes at CSIR-NAL and CSIR-NML have been of great value to Indian Defence. To improve and expedite SHM, a number of devices have been developed. A number of sensor materials as well as sensors have been developed for process control as well. Amorphous alloys have been developed and used in sensors and other applications, by CSIR-NML.
- CSIR-CGCRI has been at the forefront of Fibre-Bragg Grating (FBG) developments. In collaboration with CSIR-NML, various applications of FBG sensors including temperature profiling of continuous casting moulds, have been perfected. Real time sensing of the temperature profile of billet moulds along with "breakout" prediction was done for the *first time in the world*, at Tata Steel, using CSIR technology. An NDT device for detecting defects in wires during fabrication has been developed and installed at the sponsor's site, by CSIR-NML.

Zincometer, for online coating monitoring, developed by CSIR-NML and installed at Tata Wires

Epilogue

Since their respective inceptions, the constituent laboratories and institutes of CSIR, involved in 4M research have been striving for holistic technology developments. The vision has been recalibrated with the need for sustainable developments. The current trends and future thrusts of research and development in 4M areas are in concert with the national needs, societal upliftments and human resource skilling. In short, CSIR has stamped its leadership in metals, mining, minerals and materials research in India, achieving international benchmarks in many domains.

Acknowledgements

The information and advice provided by directors of different CSIR laboratories and their colleagues are gratefully acknowledged.

CSIR THEME DIRECTORATES

Towards Healthcare For All

Dr Ram Vishwakarma
Theme Director, Healthcare
Dr Preeti Srivastava
Innovation Management Directorate, CSIR HQ

THE vision of CSIR's Healthcare Theme is "Invent, adapt and deploy the latest bio-innovations, tapping into modern technology and traditional knowledge to make healthcare in India affordable and accessible, ensuring physical and mental wellness."

Some of the Grand Challenges identified under this theme are:

(i) **Genomic Route to Preventive Healthcare (GRouP-Health):** Design diagnostics based on genomic information unique to the Indian population and carry out extensive analysis, preferable in the regions where there is evidence for high genetic disease burden.

(ii) **Medicines of Tomorrow (MeT):** The challenge lies in integrating existing cutting-edge technologies and creating exponentially greater capacity to provide precision medicine that addresses currently intractable problems in human health.

(iii) **Pushback Infections (PIn):** Despite the tremendous gains made through vaccines and drugs, people around the world find themselves still fighting some of the same old diseases: tuberculosis, malaria, viral infections (flu, dengue, encephalitis), etc. CSIR's Healthcare Theme has identified the need to draw new strategies and new approaches if we are to make any further progress, leave alone win the battle.

(iv) **Nutritional India [NuIndia]:** The role of micronutrients in health and disease is getting realised. Several forgotten micronutrients having small daily requirement present risk for common diseases. This extremely important challenge can be addressed by multiple CSIR labs. Capability exists to take indigenised approach – to do what is needed for our population and from our natural means.

(v) **Knowledge Integration with Translation [KIT]:** This is a big impact making activity of connecting our knowledge to societal needs, hand holding industry and entrepreneurs to rise to the needs of the society, being the prime goal of it.

CSIR Strength in Healthcare

CSIR has a legacy of some major laboratories that have been working in the area of Healthcare leading to generation of knowledge, technologies, and products. These laboratories have been playing critical roles at different junctures of the country's independent journey by tackling seemingly intractable national health problems.

The laboratories playing a major role in the CSIR Healthcare Theme Directorate include:

- CSIR-Central Drug Research Institute (CSIR-CDRI), Lucknow
- CSIR-Indian Institute of Integrative Medicine (CSIR-IIIM), Jammu
- CSIR-Indian Institute of Chemical Biology (CSIR-IICB), Kolkata
- CSIR-Centre for Cellular & Molecular Biology (CSIR-CCMB), Hyderabad
- CSIR-Institute of Microbial Technology (CSIR-IMTech), Chandigarh

Healthcare – Major Highlights

Some of the significant developments in the Healthcare Theme Directorate of CSIR with major impact on the health scenario in the country include:

CSIR-CDRI

- Has developed a unique model for modernised drug research in India – having everything under one roof, from synthesis, screening, development studies, process up-scaling to clinical studies.
- Developed 12 new drugs, of which, Arteether (Brand Name: E-mal), BESEB (Brand Name: Memory Sure), Centchroman (Brand Name: Saheli) are currently in the market.
- Transferred more than 130 indigenous technologies to the pharmaceutical companies, a significant contribution in the metamorphosis of the Indian Pharma Industry.

CSIR-IIIM

- Core mandate to discover new drugs and therapeutic approaches from Natural Products, both of plant and microbial origin.
- Has discovered novel pharmacologically active natural products from plants and microbial species and translated them into drug leads and candidates by medicinal chemistry, preclinical pharmacology and clinical development.
- Carries out preclinical and clinical validation and establishment of mechanism of action of drugs used in various Indian systems of Medicines (Ayurveda, Unani, Siddha and other Indigenous systems of medicine).
- Developed agro-technologies for commercial cultivation of high value medicinal and aromatic plants from Western Himalayas including Kashmir Valley and Ladakh for national and international markets.

CSIR-IICB

- Conducted basic research on infectious diseases, specifically leishmaniasis and cholera, along with the development of technologies for the diagnosis, immune-prophylaxis, and chemotherapy of diseases.
- A neurobiology group is involved in research on the development of the vertebrate brain and also the genesis of human movement disorders.
- Bioactive substances from natural sources and chemically synthesised new molecules are being explored as potential drugs.
- Other areas being actively pursued are gastric hyperacidity and ulcer, muscular dystrophy and related disorders, macromolecular structure function analysis, development of targeted drug delivery systems, sperm biology and protein chemistry and enzymology.
- Developed an oral vaccine for cholera, herbal products for controlling gastric ulcer, empirical treatment for vitiligo, diagnostic kits for malignancy and hormonal disorders, fungal enzymes of industrial importance, radiopharmaceuticals for evaluation of the functional status of renal and hepatobiliary systems and a device for early detection of Parkinson's disease.

CSIR-CCMB

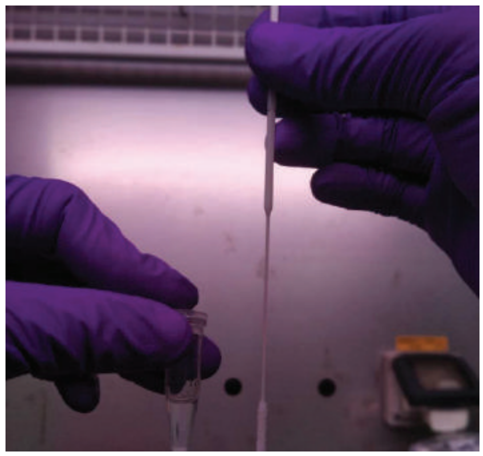
The mandate of the institute is to

- Provide integrated R&D and design base for microbial technology
- Develop and maintain gene pool resources and genetic stocks of microbial cultures and other cell lines
- Establish facilities for design of process equipment and bioreactors
- Impart training in microbiology, microbial technology and biochemical engineering
- Develop capabilities for producing design and engineering packages for industrial plants.

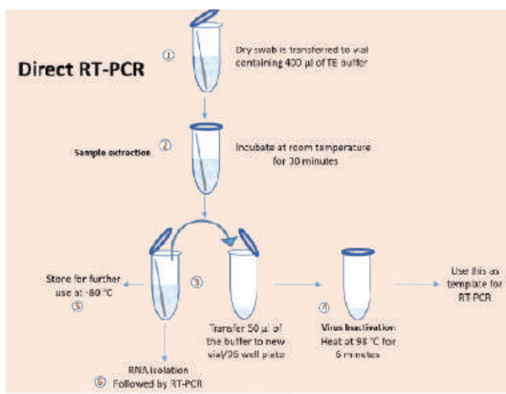
Healthcare – Significant Current Achievements

- **Genomic Sequencing (INSACOG):** CSIR labs have been at the forefront of the sequencing of the SARS-CoV-2 viral genomes since the beginning of the COVID-19 pandemic. Currently, they are active contributors to the Indian SARS-CoV-2 Genomics Consortium (INSACOG) that has been put in place for genomic surveillance in the country. CSIR has been instrumental in deciphering and identifying the variants of concern in the country and identification of the 'Indian variant' identified in Maharashtra. CSIR labs have the capacity and capability to scale up the sequencing with industry partners such as Syngene and Illumina.

  CSIR-IGIB in collaboration with the Cambridge Institute of Therapeutic Immunology & Infectious Disease (CITIID), Cambridge, UK; Department of Medicine, University of Cambridge, Cambridge, UK; University College London, London, UK; National Centre for Disease Control, Delhi, India; MRC-Laboratory of Molecular Biology, Cambridge, UK and many others have done pioneering work on SARS-CoV-2 B.1.617.2 Delta variant replication and immune evasion.
- **Dry Swab-RNA Extraction Free-Direct RT-PCR:** A diagnostic method has been developed by CSIR of collecting nasal swab in dry mode (Dry Swab) and direct RT-PCR without the step of RNA isolation. The RNA isolation is the most cumbersome, expensive and lengthy step of the diagnostic. Omission of RNA isolation and proceeding directly to RT-PCR gives comparable results to routine RT-PCR and this method has been approved by ICMR. The later step of the diagnostic uses ICMR approved kit. This method developed by CSIR particularly helps in transportation and sample handling and cuts down the time and cost significantly, also eliminating inventory requirements related to RNA isolation and Viral Transport Media while enhancing the safety of testing personnel from infected samples that might have leaked in transit. It is being implemented routinely in CSIR-National Environmental Engineering Research Institute based in Nagpur, which has tested thousands of samples using this method. Currently, unlike many others it is able to perform RT-PCR with a short turnaround time. It has also been developed into a complete kit with Apollo Hospitals.

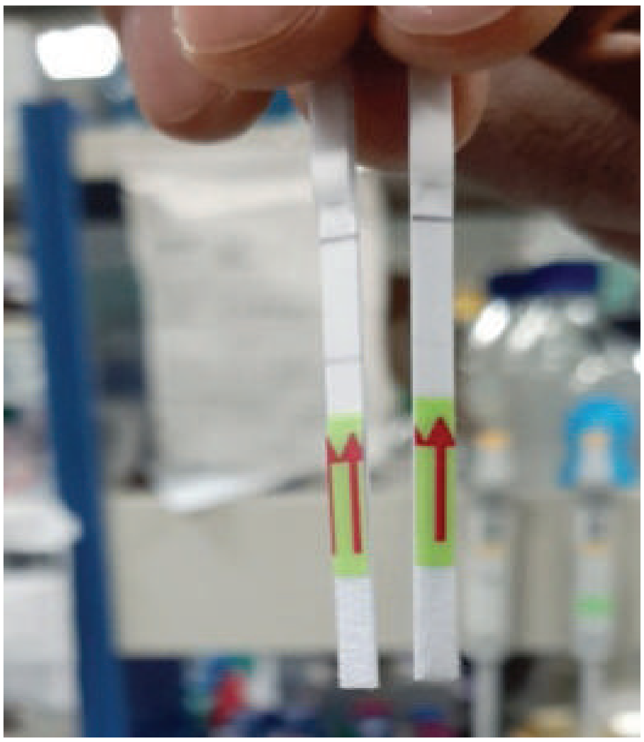


Dry swab and reagents for carrying out the test in a tube



Schematic for dry swab RNA extraction free coronavirus

- **FELUDA:** FnCas9 Editor Linked Uniform Detection Assay. The CSIR FELUDA indigenous CRISPR diagnostic technology is a novel paper based visual detection with broad reach, simpler and with less set up cost. It has been developed approved by the ICMR. This technology has been licensed to TATA Medical and Diagnostics and is now available in the market. It has accuracy similar to real time PCR and is as fast as cartridge-based tests (CBNAAT), and does not require quantitative (q) PCR machines. It has manual versions requiring minimum infrastructure capable of hundreds of tests per day, as well as an automated robotic line that costs less than a qPCR machine but can do thousands of tests per day. These have been deployed in vans. States can take advantage of such high throughput automated testing vans to rapidly increase capacity where needed during outbreaks and there is no other comparable solution currently.



- **Ready to Eat Food**: CSIR labs have developed many nutritious and ready-to-eat food that are rich in micro nutrients and protein to overcome deficiencies. These range from *dal khichdi* to rusks to spirulina chikkis, Iron and Zinc Enriched Spirulina (nut and chocolate bars), Multigrain Protein Mix, etc. These are chemical and preservative free and remain preserved for 12 months. Most importantly the ready-to-eat food reduces the manpower and minimises the inventory requirements at hospitals. During the pandemic, several tons of ready-to-eat food was provided to migrants, patients in hospitals and other places. The technologies have been licensed to many MSMEs and industries.

Launch of ready to eat food products made by CSIR labs

- **Sewage Surveillance:** A method of surveillance of sewage samples for the presence of SARS-CoV-2 has been established by CSIR-CCMB. This is based on the fact the SARS-CoV-2 infected persons (both symptomatic and asymptomatic) shed the virus in stools which can be detected in the sewage. This has been successfully tested at Hyderabad and many other cities in India and correlates well with the serological survey conducted in cities. CSIR along with DST and the Ministry of Housing and Urban Affairs has developed a National Plan for sewage surveillance across the country.
- **Aarogyapath National Healthcare Supply Chain Portal:** “Aarogyapath” has been developed by CSIR to fill the critical gaps in last-mile delivery of patient care within India via improved availability and affordability of healthcare supplies. It aims to provide real-time availability of critical healthcare supplies and serves manufacturers, suppliers and customers. The integrated public platform that provides single-point availability of key healthcare goods can be helpful to customers in tackling a number of routinely experienced issues. It also helps manufacturers and suppliers to reach a wide network of customers efficiently, overcoming gaps in connectivity between them and potential demand centres like nearby pathological laboratories, medical stores, hospitals, etc. It is now hosted on the National Health Portal of the Ministry of Health and Family Welfare.
- **Truenat (MicroPCR):** CSIR-NMITLI supported the development of the Truenat (MicroPCR) device for the diagnosis of many diseases. The device now tests the presence of corona infection. A multiplex assay combining E-gene screening and Orf1a-gene confirmatory assay has been developed. A total of 3000 devices are currently operational in 530 districts of India. More than 3 million

tests have been run on Truelab workstations so far. This innovative affordable COVID-19 testing platform has been a game-changer for testing in primary healthcare facilities of the country and quick testing in emergency departments of healthcare facilities in India.

- **Antiviral Mission:** The primary objective of the CSIR-Antiviral drug development initiative is to develop safe and effective antivirals (small molecules as well as biological i.e. therapeutic antibodies) to combat emerging variants of SARS-CoV-2, and to build sustainable platforms for targeted drug discovery and development creating a robust pipeline of active molecules against other viruses with pandemic potential. The key USPs of these antivirals will be their efficacy through oral/ intranasal or IV routes; can be taken preferably at home early in the course of infection and would prevent transmission of the virus during infection surges in hospitals and communities. The consortium will support the most promising antiviral candidates and support their preclinical and clinical development & production to accelerate drug development for COVID-19 and related viruses with pandemic potential, such as the viruses from paramyxoviridae, bunyavirales, picornaviridae, filoviridae, togaviridae, and flaviviridae families. CSIR has signed an agreement with a leading pharmaceutical company, Mylan Labs Ltd, Hyderabad, which has provided a fund of Rs. 15.00 Cr for this programme.
- **CSIR-NMITLI supported clinical trials of Sepisvac:** CSIR has supported Cadila Pharmaceuticals under CSIR-NMITLI for conducting clinical trials to evaluate the efficacy of an existing gram-negative sepsis drug, called Sepisvac for COVID-19 patients. The drug now is being tested in Phase-III Clinical Trials for three different categories of COVID-19.
- **Alhydroxiquim-II adjuvant system**: Bharat Biotech International Limited (BBIL), Hyderabad is using adjuvant system called "Alhydroxiquim-II" to boost the immune response of Covaxin under a licensing agreement. In order to produce the vaccine in bulk scale, BBIL required imidazoquinoline molecule in larger quantities as part of the adjuvant component. BBIL approached CSIR-IICT to develop a scalable and cost-effective process to make this molecule in the desired quantities. The molecule (IMDG) is a heterocyclic, complex molecule and has critical synthetic transformations to achieve purity and manufacture the molecule on the required scale. CSIR-IICT took the challenge and successfully delivered the molecule using indigenous chemicals. The same is being used in the production of Covaxin.
- **mRNA-based platform for vaccines and therapeutics**: Considering the success of mRNA Vaccine for prevention of COVID, CSIR-CCMB along with CSIR-IICT, CSIR-IICB, CSIR-IMTech, CSIR-NIIST, CSIR-IGIB and CSIR-IIIM is working on mRNA-based platform for vaccines and therapeutics. The aim of the project is to develop an In Vitro Translation (IVT) platform to produce mRNA and formulate lipid nanoparticles for vaccine purposes. The platform focuses on spike protein of delta variant of COVID and explores the suitability of the platforms for other bio-therapeutics.
- **Spike Protein-based Vaccine**: CSIR-IMTech, Chandigarh is working on Stabilised Prefusion Spike Protein-based Vaccine Design for COVID-19. Aurobindo Pharma is interested to take the project forward once the stable cell line-based expression process is ready (ongoing work), along with preclinical immunogenicity and efficacy (Viral neutralisation, Transgenic Mice/ Hamster or other suitable model) data.
- **API Mission**: Under the COVID API Mission, CSIR has developed technology for Remdesivir and Favipiravir which have been transferred to industry. The CSIR intervention in the area has made these drugs accessible and affordable to common people.
- **Drug Discovery:** Orally active fracture-healing molecule CDRI S007-1500, Novel anti-osteoporosis candidate CDRI-99/373, CDK9 inhibitor for metastatic pancreatic cancer-IIIM290 are ready for the clinical trials. IIIM-160, a dual IL-6/anti-nociceptive, an IND application to DCGI has been filed under phytopharmaceutical mode.
- **Medical-grade Oxygen (MO_2)**: The COVID-19 pandemic has highlighted the need of distributed Medical-grade Oxygen (MO_2) generation capability for the Indian market. Typical demand is 5-20 Litre per Minute (LPM) per patient, depending upon the severity of the respiratory distress. Given the large requirements in hospitals, in-house generation of medical grade Oxygen offers independence from external parties and eliminates the risk and difficulty of handling bulky cylinders. CSIR-IIP has developed the technology for Medical Grade Oxygen device. The design is scalable and process packages are ready for 100-500 LPM plants. Currently, 120 units are being supplied across the country with funding from PMCares. In addition, 35 units are being supplied to different agencies.
- **Air Duct Disinfection System**: CSIR-CSIO has designed the UV-C Air Duct Disinfection System as a retrofittable unit into existing HVAC Air Ducts using customisable sliding mechanisms. The system has been installed in Parliament. The technology has been licensed to 32 industries. CSIR-CSIO has also developed indigenous air sampler, which can detect the presence of virus in the air samples. It is used for sampling air from large volume of space like hospital OPD, shopping malls, and bus stand terminal, where there is possibility of virus & bacteria infection.

Acknowledgement
The information provided by Scientists of Technology Management Directorate and Innovation Management Directorate of CSIR Headquarters and Directors of CSIR laboratories and their colleagues are gratefully acknowledged.

CSIR THEME DIRECTORATES

Propelling Growth of Aerospace, Electronics, Instrumentation & Strategic Sector

Dr Abhay Pashilkar
Director,
CSIR-National Aerospace Laboratories (CSIR-NAL)

Mr R. Venkatesh
Chief Scientist & Head, Business Development,
CSIR-National Aerospace Laboratories (CSIR-NAL)

CSIR laboratories working in the area of civil & military aviation are high-technology oriented R&D institutions focusing on advanced disciplines in the aerospace sector and aligned to develop technologies for the civil & military aviation sector. The major aerospace programmes of ISRO & DRDO have significant contributions from the CSIR laboratories. CSIR's developmental work in strategic areas has helped the country in overcoming the technological denial regimes especially the Light Combat Aircraft (LCA-Tejas) programme. Additionally, it has helped to protect confidentiality of strategic data and enhanced the nation's prestige in the international arena.

CSIR laboratories have been instrumental in the development of new generation aircraft, flight system technologies and radomes for weather prediction applications to medical instruments & devices including prosthetic & assistive devices for rehabilitation and imaging & machine intelligence based technologies.

Aerospace

HANSA 3-NG is one of the most advanced flying trainer powered by Rotax Digital Control Engine with unique features like Just-In-Time Prepreg (JIPREG), composite lightweight airframe, glass cockpit, bubble canopy with wide panoramic view, electrically operated flaps, etc. It is designed to meet the needs of Indian flying clubs and is an ideal aircraft for Commercial Pilot Licensing (CPL) due to its low cost and low fuel consumption. CSIR-NAL has already received more than 80 orders from various flying clubs.

Hansa 3-NG aircraft had a successful maiden flight on 3 September 2021. The aircraft has completed 58 flights including sea-level trials at Puducherry. Hansa 3-NG can also be used for bird reconnaissance at airfields, cadet training, coastal surveillance, and hobby flying.

Hansa -NG First Flight on 3 September 2021

Hansa 3-NG displayed at Wings India

As per the country's civil aviation policy (UDAN Scheme), India needs a light transport aircraft for remote and tier 2 & 3 cities. It is estimated that the potential demand for small civil and military aircraft would be to the tune of 120 to 160 in the next 10 years. SARAS-MkII – Light Transport Aircraft (LTA) developed by CSIR-NAL will be instrumental for commuting and connecting the smaller towns for the purposes of education, employment, tourism, medical, etc.

SARAS-Mk-II is a 19-seat Light Transport Aircraft with multirole capabilities like Passenger transport, Troop transport, VIP transport and Casevac (Air Ambulance). The aircraft is exclusively designed for operations from short runways, hot and high airfields, and semi-prepared runways for connecting Tier 1 & Tier 2 cities/towns.

The unique aircraft has a Pressurised Cabin, Digital antiskid braking, Autopilot with Cat-II landing, two-lever engine operation, and made of lightweight materials keeping the cost minimum. The specifications of the SARAS-Mk-II aircraft have been evolved through interactions with Airline Operators and Armed Forces to meet their current operational requirements. The first flight is likely to be in 2025 and the production will start after its certification by the production partner HAL.

CSIR-NAL is also working on the feasibility of the development of a Regional Transport Aircraft with 90-seat capacity that can be adaptable to military transport aircraft by modification in the rear fuselage.

Saras MK-II full scale fuselage mock-up displayed in wings India 2022

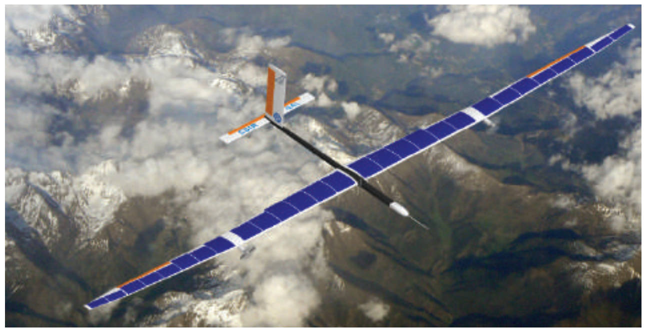
Indian RTA Model

Further, CSIR-NAL has developed a medium-class BVLOS (Beyond Visual Line of Sight) multi-copter Unmanned Aerial Vehicle (UAV). The UAV is made out of a lightweight carbon fiber foldable structure for ease of transportation and has unique features like autonomous guidance through MEMS-based digital Autopilot with advanced flight instrumentation systems.

Subsequently, the NAL drone has completed about 50 hrs of flying to verify the performance parameters. NAL's octocopter can carry a payload up to 20 kg with a hovering endurance of 40 minutes. It can fly at an operational altitude of 500 m AGL and a maximum flying speed of 36 kmph. It has a 360-degree collision avoidance system making it one of the best UAVs in its class. The UAV is perfect for last-mile delivery, floriculture mapping, geo exploration, precision agriculture pesticide spraying and medical transport at remote places. The technology is being transferred to industries to build about 100-200 drones per month.

NAL OCTA-AGRI

NAL has also taken up the development of High Altitude Platforms (HAP) for applications like broadband communication, surveillance, earth observation, climate research, etc. HAP is a solar-powered UAV with Beyond Visual Line of sight operation capability. HAP will be a game-changer in its ability to work as a pseudo satellite for telecommunication applications in the 5G & 6G spectrum with advantages like low data latency, high bandwidth, flexibility of launch and low cost.



CSIR-NAL's High Altitude Platform Vehicle

The majority of the aircraft produced in the country are under license from foreign companies due to which large portions of systems/components are procured from abroad. This constitutes almost 30% of the overall cost of the aircraft. With indigenous aircraft development programs, the requirements for local sourcing of various systems/subsystems have become a necessity. In these systems, the line replaceable units (LRUs) are modular components, which are designed in such a fashion that these can be removed and replaced quickly in the field level without affecting the performance of other components in the system. CSIR-CMERI along with other CSIR labs & MSMEs are trying to indigenize some of the LRUs, suitable for both civilian and fighter aircraft.

DRISHTI, an airport runway visibility assessor system developed by NAL, has completed supply of 105 systems working in 21 civilian international airports and 18 Indian Airforce Airbases (51 systems to Civilian and 54 systems to Defence Airports). Following this success, the Airport Weather Monitoring System (AWMS) developed by the laboratory has been installed at Mangalore International Airport in June 2017. This airport is the first airport in the country to have an indigenously developed AWMS. The system measures Wind Speed, Wind Direction, Humidity, Pressure, Temperature and Dew Point along with Visibility.

The KIA international airport, Bengaluru has become the first airport in the country to install six Drishti transmissometers at both runways. CSIR-NAL has transferred technology to Central Electronics Ltd., Ghaziabad and Tata Advanced System Ltd. (TASL), Hyderabad. TASL isexecuting the IAF order for installation of 66 systems and CEL is expected to get installation of Drishti & AWMS for 20 systems from IMD. CSIR-NAL, HAL & CEL have signed MoU to install Drishti & AWMS at Tumkur

Drishti & AWMS at KIA Bengaluru & Kannur International Airport

Helipad to be inaugurated by the Hon'ble PM as part of Azadi Ka Amrit Mahotsav.

CSIR-IIP Dehradun's home-grown technology to produce bio-jet fuel has been formally approved for use on military aircraft of the Indian Air Force (IAF). The technology has undergone evaluation tests and trials over the last three years. This certification represents India's growing confidence in the aviation biofuel sector.

Earlier on 26 January 2019, an AN-32 aircraft, filled with blended bio-jet fuel, was flown over the Raj Path at New Delhi during the Republic Day celebrations. Thereafter, the performance and reliability of the Indian technology were also tested when the Russian military aircraft safely landed and took off from Leh airport on 30 January 2020 at high altitudes under severe winter conditions. The fuel was also used on a civil, commercial demonstration flight operated by SpiceJet on 27 August 2018 from Dehradun to Delhi.

An-32 transport aircraft using bio-jet fuel developed by CSIR-IIP at the Republic Day flypast in 2019

Electronics & Instrumentation

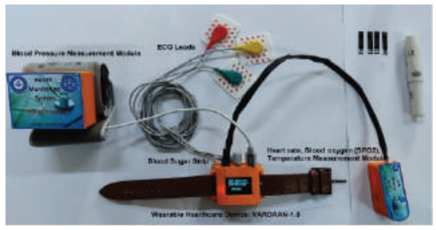
In the area of advanced electronics systems, CSIR-CEERI has developed many technologies both for the society and the industry. Its milk adulteration detection system detects adulterants like urea, salt, boric acid, caustic soda, sodium bicarbonate, ammonium sulphate and hydrogen peroxide within 20-25 second. It is user friendly with wireless communication. The technology has been transferred to many MSMEs.

Ksheer Tester

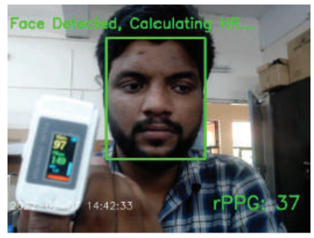
Ksheer Analyzer

Other developments include, AI-powered face recognition based attendance system, IoT enabled static water quality measurement system for different water quality parameter measurements (pH, TDS, turbidity, temperature, salinity, conductivity and ORP), remote photoplethysmography (rPPG) based solution for heart rate measurement using RGB camera, and Ultra-low power, IoT based watch for rapid vital health parameter measurement (BP, Blood Sugar, ECG, SPO_2, heart rate and body temperature), among others.

CSIR-CEERI is also involved in development of technological solutions for contactless alive/dead detection of victim soldiers in the battlefield based on Doppler phenomena; buried metallic object detection system based on time-domain electromagnetic, and non-intrusive load monitoring (NILM) based e-sense for appliance level energy consumption. The ongoing developments include AI-enabled technologies and systems for healthcare, cyber security & privacy, advanced material design, etc.



Wearable healthcare device



Remote photoplethysmography

CSIR-NAL made significant contributions in COVID-19 mitigation. NAL quickly responded to the call of the Government of India by developing and deploying in record time "SwasthVayu – BiPAP Non-invasive Ventilator" for the treatment of mild to moderate COVID-19 patients in hospitals. The technology was transferred to industries for commercial production which resulted in quick deployment of about 1500 SwasthVayu units to hospitals of NCT-Delhi, Ramgarh & Chatra-Jharkhand, Bhopal-Madhya Pradesh, Mysore, and Hyderabad.

SwasthVayu - BiPAP Non-invasive Ventilator

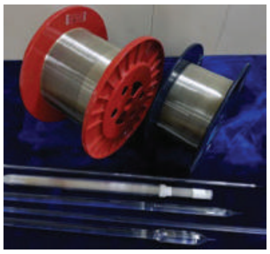
CSIR-CSIO has developed instrumentation for smart agriculture. Besides, its instrumentations in healthcare cover a wide spectrum of medical instruments. During the COVID-19 pandemic, to fulfill the requirement of ventilators CSIO developed a Respiration Assistive Intervention Device Respi-AID based on the Ambu bag where the operation of Ambu bag is automated by a motorised mechanism. It has provisions to set the ventilation parameters i.e. Tidal volume, Respiration rate, I:E ratio, PEEP value, FiO_2, etc.

DivyaNayan is a reading machine for the visually impaired or illiterate persons where any printed or digital document can be accessed in the form of speech output. The device uses a contact line scanner for acquiring the image of a printed document. It currently supports Hindi and English but can be further configured to other Indian and foreign languages.

CSIR-CSIO's Electronic Knee is an intelligent prosthetic device for trans-femoral (above knee) amputees. For adaptive gait, the knee adapts to patient movement style in real time with the integration of indigenously developed electro-goniometer, force resistive sensor and accelerometer in order to control the swing phase dynamically. The CSIR-CSIO has also developed myoelectric arms.

Specialty optical fibers are instrumental in development of fibre optics based optical components for applications in communications, oil and gas exploration, healthcare, defence, automotive and aerospace sectors. CSIR-CGCRI has developed high power fiber lasers at operating wavelength of 1064nm; Erbium-doped Fiber Amplifier (EDFA), a key component for community antenna television and fibre-to-the-home (FTTH) technology.

CSIR-CMERI has come up with the e-Dak Kiosk, which is a self-service, integrated communication kiosk



Specialty optical fibres

EDFA

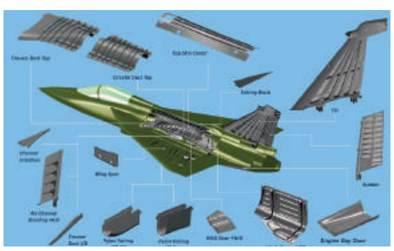
system suitable for installation in public places, particularly in schools, colleges, municipalities, rural areas and villages. The system is perfectly customizable and can be used for any communication related application. It has a robust, theft-proof, vandal-resistant design.

e-Dak Kiosk

Strategic Sector

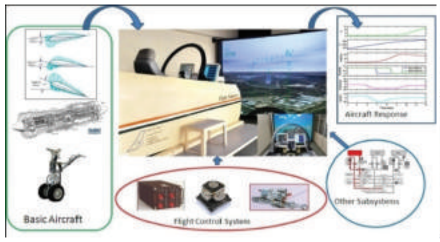
CSIR laboratories have also contributed to programmes of the Indian Space Research Organization (ISRO), Defence Research and Development Organization (DRDO) and Department of Atomic Energy (DAE). The S&T contributions of CSIR laboratories in these strategic areas has helped the country in overcoming the technology-denial regimes at critical junctures and has also put the Nation in a better bargaining position when import of technology was considered unavoidable. Additionally, it has helped to protect confidentiality of strategic data and enhanced the nation's prestige in the international arena.

Over the years CSIR-NAL has developed many critical technologies for ADA's Light Combat Aircraft (LCA) – Tejas. Composites offer a very attractive option in modern aircraft development because they are lighter than metal and are just as strong. Tejas airframe is 45% composites (mostly carbon epoxy) by weight contributing to its reputation as the world's smallest light weight fighter aircraft. CSIR-NAL successfully led the National team for the composite wing development for Tejas and has pioneered the development and fabrication of composite structures using innovative and cost-effective fabrication technologies including co-curing/co-bonding construction. Structures like wing, horizontal and vertical tails, fuselage shells, control surfaces like rudder, elevator, aileron, flaps etc. have already been developed for LCA-Tejas.

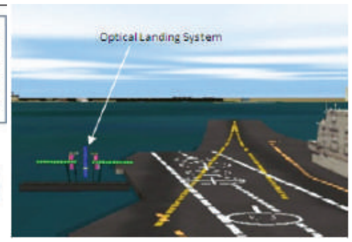


The innovative technology not only reduces the cost but also improves the structural efficiency by minimizing the number of mechanical joints. With this innovation, composite aircraft structures have become cost effective and structurally far superior to conventional aircraft structures. Co-curing technology has resulted in more than 20% savings in cost and about 15% reduction in weight.

CSIR-NAL has led the national team effort to design, develop and certify the fly-by-wire flight control laws and air-data algorithms for Tejas. Aero-database validation and update work using state-of-the-art system identification tools has led to successful envelope expansion for LCA Airforce Fighter, Trainer and Navy variants. Today Tejas compares with the best fighter aircraft in the world with features such as boundary limiting, automatic low speed recovery and carefree maneuvering.



Technologies for Research simulators



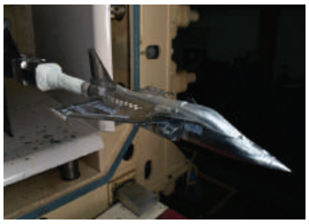
Fresnel lens optical landing systems for LCA navy

Automatic Take-Off and Landing (ATOL) control laws for LCA-Navy Aircraft

Head-up display is an essential aid for pilots, especially fighter aircraft. It aids pilots in taking split-second decisions. The flight information, navigation and target/weapon release cues are generated on a display surface which is collimated by an optical module and projected on the outside scene in the field of view of the pilot through the windshield. The innovative indigenous head-up display developed by CSIR-CSIO has high display brightness range, which is best in the world, with no sunglare, full readability against sunlight, with clear view in twilight conditions and High Positioning Accuracy of the order of 0.2 mR. The technology of HUD has also been transferred to BEL and they have produced more than 100 HUDs for the LCA-Tejas.

HUD for LCA - Tejas

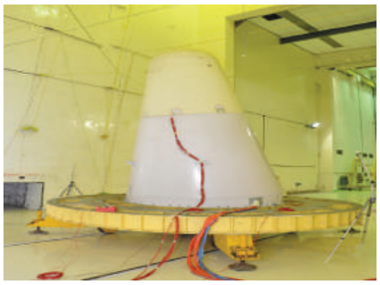
The 1.2 m National Trisonic Aerodynamic Facility at CSIR-NAL has been serving the country as a nucleus of research & development in high-speed aerodynamics since the last five decades. The wind tunnel has successfully completed more than 55000 blowdowns and continues to serve the major national aerospace programmes of ISRO, DRDO, ADA, HAL & IAF through timely generation of voluminous aerodynamic data.



Combat Aircraft model in 1.2 m WT

RLV Ascent phase model in 1.2m WT

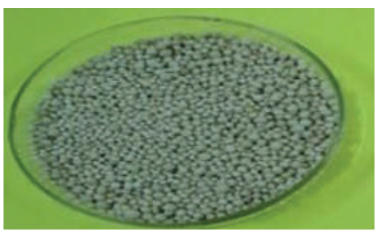
The Indian Space Programme has also been ably supported by CSIR-NAL's Acoustic Test Facility (ATF) over the last three decades. Acoustic qualification of space bound hardware has been very crucial to ensure the reliability of the hardware and successful completion of the mission. Acoustic tests have also been carried out on the PSLV-PS4 Flexible Solar Panel ATF and Test Vehicle Equipment Bay (EB) for testing certain critical components of the Gaganyaan Crew Escape System. ATF also qualified the Core Base Shroud of the Small Satellite Launch Vehicle which is one of the crucial subsystems of the highly modular small satellite launcher.

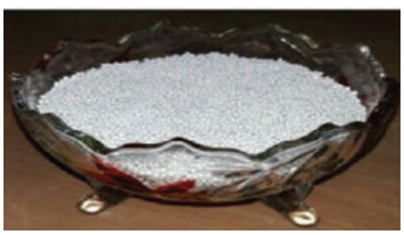


RLV-TD & GSLV – L40SONC in ATF

An indigenous 42 GHz gyrotron has been designed and developed by CSIR-CEERI for the first time in the country. It was transported from CSIR-CEERI and safely delivered at IPR, Gandhinagar.

Thyratron developed for high power and high PRF switch have been delivered to BARC – it finds applications in LASER, crowbar and RADARs. Temperature sensors have been developed and delivered to the Indian Navy, Mumbai. Other technologies include, pressure sensors, MEMS acoustic sensors for launch vehicles of ISRO, RF-MEMS switches, MEMS magnetic field sensor and GaAs based Hall sensor for DRDO.

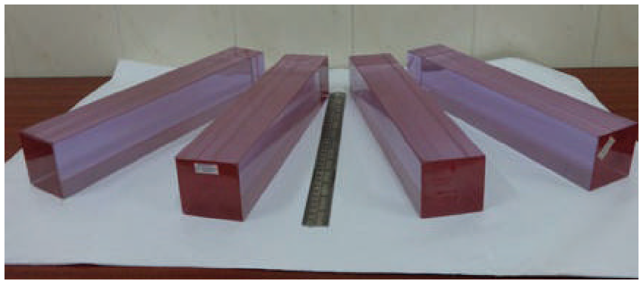




Specialty Borosilicate Glass Bead for Nuclear Waste Immobilization

High level liquid waste produced by nuclear plants contains extended half-life isotopes that have to be immobilized to ensure safe disposal. Borosilicate glass beads with specific sizes, molecular structures and physical shapes have been developed by CSIR-CGCRI that exhibit stringent physical, chemical and mechanical specifications. The technology allows remote control of the entire operation and allows recovery and recycling of valuables and is non-hazardous to the operating personnel.

Indigenous technology for development of large sized Nd-doped phosphate glass is being developed at CSIR-CGCRI for high-power high-energy laser systems. Facilities exist for 5 litre melting to produce glass blocks of stipulated sizes, while a pilot plant of 15 litres scale glass melting facility is being established.



Neodymium doped phosphate glass for high energy and high-power laser application

Radiation shielding glasses are used in nuclear reactors and nuclear processing units. CSIR-CGCRI technology encompasses production of homogenous defect-free high density RSW glass block (stabilized and unstabilized) of varying sizes. Applications include in nuclear installations including nuclear hot cells, x-ray room, radiation therapy room, etc

High Density Radiation Shielding Window Glass for Nuclear Hot Cell Application

Underwater vehicle (UV-150) developed by CSIR-CMERI can be deployed for seabed mapping, coastal surveillance, mine counter measure and oceanographic measurements during adverse weather conditions. It can perform various jobs related to underwater inspection with camera, surveying, etc. the distinct features of the UV-150 include reduction in control complexity, better diving control and safety, and capability of autonomous navigation through pre-defined trajectory.

Acknowledgements

Information provided by Directors and Staff of AEISS theme laboratories

"Ecology, Environment, Earth Sciences, Ocean & Water"

CSIR Addressing Sustainability Science

CSIR THEME DIRECTORATES

Dr V.M. Tiwari

Director, CSIR-National Geophysical Research Institute (CSIR-NGRI)

Theme Director, Ecology, Environment, Earth Sciences, Ocean and Water

SUSTAINABILITY science is a solution-oriented discipline requiring fundamental research entrenched with multi/intra-disciplinary approaches. CSIR has created a thematic area – "Ecology, Environment, Earth Sciences, Ocean and Water" (E3OW) – to address issues of socio-economic and environmental importance for the country.

CSIR researchers working on the sustainability science are enhancing our knowledge of the functioning of the Earth system and its critical thresholds and also developing response strategies to global changes with focus on people, prosperity and planet. The theme E3OW becomes increasingly prominent as humanity confronts daunting challenges in finding natural resources to sustain the burgeoning population, in mitigating natural hazards that impact life and infrastructures, and in achieving sustainable environmental stewardship for the country.

The actions in the E3OW theme, therefore, are aimed at preserving:

a) **the water cycle,** altered by reservoir construction, agriculture, groundwater extraction, and urbanization, often leading to significant groundwater depletion;

b) **the carbon cycle,** central to climate but heavily affected by anthropogenic greenhouse gas emissions and land use, and also recent geo-engineering practices aimed at reducing the human impact on climate;

c) **the Earth's surface,** transforming in its physical, chemical, and biological state, with accelerated soil erosion, mobilization and deposition of metals and toxins;

d) **the coastal areas,** hosting >60% of the world's population and due to forcing from both ocean and land processes, experiencing coupling of geomorphic, hydrological, ecological, climatic, and biogeochemical phenomena.

Water

Source sustainability

The scarcity and deteriorating quality of water in several regions of the world, including in many Indian states, is alarming. Climate change impacts are likely to aggravate the water problems. India is one of the most water-intense economies and is one of the largest water users per unit of Gross Domestic Product (GDP).

Groundwater reserves source about 90% of the agricultural requirements, causing an imbalance between groundwater recharge and extraction resulting in rapid groundwater depletion in several parts of India. Groundwater overexploitation has economic and social consequences due to persistent excavation of deeper new wells, increased energy cost in lifting groundwater, spread of geogenic contaminants — arsenic, fluoride, salinity — and ingress of seawater in freshwater aquifers in coastal areas.

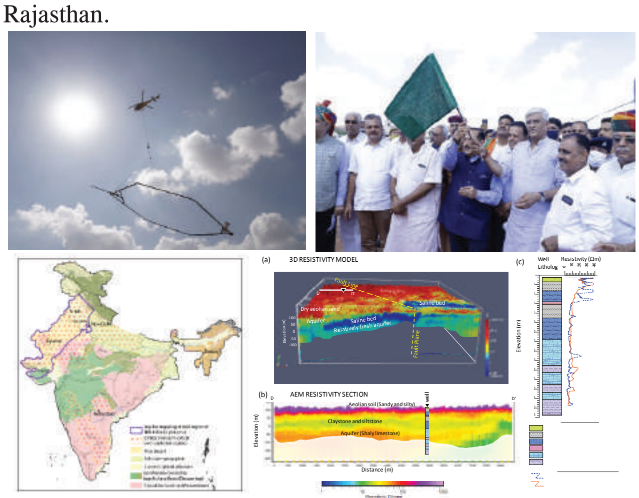
In addition to affecting the huge rural and urban population, water scarcity in India also extensively affects the river ecosystem. The enormity of the challenge requires well-informed science-based solutions as well as policy framework based on water management options.

Managed Aquifer Recharge (MAR) is a potential method to control over-abstraction, restore the groundwater balance and address the issues of contamination to certain extent. Information on the disposition of aquifer system is an essential requirement for managed recharge of aquifers.

CSIR-National Geophysical Research Institute (CSIR-NGRI) has demonstrated how MAR based on aquifer knowledge and community participation could bring a paradigm shift in agriculture-based income in the villages situated in Choutuppal Mandal of Telangana state.

For upscaling of geophysical mapping of aquifers and rapid survey over a large region, CSIR-NGRI has adopted a new technique of Heli-borne TEM, which has provided very promising results in aquifer mapping in India. With state-of-art ground and Heli-borne geophysical technologies, CSIR-NGRI in collaboration with Central Ground Water Board (CGWB), Ministry of Jal Shakti, Government of India has initiated a mega project of High-Resolution Aquifer Mapping & Management in arid regions of North Western India coving about 4 lakh square kilometres to identify potential groundwater bearing zones for water supply and recharge.

Hon'ble Union Minister of Jal Shakti Shri Gajendra Singh Shekhawat and Hon'ble Union Minister of Science and Technology Dr Jitendra Singh inaugurated the state-of-art heliborne geophysical investigations for groundwater management in arid regions on 5 October 2021 at Jodhpur, Rajasthan.



Launch of Heli-borne geophysical survey of arid regions of NW India (left); Planned survey area (middle), and right, 3D resistivity model of aquifer in the Thar desert, Jaisalmer, Rajasthan (Source: https://doi.org/10.1016/j.wasec.2022.100111).

A recent investigation using the Heli-borne technology in the Prayagraj region, Ganga river basin shows a pathway of an ancient river that has comparable dimensions to that of the rivers Ganga and Yamuna in Prayagraj region of Uttar Pradesh. The newly traced paleo-river can serve as reservoir of underground water in the depleting aquifers in the Ganga-Yamuna doab.

Treatment

Water desalination is a common practice to achieve the overarching goal of providing drinking water. Reverse Osmosis (RO) has been practiced commercially. During desalination, the salinity is lowered – which is desired – but the concentrations of nutritious constituents are also reduced excessively – which is undesirable. The development of a methodology that enables desalination to be conducted with better retention of nutritious ions would be of considerable interest.

CSIR developed the electrodialysis (ED) process for the separation of mono- and bivalent ions employing polyaniline (PANI)-modified interpolymer type of ion-exchange composite membranes (Thakur *et al.*, 2014). Due to sieving and hydrophobic effects, the PANI coating demonstrated improved retention of nutritious minerals in the desalinated water which is also a mineral-balanced alkaline water. The technology is scalable with productivity of desalinated water from 10 LPH to 500 LPH, and suitable for domestic as well as societal uses. The cost of such electrodialysis units may vary from Rs. 30,000 to Rs. 15,00,000 depending on productivity.

Plant capacity – 0.1 MLD (100 m^3 per day)
Raw water – 10000-12000 ppm
Product water – < 500 ppm (WHO standard)
Product recovery - ~50%

Electro-dialytic desalination plant (Plant capacity -0.1MLD (100m3 per day; Raw water -10000-12000 ppm; Product water < 500 ppm (WHO standard); Product recovery - ~ 50%) by CSIR-CSMCRI (Source: DOI: 10.1016/j.desal.2013.12.007).

Higher concentrations of Fluoride, Arsenic, Iron, Uranium, etc. in drinking water are a major problem for human health in various parts of the country. CSIR Laboratories have developed several water treatment technologies for these contaminants to enhance water potability. These include ceramic membranes technology, adsorbent based technologies which can operate without electrical power, gravitational based technology, and technology for removal of pathogens.

A low-cost purification media (disc/candle) produced from locally available materials like Red-clay, sand and saw dust is also developed to remove excess iron along with suspended particles. These technologies can be deployed at domestic to community levels and utilised across the country. Potable drinking water using gravitational based community level Fluoride, Arsenic and Iron Removal (FAIR) technology has been recognized by the West Bengal Pollution Control Board (WBPCB).

CSIR-NEERI's solar Electrolytic Defluoridation (EDF) based filter for the treatment of excessive fluoride in water sources has been successfully installed at 200 fluoride-affected villages in India. It was found that EDF plants produced the treated water with fluoride less than 1 mg/L and 90-99% reduction in bacterial load from the raw water with the fluoride in the range 2-5 mg/L and total coliform and faecal coliform counts in the range 120–630 CFU/100 ml and 70-100CFU/100 ml respectively in raw water. Reduction in hardness and nitrate was also observed in treated water. Till now, it is estimated that more than 1,00,000 people have been saved from fluorosis through application of the EDF technique developed by CSIR-NEERI.

Supply

Drinking water supply systems in Indian villages face multiple challenges of drying up of groundwater source, pump failures, irregular and inadequate water supply, etc. The need of the hour is to ensure and put in place systems to effectively monitor and manage rural water supply.

Six CSIR labs together developed and demonstrated an integrated IoT based SMART Water Management system comprising of Sensor-nodes, Gateways, Cloud & Analytics, and Dashboard-visualization for service delivery measurement and monitoring (quality, quantity and regularity). CSIR IoT technologies will be deployed at 115 clusters covering ~20 states as a model project in collaboration with Jal Jeevan Mission of Ministry of Jal Shakti.

CSIR-NEERI has developed a software RISK-PiNET for assessment of contamination in drinking water distribution system and to identify the exact contaminant intrusion point in the network of pipelines. The software assesses the pipe condition, hazard due to sewage and drain, and risk. The software also assesses the failure rate and remaining useful life of each pipe considering the year of pipe-installation, length, diameter and pressure therein the pipe. Accordingly, rehabilitation of the contaminated pipeline can be planned rather than changing the water distribution system at large scale. This software is useful for various Municipal Corporations in the country as the potable water is supplied to consumers through pipelines in urban areas.

A huge quantity of sewage is generated in ever expanding urban areas. With limited installed capacity of treatment in centralized manner, a large portion of this sewage remains untreated and is diverted to water bodies. To prevent water bodies from pollution CSIR-NEERI developed a PHYTORID technology, which is a constructed wetland exclusively designed for the treatment of municipal, urban, agricultural and industrial wastewater. PHYTORID is a subsurface flow constructed wetland system (SSFCW) with demonstrated continuous operation as a standalone sewage treatment system. It has a large potential for decentralized treatment of sewage in urban and rural areas of the country with concomitant advantage of water resource conservation. Till date about 80 such plants have been set-up across India and are providing treated water for reuse and recycle. The technology has been transferred to 15 agencies (private and government) for dissemination and implementation.

Environmental Solutions

In response to the emerging reality of environmental pollution and degraded ecosystems due to increasing anthropogenic pressure, rapidly shrinking ecosystems, depleting biodiversity and changing global climate, CSIR is addressing the scenario on a priority basis.

CSIR has developed environment-friendly firecrackers, which are made using less polluting raw materials, thus causing less pollution as compared to normal crackers. Their chemical composition also helps them suppress dust when they are burnt. The Indian Fireworks industry has an over rupees 6000-crore worth of annual turnover. At an annual growth rate of about 10 percent, it is providing employment opportunities to over 5 lakh families directly or indirectly. Thus, CSIR is aiming at providing solutions that not only address the pollution related concerns of firecrackers and fireworks, but also protect the economy and the livelihoods of the professionals involved in this trade.

Green firecrackers developed by CSIR laboratories (Source: CSIR-NEERI)

The treatment and safe disposal of effluents using High Rate Transpiration System (HRTS) has been demonstrated at various locations by CSIR-NEERI. HRTS involves the use of dynamic, multicomponent soil system as a live filtration device to rejuvenate the wastewater through adsorption, ion exchange, precipitation and stabilization of pollutants through microbial degradation. It is a land application system where the wastewater is applied in specially designed field layouts with wide ridges and furrows. In ridges, trees with much higher transpiration capacity are planted, while wastewater is allowed to flow through the furrows. The high transpiration capacity of plants enables the system to serve as a biopump through stomatal network. All the wastewater is utilized in this process, obviating the problem of ground water pollution. It is a cost effective and environmentally acceptable solution to manage the problem of coloured wastewaters. HRTS ensures the reuse of effluent and its nutrient contents for biomass production. It prevents ground and surface water pollution.

Minerals and Hydrocarbon Resources

India and surrounding oceans are locales of rich mineral and hydrocarbon resources. Exploration and environmentally viable exploitation of these resources will be major steps towards sustainability.

The occurrence of placer minerals in the beaches and near shore zones around Manavalakuruchi and Midalam areas, Kanyakumari, south Tamil Nadu has been known since long. Economically workable deposits are reported for a stretch of 10 to 15 km along the coastal belt. Real-time observation and measurement of all beach profiles for a period of 15 months indicates the replenishing nature of sand in the Manavalakurichi to the tune of 5.7 Lakh tons along 5.8 km long stretch.

CSIR institutes are working extensively on non-conventional energy sources like gas hydrates, shale gas, coalbed methane, and geothermal. Gas hydrates, ice-like crystalline solids of gas, are considered as the future source of energy and will be of great economic importance if exploited properly. CSIR-NGRI has prepared a gas-hydrate stability thickness map along the Indian continental margin from available bathymetry, sea-bottom temperature and geothermal gradient data. The map is also useful for exploration scientists.

India has the fifth-largest proven coal reserves globally, and hence, it is likely to have significant prospects for CBM exploitation. According to Govt. of India's data, the prognosticated CBM resources in the country are approximately 92 Trillion Cubic Feet (TCF) in 12 states of India; however, the established reserves are only 9.9 TCF. The present-day major CBM projects exist only in the Damodar and Son valley coalfields, while other regions are yet to be fully explored (DGH, 2019).

An initiative by Coal India, CSIR-NGRI and Central Mine Planning and Design Institute (CMPDI) carried out 3D-high resolution seismic surveys to map coal seams suitable for CBM exploration. The Ib valley coalfield is one of the prospective regions of the Mahanadi basin, identified for exploring Coal Bed Methane.

Since the coal blocks are not well-explored using geophysical data in this region, CSIR-NGRI took up 3D seismic exploration studies in Belpahar Sector-III, Jharsuguda district, Odisha state of Ib valley. The seismic section revealed the roof and floor contour maps of the regional coal seams. Given the presence of shale-rich thick Barren Measures in the Damodar river valley basin, some of the sub-basins are being explored for shale gas prospects. According to an estimate given by CMPDI, 45 TCF of shale gas reserves are expected in Gondwana sub-basins (Jharia¸ Bokaro, North Karanpura, South Karanpura, Raniganj & Sohagpur); however, a detailed geophysical mapping of the prospective zones has not been done.

CSIR-NGRI has carried out 2D seismic studies for EOGEPL in Raniganj East to map different Gondwana Formations. Further, CSIR-NGRI carried out detailed 3D seismic surveys in two new blocks of the Raniganj and Jharia coalfields of Damodar valley basin, and the thickness of the prospective Barren Measures was mapped along with associated structural features. The preliminary investigations estimated more than 1.2 Billion Cubic Meters of shale gas potential in the studied coal blocks of Jharia and Raniganj coal fields.

In addition to exploration programmes CSIR institutes are working to enhance oil recovery. This was demonstrated in the Balol heavy-oil field in the Northern Cambay basin, using 4D seismic data.

Marine Living Resources

Fishery resources along the Indian coast vary due to driving forces such as physical mixing, nutrients availability and plankton diversity. The formation of temperature fronts enhances nutrient concentrations and biological production where fish is aggregated. These regions are transient in nature, unlike fronts found in the subtropical/subpolar region. Hence accurate prediction of the location of these regions is helpful for fishermen to identify the zone of fishing for better yield. Based on oceanographic surveys and mesocosm experiments, the development of fronts and ecosystem within them can be evaluated; this information can be included in the numerical models for better prediction of regions of potential fishing in the coastal waters along with India.

There are many regions along the Indian coastline, such as the Gulf of Mannar, Wadge Bank, Quilon Bank, etc., that are characterized by high fishing resource potential. Though these regions have been known to fishermen since long as important fishing areas, the key environmental mechanisms in such regions supporting rich fisheries are largely unknown. Comprehensive knowledge of the ocean processes and their bio-physical linkages are essential for understanding ecosystem functioning, which in turn, supports valuable living resources in a marine environment. Therefore, by adopting an ecosystem ecology approach, the water column and sea bottom characteristics of these high-fishery regions can be quantified to explain the major driving environmental mechanisms in these regions. This work falls under the Deep Ocean Mission and also Blue Economy of UN SGD 14.

Seaweed/macroalgae are one of the most important biological resources from rocky intertidal regions. They provide numerous ecosystem services like food, shelter and refuge to various organisms such as fish, crustaceans, etc. The macroalgal bed also serves as a nursery for fisheries and protects them from predators. Seaweeds are a great source of cosmeceutical, nutraceutical and pharmaceutical active ingredients due to myriad health benefit compounds like antioxidant, anti-allergy, anti-inflammatory, anti-diabetic, cytoprotective, photo-protective agents, vitamins, etc. However, despite the immense potential seaweeds entail, they are understudied. A step has been initiated to study seaweed diversity along the Konkan coast to explore the functional benefits of seaweed.

In recent years, consumers' preferences are shifting from synthetic to organic food. This is due to the perception that organic or natural source is safe and healthy. Food comes in a variety of colours. Food without the right colour is considered unappealing. The sensorial connection of food and colour has increased the demand for natural colour compounds in the food industry. Natural colour compounds are chlorophylls, carotene, anthocyanins, etc. Seaweeds are rich in these pigments.

Additionally, these natural colour pigments contain many biologically active ingredients beneficial to human health. The incorporation of these colourants will also provide the much-needed nutrients to those suffering from undernourishment. This undertaking can make a positive contribution to the National Mission 'Poshan Abhiyan' to alleviate malnutrition amongst the impoverished community and to the nation's blue economy policy.

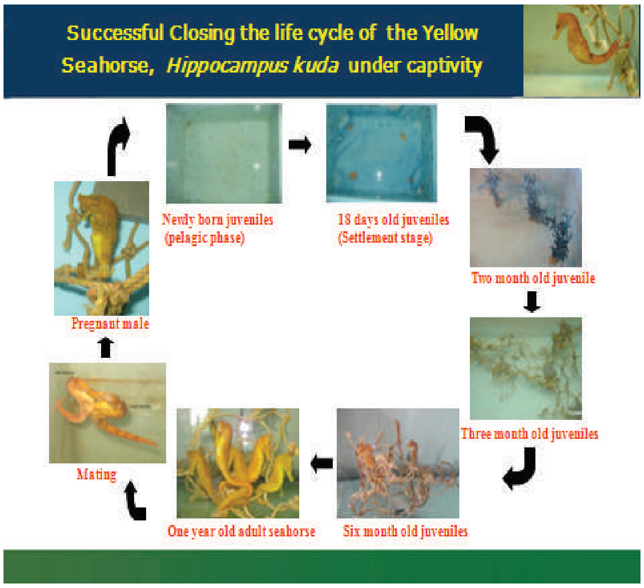
Green Mussel culture program: In the wake of ever-increasing demand for this gourmet seafood and the dwindling natural harvest, farming of green mussels, locally known as '*Xinanneo*', holds enormous potential. To bridge the vast gap between the supply and demand, recently CSIR-NIO successfully conducted a tech-demo of rack technique of farming of green mussels (area, 18 m^2) in a sheltered Bay at Madkai Village, Goa. This was carried out to complement CSIR's Integrated Skill Initiative.

Sustainably high production of 6120 green mussels (340 Nos./m^2) with a total biomass of 200 kg with shell-on (11 kg/m^2) was achieved during the culture period of five months. Monthly growth rates of 7.5 gm in weight and 13 mm in length were witnessed and an average weight of each cultured mussel at the time of harvest was 42 gm.

Acting as a knowledge-partner, the CSIR-NIO provided regular advisories to the skill trainees and information on environmental and growth parameters and the nutritive value of cultured mussels was also collected at fortnightly intervals. This technological diffusion could help in realising one of the Grand Challenges 'Doubling Fishermen's incomes by 2022' as envisioned by the Government of India.

Indian Yellow seahorse: Seahorses form an ingredient in traditional medicine, particularly in Southeast Asia where traditional Chinese medicine (TCM) and its derivatives (e.g. Japanese and Korean traditional medicine) are practised. In TCM, seahorses are credited with having a role in increasing and balancing vital energy flows within the body, as well as a curative role for ailments such as impotence and infertility, asthma, high cholesterol, goitre, kidney disorders, and skin afflictions such as severe acne and persistent nodules. They are also reported to facilitate parturition and act as a powerful genital tonic and as a potent aphrodisiac.

The current demand for seahorses appears to far exceed the supply, with at least 25 million seahorses (>70 tonnes dry weight) traded globally. Researchers at CSIR-NIO have successfully closed the life cycle of Yellow seahorse under captivity. This technology has great potential to integrate both conservation objectives and provide alternative livelihood options for fishers in the source countries, who in the absence of fishing alternatives, continue to exploit the declining seahorse populations.



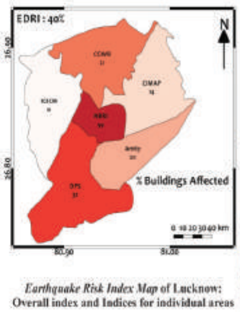
Life cycle of seahorse (Source: CSIR-NIO)

Natural Hazards

The densely-populated Bay of Bengal (BoB) rim witnesses the deadliest Tropical Cyclones (TCs) globally before and after the summer monsoon. Earlier studies indicated enhanced salinity stratification and deeper thermocline reduce cooling under BoB TCs after the monsoon, suggesting that air-sea coupling may favour stronger TCs during that season.

Using observations and simulations from a regional ocean-atmosphere model, CSIR-NIO scientists show that BoB TCs are actually stronger before the monsoon due to a more favourable background atmospheric state (less vertical wind shear, larger maximum potential intensity, more humid mid-troposphere). Further they have developed two nonlinear Tropical Cyclones (TCs) intensity hindcast schemes, for the first time globally. These schemes are based on either Support Vector Machine (SVM) or Artificial Neural Network (ANN) algorithms. Contrary to linear schemes, which perform slightly better when trained individually over each TC basin, nonlinear methods perform best when trained globally. Globally trained nonlinear schemes improve TC intensity hindcasts relative to regionally trained linear schemes in all TC-prone basins, especially the SVM scheme for which this improvement reaches 10% globally. The SVM scheme, in particular, partially corrects the tendency of the linear scheme to underperform for moderate intensity (category 2 and less on the Saffir–Simpson scale) and decaying TCs. This improvement is sufficiently large to motivate more testing of nonlinear methods for statistical TC intensity prediction at operational centers.

The highly populated Indo-Gangetic-Plains (IGPs) are facing high seismic threat from impending large earthquake(s) occurring in the Himalayan area. Towards making an earthquake resilient infrastructure, CSIR-NGRI has recently estimated the parameters viz. the thickness of the soft sediments and the Ground Motion Prediction Equations (GMPEs) of the IGPs and Himalayan region. Based on this research, earthquake risk maps of Lucknow and Dehradun cities, located in the IGPs and the Himalayan hinterland respectively, have been prepared by characterising the hazard and its uncertainty, to serve as input for risk assessment and earthquake resistant design for different applications – ranging from private homes to multi-storied buildings and critical infrastructures such as bridges or dams. Both the maps were shared with the main stakeholders – Uttarakhand and Uttar Pradesh State Disaster Management authorities. They agreed to use the outcome for revising land-use maps with revised hazard components and the building bye-laws to outlaw unsafe and vulnerable typologies of houses in both the cities.



Release of earthquake risk maps of Lucknow and Dehradun cities

Natural disasters such as landslides, Glacial Lake Outburst Floods (GLOFs), and other catastrophic flash flood events are major hazards in the Himalayas. They are a growing threat in a warming climate. Retreating glaciers and permafrost degradation causes the growth of glacial lakes and destabilization of mountain slopes, increasing the flash flood and landslide hazard in vulnerable mountainous regions. These events pose a large risk to downstream communities, causing loss of life and destruction of homes, businesses, roads, livestock and hydropower infrastructure. Catastrophic floods are of particular concern for hydropower development, a rapidly growing industry of increasing economic importance for India, especially in the Himalayan mountains. The 2013 Kedarnath and the 2021 Dhauli Ganga floods are stark examples.

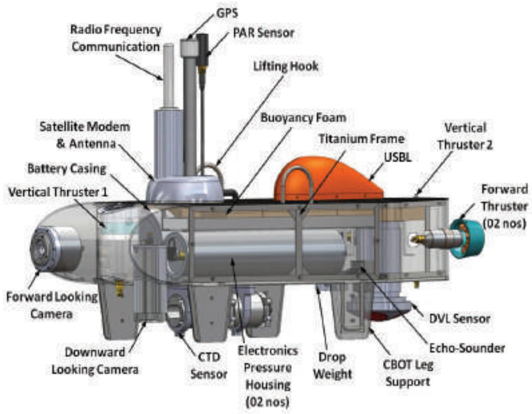
While glacial lakes can be identified through satellite data and can be equipped with ground-based warning systems for GLOF hazards, landslides and subsequently triggered flow cascades are extremely difficult to anticipate in both space and time. While some individual slopes may be monitored, this quickly becomes unfeasible across the population of potential failure sites along the entire belt. Similarly, monitoring of individual lakes or channels for flash floods becomes unfeasible for the entire region.

However, seismic recording of the ground shaking caused by landslides, GLOFs, and other catastrophic floods, which travel as elastic waves at high speeds of a few km per second, offers an alternative paradigm for early warning. The resulting seismic waves can be detected remotely, even at large distances from the flood source, thereby raising the possibility of a distributed early warning system based around networks of seismometers that could simultaneously monitor geomorphic hazards over large regions (Cook *et al.*, 2021).

Autonomous Vehicles

CSIR-NIO has recently developed an autonomous underwater vehicle to monitor coral reefs. The other applications include seabed photography, underwater pipeline inspections, harbour/island surveillance, satellite validation and calibration, coastal/ocean/fresh water studies. Coral reef monitoring is considered by most climate scientists as a reliable proxy indicator of climate change because corals are sensitive to small changes in temperature and pH. The conventional diver approach involves high cost and strenuous human effort to survey the coral reef area. The C-Bot being developed at the CSIR-NIO shall address the challenge of large area coral reef bed monitoring.

For the first time in India, drone-borne magnetic measurements were recorded using the light weight potassium magnetic sensor towed as under slung by an indigenously developed UAV. A survey over dolerite dyke intrusion in granitic-gneissic terrain, near Hyderabad was carried out to show the efficacy.



(Left) CBOT with sensors and electronic modules. (Right) CBOT at Bambolim beach for field test (Source: CSIR-NIO).

Acknowledgement

Article is benefitted by inputs from CSIR Theme E3OW Progress Reports, Review Reports and CSIR-NGRI Annual Reports, Technical Reports and other relevant records whereever required.

Driving the Indian Chemical Sector

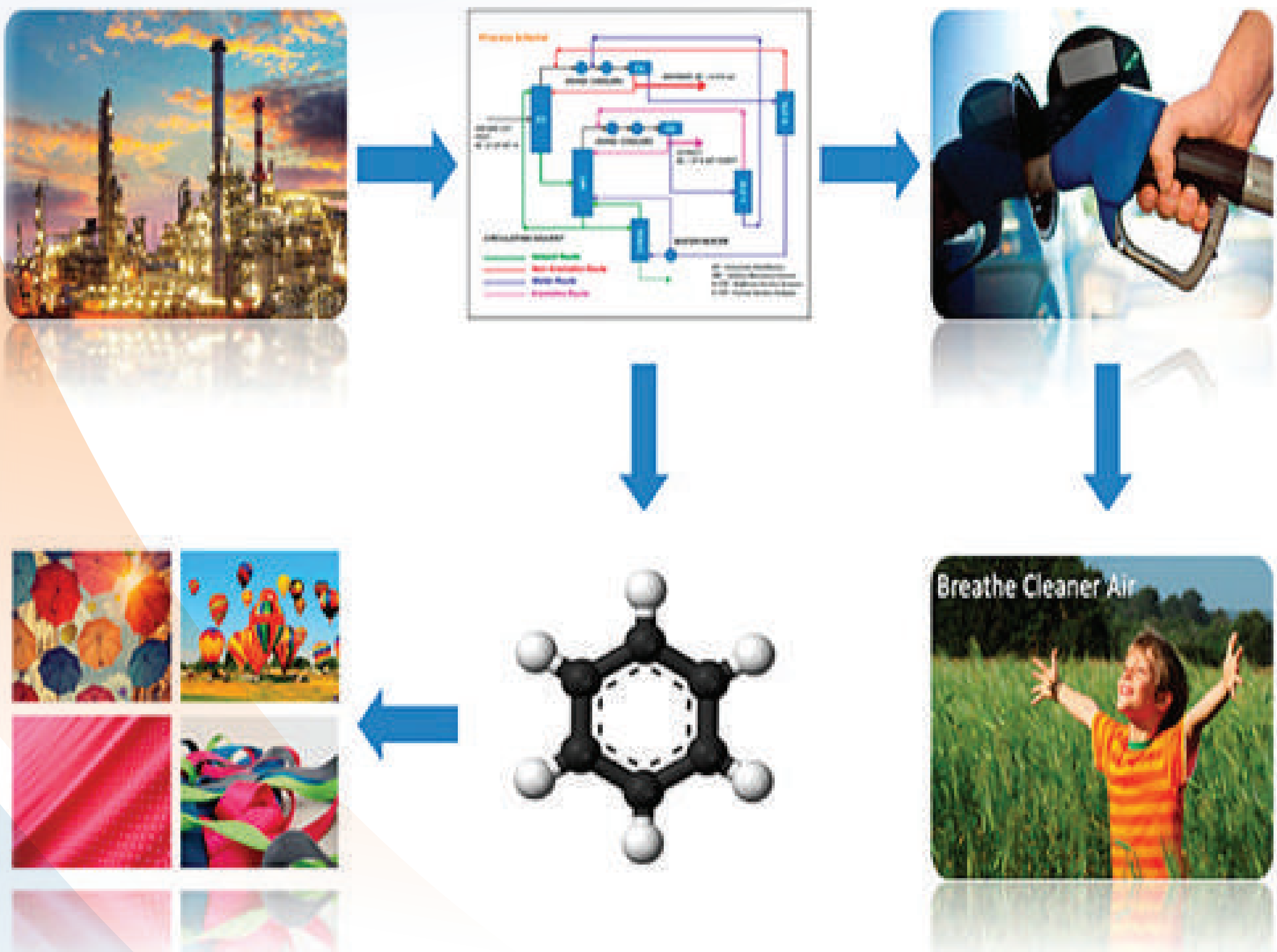
A Success Story Crafted by CSIR

Dr K.J. Sreeram

Director, CSIR-Central Leather Research Institute, Chennai

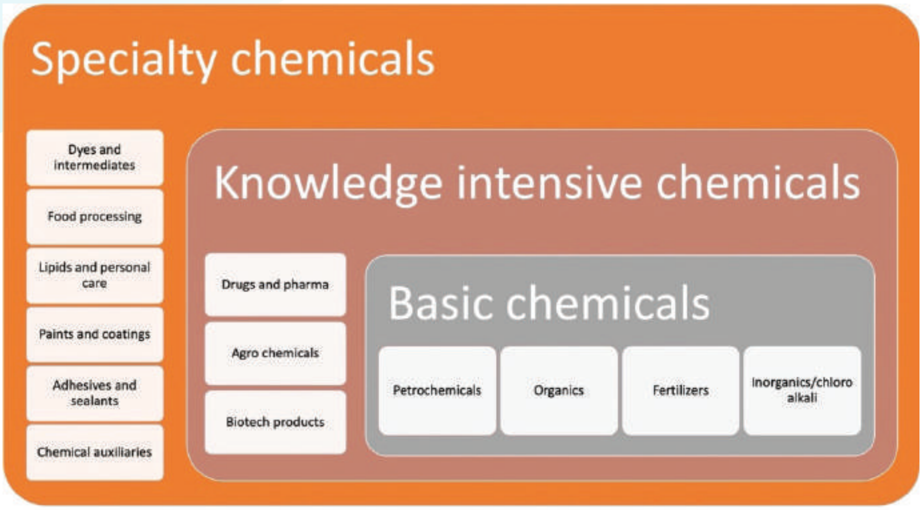
Theme Director, Chemicals (Incl. Leather) and Petrochemicals

CSIR THEME DIRECTORATES



The Chemical Sector – Towards Atmanirbharata

Basic organic chemicals, specialty chemicals, chloro-alkali, pesticides, dyestuff, and alcohol-based chemicals, covering about 80,000 products, constitute the Indian chemical industry. From an R&D perspective, the specialty, knowledge-intensive, and basic chemical sectors represent this diverse sector.



Broad classification of the chemical industry

The chemical sector is considered a backbone of the US$5 trillion Indian economy and will contribute around US$ 300 billion to the GDP by 2025. According to the Director General of Commercial Intelligence and Statistics (DGCIS), the exports of chemical and petrochemical products stood at Rs. 279337 Crores, while the imports were at Rs. 373714 crores during 2020-21.

The industry has the potential to grow and become self-reliant on account of the rise in demand from domestic end-user sectors. A post-COVID analysis indicates that the global companies in the chemical consumer chain are likely to de-risk their dependency on China, which could bring significant growth to the Indian chemical industry. The production-linked incentive scheme of the GOI is like to aid agrochemicals. The navaratnas have started investing in high-value specialty manufacturing, such as the maleic anhydride unit at Haryana by IOCL.

By 2035, the chemical industry will have a mix of chemicals based on renewable resources with a much less adverse impact on health and the environment. A large segment of the chlorine-dependent products and intermediates, such as CFC, DDT, chlorinated flame retardants, and polychlorinated biphenyls, PCP, PVC, etc., would be phased out, and the chlorine tree would be leaner. Bioresources would likely be a small but significant replacement. Gross estimates indicate that 38% of the turnover of the chemical sector would be from basic chemicals and that of specialty and knowledge intensives at 22% and 40%, respectively, by 2035.

The criteria for R&D in chemicals, leather, and petrochemicals would be to enhance our self-reliance on supply deficient chemicals such as in petrochemicals and leather auxiliaries. Enhancing our leadership in developing alternatives to 27 agrochemical molecules that have been banned, active pharma ingredients for drugs whose patents are to expire in the next few years, is another segment.

The focus of Indian R&D on chemicals will be on developing benchmarkable technologies that are economically, environmentally, and socially sustainable. Process technologies leaving lower carbon, energy, and water footprints, would contribute significantly to affordable healthcare, safer agriculture practices, and net zero carbon footprint in the chemical industry.

CSIR for R&D and Self-Reliance in Chemicals

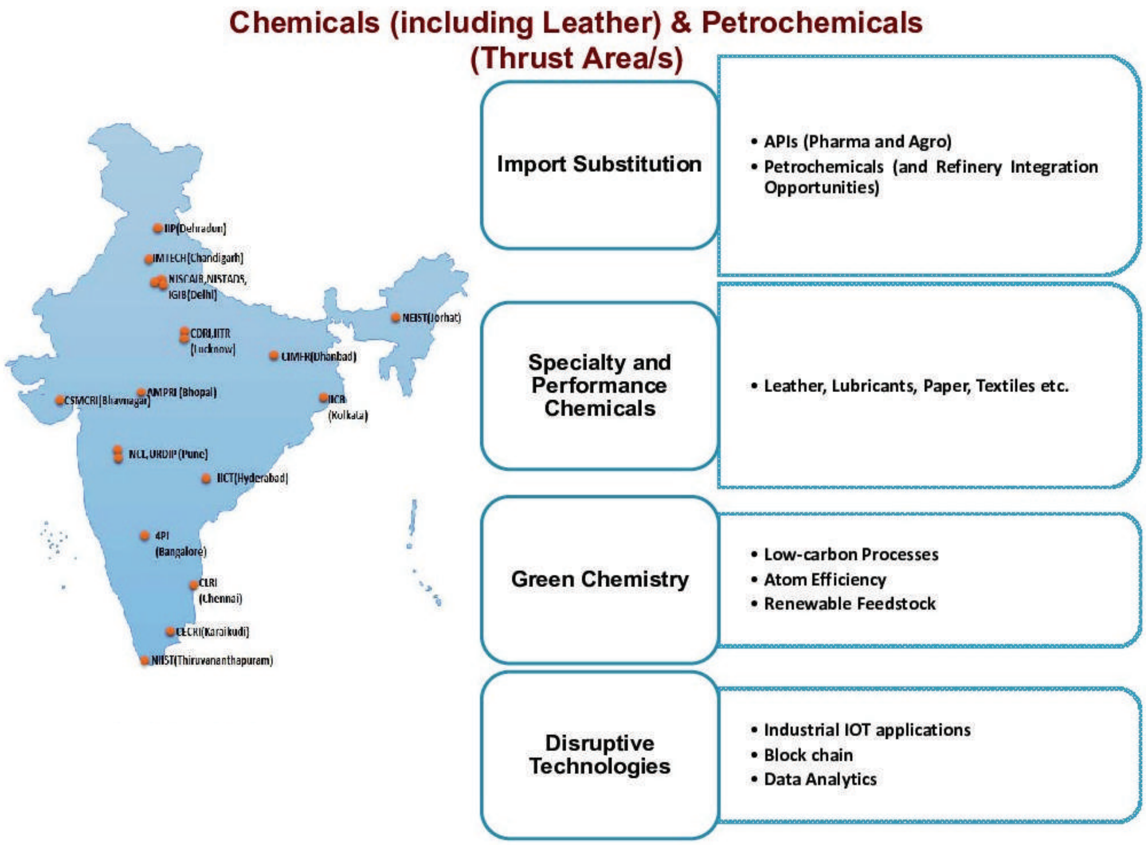
Core competence, intellectual range, infrastructure, and an established network of sister laboratories of varying core strengths are limited in the global S&T environment. Providing indigenous specialty chemicals and customized agro and pharma products to a market where agility to technology changes and meeting consumer demands is the key. The inherent strength of CSIR thus provides expanded scope in the worldwide chemical research and education scenario.

The thematic grouping of CSIR laboratories, wherein one of the themes is Chemicals (including Leather) and Petrochemicals (CLP), has led to diversified yet concerted R&D based on specific industrial needs. The success of the technology translation from the CLP group of laboratories is a strong academy–research–industry partnership.

Four out of 13 centres of excellence under the Ministry of Chemicals and Fertilizers are in CSIR — focusing on polymers, membranes, coatings, and chemicals for strategic applications. Through seven decades of service to the nation, the CLP theme laboratories have brought in self-reliance in chemicals and fertilizers to a large extent. CSIR technologies can take the export-to-import ratio of basic chemicals from 0.7 (in 2020) to 0.8 (in 2035). Similarly, specialty and knowledge intensives can shift from 5.0 to 6.0 and 2.0 to 3.0 as we progress from 2020 to 2035.

Some of the highlights of the contribution of CSIR in the self-reliance of the chemical sector in the country:

- Hindustan Insecticides Limited and Hindustan Organic Chemicals limited are borne out of the research on agrochemicals in CSIR laboratories.
- Balmer Lawrie & Co. Ltd has brought in self-reliance in leather chemicals (fatliquors and syntans) through the technologies developed in CSIR.
- Developing process chemistry, engineering, plant designs, safety and risk analysis for a range of organic building block chemicals.



- Catalysis research stems from CSIR and leads to several commercial technologies for catalysts leading to several products and processes, including carbon chemistries.
- Waste plastics to fuel and petrochemicals.

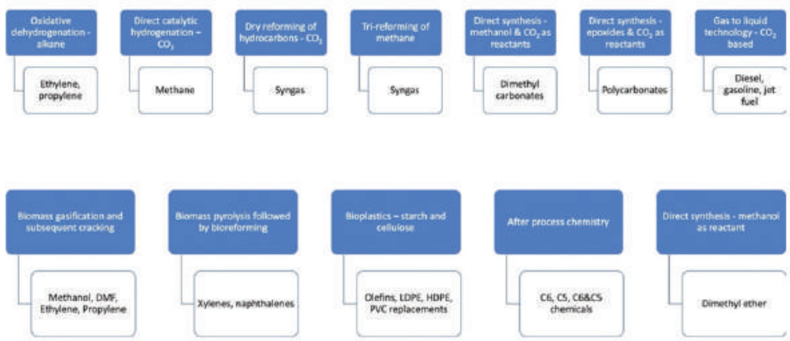
While this list can go on, some of the specific contributions in recent times include the synthesis of TLR 7/8 agonist molecule (IMDG), which is used as an adjuvant in Covaxin produced indigenously by Bharat Biotech India Limited.

Sustainability has been the key to innovations in CSIR. A single-step process to make sustainable aviation fuel from non-edible and used cooking oil has led to a long-term relationship between various airlines and CSIR.

Technology for producing sulfate of potash from sea bittern is environmentally benign and finds application as fertilizer. Similarly, refractory grade magnesia finds application as refractory lining for primary steel making and magnesium metal production.

CSIR in Innovation & Entrepreneurial Landscape

Basic chemicals: Driven by the 3 E's — environment, energy, and eco-benign – process intensification would drive the efficiency and selectivity of chemical reactions. Biorefining is likely to move to biomass-based resources. In the petrochemical segment, the CSIR-guided research programmes are likely to create a range of chemistries.



Innovation-driven progress in basic chemicals

Fertilizer: Global potash fertilizer capacity will likely reach 60 MT/year by 2035. India's resource base of potash is close to zero, and our efforts are towards extraction from sea bittern. This technology has been successfully demonstrated at 4500 tons/year levels and is also in practice at more minor scales. When expanded further, it has the potential to substitute imports by 20%, i.e., around 8 lakh tons per annum. Another option for potash explored is the use of distillery spent wash and incinerator ash.

Chloroalkali: The replacement of mercury cells in caustic soda and chlorine manufacture would stem from the developments in fuel cells. Solvay process would likely change the use of excess CO_2 from ammonia in the soda ash process and better heat and mass transfer.

Organics: The strength gained in catalysis over the decades will likely enhance the process intensification efforts. Aromatics to nitriles, trisubstituted olefins to ethane, dyes for solar cell sensitization, etc., are some outcomes based on catalysis.

Agrochemicals: This segment is worth Rs. 42000 Crores with an export potential of Rs 20000 Crores. Biofertilizers, micronutrients, and biostimulants are the new areas that CSIR would add to this basket. The potential ban on 27 agrochemical molecules currently in use will likely enhance this transition to biomolecules and trigger research on new molecules. CSIR had launched an agro mission programme to look at insecticides, fungicides, and herbicides. Twelve molecules were identified, and the processes to manufacture 11 of them were developed indigenously. Three molecules were demonstrated at industrial scales. In continuation of these efforts, further work on high potent agrochemicals is on the anvil.

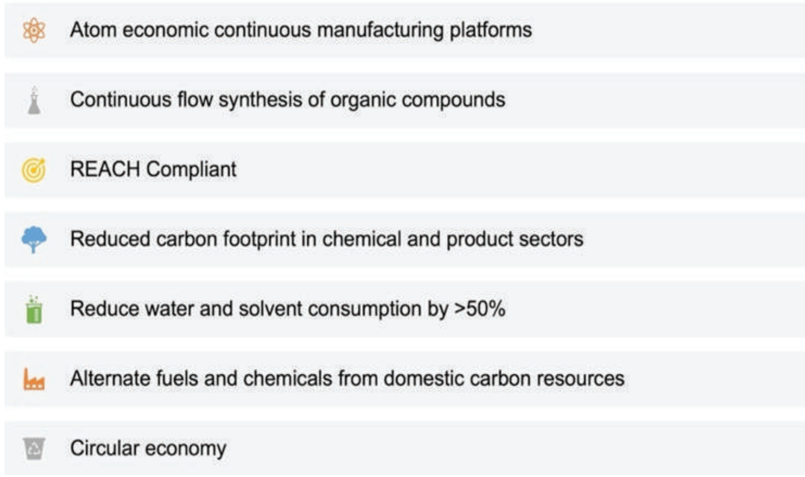
Pheromones: These are communication chemicals secreted by insects and are today explored as alternatives to pesticides. Pheromone application technology is used today in managing miners and borers. CSIR is working to expand the technology to season-long lures.

Active Pharma Ingredients (API) and Key Starting Materials (KSM): This is the third largest segment in volume terms and the 14th in value terms. More than 68% of the API is imported from China, affecting the country's pharma industries. A good opportunity awaits as, by 2024, USD 251 billion worth of branded drug patents will likely expire. CSIR has launched the Inprotics–pharma (Innovative Processes and Technologies for Indian Pharmaceutical and Agrochemical Industries) and API for COVID-19 mission mode programmes to speed up indigenous API development. Some likely avenues for API development are solvent-free mechanochemical and solvent-based solid form screening, nanoformulations as vehicles for API, and understanding the structure-property relationship as a key to API development.

Performance chemicals: The major innovation from CSIR is on security printing inks and coating materials. Another feature would be on performance chemicals such as those which can provide for stain-free surfaces, superhydrophobic surfaces, smart colorants, etc., that would have applications in textiles and up-segment leathers.

Sustainable Chemistry

Economic, environmental, and social sustainability are gaining more and more significance. Carbon neutrality is likely to govern the manufacture and use of chemicals.



Areas of significance for sustainable chemical manufacturing

In the case of bulk chemicals, self-sufficiency would be the key. An effort to combine process chemistries with advanced process engineering and development and a transition from batch to continuous processes is the way forward. Chemistries will undergo intensive toxicological studies, regulatory compliance, etc. AI-based tools for predicting scale-up criteria and validation will likely speed up a lab-to-market translation.

A higher emphasis on marine chemicals would lead to marine-based inorganic substances, elements, natural products, etc.

Grassroots Stakeholders

CSIR laboratories work in all the four quadrants of development, viz., public goods (publications, etc.), private goods (patents), society development (technologies from grassroots innovators and incubation/start-ups), and strategic goods (for the strategic sector). Much of the technologies require low levels of capital investment, making them viable for grassroot stakeholders.

In a small segment, viz., leather, CSIR, through its indigenous leather chemicals, process technologies, etc., has been able to bring about a transformation of the industry from a trader of hides/skins to a manufacturer and exporter of niche leather and leather products – taking India from Rs. 0.3 Crore exports (as hides/skins) in 1948 to Rs. 4800 Crores now. In this process, employment for over 44 lakh people has been generated. More than 50% of the 44 lakh employed in this sector are women.

CSIR, through its Chemicals (including leather) and petrochemicals theme-based approach has been working on atmarbharatha in chemicals. CSIR Vision 2030 for the CLP theme is to provide globally benchmarked sustainable processes for chemicals leading to a reduction in trade deficits.

Acknowledgement

The article derives its strength from the discussions held with the leadership of CSIR laboratories involved in chemical research. The Vision 2035 for the Manufacturing Sector – a document prepared by TIFAC, DST – has formed the basis for this article.

CSIR's cutting edge S&T in Agriculture, Nutrition and Biotechnology

CSIR THEME DIRECTORATES

Dr S.K. Barik
Director, CSIR-National Botanical Research Institute (CSIR-NBRI)
Theme Director, Agriculture, Nutrition and Biotechnology

THE Committee on Doubling Farmers' Income (2018) highlighted the need for developing advance technologies for the agriculture sector in the following words: "Technology fatigue is manifesting in the form of yield plateaus. India's yield averages for most crops at global level do not compare favourably. The costs of cultivation are rising. The magnitude of food loss and food waste is alarming".

The Committee further went on to state: "….despite several challenges, India's agriculture has demonstrated remarkable progress. It has been principally a contribution of the biological scientists, supplemented by an incentivizing policy framework. The Committee recognizes their valuable service in the cause of the farmers. It is now required to supplement this effort with expertise in post-production technology. The biological scientists now need to focus on new science and technology that will shift production onto a higher trajectory that is defined by benchmark productivities and sustainability."

In view of the above assessment, the Agriculture, Nutrition and Biotechnology (ANB) theme of CSIR has set a vision to ensure sustainable agriculture and nutritional security for the country through globally competitive biotechnological research and innovation. The theme's mission has been to develop innovative agro-technologies, value-added products and improved crop varieties.

CSIR has been committed to achieve its goal of improving the country's self-reliance in agriculture, food and nutritional security through farm mechanization, precision agriculture and innovative biotechnological interventions. The ANB theme implements its programmes through the following seven sub-verticals:

(i) Agro technologies and improvement of medicinal and aromatic crops,
(ii) Biofertilizers, Plant Growth Promoting Rhizobacteria, and Biostimulants,
(iii) Crop improvement through breeding, transgenics and genome editing,
(iv) Enzymes,
(v) Farm mechanization and Precision agriculture,
(vi) Nutritional Security, and
(vii) Value addition.

Since its inception in 1942, CSIR's journey in ANB sector has been spectacular, and marked by several key S&T contributions that have shaped India's agriculture, nutrition and biotechnology landscape. Some of these technologies, which are widely deployed in the country and are part of our day-to-day life or are in the process of maturity/deployment have been presented here.

Infant food technology from buffalo milk

In the 1950s, to make use of surplus buffalo milk available in parts of Punjab, Saurashtra, Bihar, Uttar Pradesh and Bombay, and to reduce the country's import burden of infant food, the CSIR-Central Food Technological Research Institute (CFTRI), Mysore investigated the longstanding problem of processing buffalo milk into milk powder/infant food, which is not encountered with cow's milk. CFTRI successfully established the conditions and processes for the production of milk powder which include, pasteurization, partial skimming, adjustment of composition, concentration, fortification with vitamins, homogenization and spray drying. The protein (20-22%) and fat (14%) contents of the final product were those considered optimum for children in tropical countries (Chandrashekhara *et al.*, 1958).

Addressing under-nutrition

Macronutrients such as carbohydrates, protein, and fat along with micronutrients are essential components in the human diet, which provide energy in the form of calories and are vital for normal growth and development. Undernutrition is still highly prevalent in India leading to a multitude of problems as it weakens the health and increases the risk of infections and diet-related diseases due to lowered immunity.

Protein-energy Malnutrition (PEM) is a major public health problem in India. It affects particularly preschool children (<6 years) with its dire consequences ranging from physical to cognitive growth and susceptibility to infection. This affects the child at the most crucial period of time of development, which can lead to permanent impairment in later life. This accounts for 22% of the burden of disease in India and adversely affects the economic growth of the country with an estimated adult productivity loss of 1.4% of Gross Domestic Product (GDP).

Despite an increase in per capita food production and a decline in poverty, India continues to feature increased rates of undernutrition. The prevalence of stunting among under-fives is 48% and wasting is 19.8% and with an underweight prevalence of 42.5%, it is the highest in the world.

Therefore, CSIR-CFTRI, CSIR-IHBT and CSIR-NBRI have been developing cost-effective nutraceutical/nutrient-supplement products continuously to address the problem of under-nutrition. Some of these are:

- Protein blends with improved digestibility for nutritional supplementation, functional properties, therapeutic applications, and sports nutrition.
- Developing protein-rich healthy snack products with iron and calcium contents to address protein-energy malnutrition.
- Vegan-based protein-rich functional food formulation with micronutrients targeting malnutrition.
- Validating functional food formulations and products to prevent essential fatty acid deficiency.

Nutraceuticals

Nutraceuticals are biologically active phytochemicals that possess health benefits. These may be delivered to the consumer as a dietary supplement and/or as a functional food. Under-nutrition and over-nutrition need to be concurrently addressed by developing new technologies/products, and deploying them to achieve the SDGs. CSIR labs, such as, CSIR-CFTRI, CSIR-IHBT, CSIR-NBRI, CSIR-IICT have developed several nutritionally rich products during the past two decades, and many of these are successfully deployed in the market.

These products range from low calorie natural sweeteners, herbal soft drinks and antioxidant-containing tea to Polyphenols-Zinc rich food supplement, microalgae as source of essential fatty acids and Omega 6 fatty acid from *Spirulina platensis*.

High value spice crops in non-conventional areas

CSIR-IHBT has introduced Saffron (*Crocus sativus*) and Hing in non-conventional areas by developing appropriate technologies. This has helped India in reducing its import burden.

Green molecules

CSIR-NBRI developed Anacardic Acid based formulation that increases quality of cotton fibre and enhances yield by 20% besides inducing early flowering in cotton crop. The formulation is being commercialized through two firms. Anacardic acid is extracted from the shell of the cashew nut.

CRMs

The global Certified Reference Materials market is expected to grow at a CAGR of 6.8% during the forecasting period (2021-2028). Indigenous development and production of CRMs is important because to save foreign exchange since imported CRMs are costlier. CSIR-NBRI has undertaken production of Certified Reference Materials of medicinal and aromatic phytomolecules.

Initially 20 Phytomolecules are being prepared. The institute has prepared seven CRMs and 2RMs of aromatic and medicinal Phytochemicals, which have been approved by NABL. CSIR-NBRI has got the NABL accreditation as reference material producer as per the requirements of ISO-17034-2016. CSIR is working towards converting India from a CRM importing country to exporting country.

Biofertilizers, Plant Growth Promoting Rhizobacteria (PGPR), Biostimulants

Bacteria that colonize plant roots and promote plant growth are referred to as plant growth-promoting rhizobacteria (PGPR). PGPR are highly diverse and many rhizobacteria act as biocontrol agents.

Plant growth promoting and stress ameliorating microbial formulations using *Rhizobium, Bacillus, Ochrobactrum, Alcaligenes, Panebacillus, Pseudomonas* based microbial formulations for salt, drought and low and high temperature stress were developed using microbial consortium for plant growth promotion by CSIR-NBRI, CSIR-IHBT and CSIR-NEIST.

Capsules/Nano based biostimulant formulations were developed by CSIR-NBRI and CSIR-IHBT. Several bio-pesticide formulations using *Bacillus*, *Pseudomonas*, *Beauveria*, NPV, *Trichoderma* were developed by CSIR-NBRI, CSIR-IHBT, CSIR-IIIM, CSIR-CIMAP for plant disease control. Microbial consortia were developed as stress buster by CSIR-NBRI, CSIR-IHBT, CSIR-NIIST and CSIR-NEIST.

Novel brackish-adapted PGPR from salt-tolerant Pokkali rice were isolated by CSIR-National Institute for Interdisciplinary Science and Technology (CSIR-NIIST, Thiruvanthapuram) and formulated as biofertilizers.

Seaweed based biostimulants

Seaweed extract formulations for plant growth promotion in saline soil were developed by CSIR-Central Salt and Marine Chemicals Research Institute, Bhavnagar, Gujarat (CSIR-CSMCRI). For plant growth promotion, Phycocolloid and sap from *Kappaphycus alvarezii* were used and process technology for *Sargassum* seaweed biomass was developed.

Industrial Enzymes

The industrial enzymes market was valued at over USD 6,000 million in 2021, and the market is projected to register a CAGR of more than 6% during the forecast period (2022-2027). Similarly, the specialty enzymes market was estimated to be valued at USD 4.4 billion in 2019 and is projected to reach USD 6.6 billion by 2025, recording a CAGR of 6.9%. The brewing enzymes market was estimated at USD 352.1 million in 2018 and is projected to reach USD 484.7 million by 2023, at a CAGR of 6.6% from 2018, in terms of value. The market for food enzymes is projected to reach USD 3.1 billion by 2026, recording a CAGR of 6.4%.

CSIR has been promoting indigenous production of industrial enzymes to reduce import burden as currently India imports 70% of its enzyme requirements (~40% China). Many CSIR labs have nationally recognized licensed enzymes and related technologies, state of the art facilities and high-quality human resources.

Crop Improvement

CSIR laboratories have carried out extensive work in the area of gene-mining for important traits and utilized these to develop plants with enhanced productivity and stress response. Gene mining has been successful for cotton fibre development, banana and mango fruit ripening, arsenic response in rice, flower petal abscission, secondary plant product biosynthesis as well as biotic and abiotic stress response.

Improved Sambha Masoori Rice: The CSIR-Centre for Cellular and Molecular Biology (CSIR-CCMB), Hyderabad in association with ICAR-Indian Institute of Rice Research (ICAR-IIRR) has developed Improved Sambha Masoori (ISM) variety rice with low Glycemic Index (GI). It is also resistant to bacteria blight. Rice with low GI is considered suitable for people with diabetes. ISM has lowest GI of 50.99 against the normal 53 to 70 in several rice varieties. Consumption of food with low GI results in slow release of glucose into the bloodstream reducing the ill-effects of diabetes. The molecular breeding of ISM was done by CSIR-CCMB and traditional rice breeding at ICAR-IIRR.

Low Grain Arsenic Rice: CN1794-2-CSIR-NBRI is a low grain arsenic and high yield (5.0-6.0 t/ha) variety named '*Muktashree*', developed by CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow in association with the Rice Research Station at Chinsurah under West Bengal Agriculture Department. *Muktashree*, now released at national level as a variety by the Govt. of India, demonstrated a yield advantage of 10-15% over popularly grown varieties, thus increasing the income of farmers in arsenic prone districts of the country. The unique advantage of *Muktashree* is that it decreases the risk of cancer and arsenicosis. The grain As in this variety (286 $\mu g\ kg^{-1}$) is considered safe for a 60 kg person consuming rice as subsistence diet (420 g) calculated on the basis of maximum tolerable daily intake (MTDI) of 2 μg As kg^{-1} body weight/day (WHO, 1993).

At CSIR-NBRI, a novel arsenic methyltransferase gene of *Westerdykella aurantiaca* isolated from arsenic contaminated soil, when expressed in rice was able to convert toxic inorganic arsenicals to methylated arsenic species (volatile compounds also), thereby reducing arsenic accumulation in rice grains. This could be a potential strategy for developing transgenic rice capable of low arsenic accumulation not only in grain but also in straw and feed, which are used for livestock.

Poppy: Increasing global demand of Oripavine is estimated to be 200-300 MT. so, at CSIR Oripavine rich lines are being developed. CSIR-NBRI has developed varieties like Ayush (NBIHT-3), Abha (NBMHT-4), and Mandakini (high opium) variety.

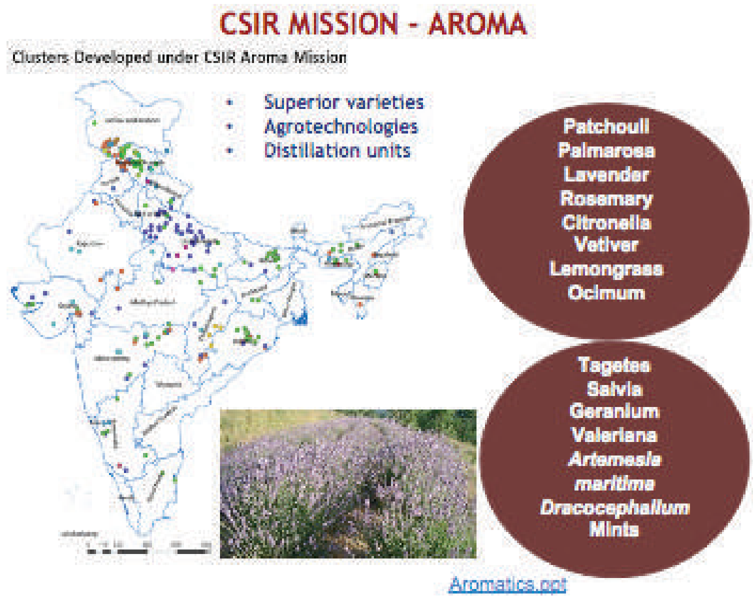
Cannabis: CSIR-NBRI, CSIR-CIMAP and CSIR-IIIM are working on development of low THC and high CBD cannabis lines for high fibre, oil, and proteinaceous seed.

Early maturing and flavonoid rich tomato: The accelerated growth and maturity by about a month was observed in the tomato variety. A reduction in total field water use, especially at the onset of summer, and a relative reduction in fertilizer/nutrient use was achieved. Another advantage is availability of the field for growth of other crops.

Next generation transgenic cotton: CSIR-NBRI has developed more than 40 transgenic cotton lines that express whitefly toxic protein Tma12. The Institute is working for improvement in cotton productivity of the country through sustainable control of field insect pests by providing the technologies to farmers in form of seeds. Developing effective insect-resistant cotton lines and their pyramiding to obtain a broad-spectrum resistance against crop pests in the field will achieve this goal. CSIR-NBRI has developed a GM cotton technology namely, Cry1EC cotton against leaf armyworm. Staking of the Cry1EC cotton with Cry1Ac based Bt cotton (available in India) to develop two (Cry1EC+Cry1Ac) gene technology (suitable for various agro-climatic conditions in the country) with the ability to resist damage by major field pests and guarding against the problem of the emergence of resistance in target pests is being targeted.

50K SNP Chip for Cotton: The *Gossypium hirsutum* genome was explored for large-scale development of genomic resources, which implemented hypomethylated restriction-based genomic enrichment strategy to sequence six diverse genotypes. The indigenous sequencing efforts led to 66364 SNPs (Rai et al. 2013, *Plant Biotechnology J*). The SNP markers identified in indigenous sequencing efforts lead to development of cotton 50K SNPs chip. This cotton SNP chip is used for linkage map and QTL analysis.

Improved varieties of medicinal and aromatic crops: Led by the CSIR-Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP), CSIR has developed several hundreds of commercially important medicinal and aromatic crop varieties for industries and farmers. These varieties have been developed by CSIR-CIMAP, CSIR-IIIM, CSIR-NBRI, CSIR-IHBT and CSIR-NEIST. Many of these varieties have been planted through out the country under the CSIR-Aroma Mission.



Improved varieties of floral crops: Led by the CSIR-National Botanical Research Institute (CSIR-NBRI) and CSIR-Institute of Himalayan Bioresource Technologies (CSIR-IHBT), CSIR has developed several hundreds of commercially important floriculture crop varieties for industries and farmers. Many of these varieties have been planted throughout the country under CSIR Floriculture Mission.

Farm Mechanization — Tractor Technology

Among the several cost-effective farm machineries and post-harvest technologies that CSIR has developed for small, marginal and large landholding farmers, the tractor technology of CSIR-Central Mechanical Engineering Research Institute, Durgapur (CSIR-CMERI) played the most significant role in transforming the agriculture sector in India. In the 1970s during the Green Revolution, CSIR-CMERI developed the first ever indigenous tractor Swaraj with a capacity of 20 hp. The technology was transferred to Punjab Tractors Ltd. The second tractor was Sonalika in the year 2000, a 35 hp tractor for medium and large land holding farmers. The knowhow was transferred to M/s International Tractors Ltd., Hoshiarpur. Another tractor technology with 11.2 horsepower diesel engine was released by CSIR-CMERI in 2014 for small and marginal landholding farming communities, and the technology was transferred to Singha Components Pvt Ltd.

Precision Agriculture

Precision agriculture enhances input use efficiency of agricultural inputs such as seed, fertilizer, water, chemicals and energy. It includes deploying AI, ML and Big Data Analytics in crop production activities or agro technologies, and system dynamics model based on AI for real time crop monitoring and management using multi/hyper-spectral imageries. Some of the work being carried out in developing different technology components of precision agriculture:

- Measurement/data acquisition – sensor development/ fusion/system engineering (CEERI/CSIO/NCL)
- Analysis of the data – mobile phone/cloud based (CEERI/ CSIO/CMERI and domain experts from CSIR Agri Labs)
- Application of inputs based on analysis – ground and aerial based equipment (CMERI / NAL)
- Converting domain knowledge to visualizations to help in decision making (4PI and CSIR Agri Labs).

Floriculture Mission

The deliverables of floriculture mission with active inter-ministerial collaboration are:

- Enhancing the participating farmers' income at least by 5 times
- Enhanced quality of flowers and other floriculture products to increase export volume
- New varieties to meet the market need
- Taking indigenous wild ornamentals to international market
- Value-added products for enhanced income and entrepreneurship development
- Capacity development of stakeholders in different areas of floriculture
- Establishing effective domestic and international market linkage
- Integrating floriculture and apiculture
- Urban floriculture and expansion of area under floriculture.