59th ENGINEERS' DAY

15th September, 2026

Bharat Ratna Sir M. Visvesvarya (1861-1962)

THEME:

"Engineering Excellence for a Sustainable and Technologically Sovereign India"



SOUVENIR

The Institution of Engineers (India)

U.P. STATE CENTRE, LUCKNOW

&

The Institute of Marine Engineers (India)

The Institution of Engineers (India)

8 Gokhale Road, Kolkata, 700 020, India — Established 1920, Incorporated by Royal Charter 1935

U.P. State Centre, Lucknow

Engineers Bhavan River Bank Colony, Lucknow-226018
Mob : 7839572369; Website : ieiup.org.in

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The Institution of Engineers (India)

U.P. State Centre, Lucknow

&

The Institute of Marine Engineers (India)

15th September 2026

59TH ENGINEERS' DAY



(Sir Mokshagundam Visvesvaraya)

Souvenir

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Sir M.Visvesvaraya's Services to The Country

The life, the fortune and the happiness of every one of us depend upon our knowing something of the rules of a game infinitely more difficult and complicated than chess. The chessboard is the world, the pieces are the phenomena of the universe, and the rules of the game are what we call the laws of nature. The player on the other side is hidden from us. We know that his play is always just, fair, and patient. But we also know to our cost that He never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with the sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated- without haste but without remorse. What I mean by education is learning the rules of this mighty game.

स्वतंत्र देव सिंह
मंत्री
जलशक्ति
(सिंचाई एवं जल संसाधन, बाढ़ नियंत्रण,
परती भूमि विकास, लघु सिंचाई, नमामि गंगे
तथा ग्रामीण जलापूर्ति विभाग)
उत्तर प्रदेश।

दूरभाष नं0 : 0522-2238067
सी.एच. : 0522-2213000
(आवास) : 0522-2237839
कार्यालय : कक्ष सं0-81बी-82,
मुख्य भवन, विधान भवन, लखनऊ
आवास : 05, मॉल एवेन्यू, लखनऊ।

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संदेश

यह अत्यन्त हर्ष का विषय है कि दि इन्स्टीट्यूशन ऑफ इंजीनियर्स (इण्डिया), यू0पी0 स्टेट सेन्टर, लखनऊ द्वारा भारतरत्न डा0 एम0 विश्वेश्वरैया जी के जन्म दिवस के अवसर पर दिनांक 15 सितम्बर, 2026 को इंजीनियर्स भवन, रिवर बैंक कॉलोनी स्थित सभागार/परिसर में **59वें अभियन्ता दिवस** का आयोजन किया जा रहा है तथा इस अवसर पर एक स्मारिका का भी प्रकाशन किया जा रहा है।

"Engineering Excellence for a Sustainable and Technologically Sovereign India" की प्रेरणादायी थीम के साथ अभियन्ताओं के योगदान, नवाचार, तकनीकी उत्कृष्टता एवं राष्ट्र निर्माण की भावना को सम्मानित करने का यह प्रयास अत्यन्त सराहनीय है।

मैं **अभियन्ता दिवस** के सफल आयोजन एवं **स्मारिका** के सफल प्रकाशन हेतु अपनी हार्दिक शुभकामनाएं प्रेषित करता हूँ।

(स्वतंत्र देव सिंह)

0522–2626804
0522–2614633
engineerinchiefidup@gmail.com

प्रमुख अभियन्ता एवं विभागाध्यक्ष

सिंचाई एवं जल संसाधन विभाग,

उत्तर प्रदेश, लखनऊ

पत्रांक...196.../ प्र0अ0/सिंचाई

दिनांक...9/9/26...

शुभकामना संदेश

मुझे यह जानकार हार्दिक प्रसन्नता हो रही है कि इन्स्टीट्यूशन ऑफ इन्जीनियर्स (इण्डिया), यू0पी0 स्टेट सेन्टर लखनऊ एवं दी इंस्टीटयूट ऑफ मरीन इंजीनियर्स इंडिया संयुक्त रूप से भारत रत्न डॉ. मोक्षगुंडम विश्वेश्वरैया की जयंती के पावन अवसर पर 59 वां अभियन्ता दिवस दिनांक 15 सितम्बर 2026 को लखनऊ में मना रहा है। जिसमें **"Driving Sustainability with Engineering Solutions Embaracing the Latest AI Driven Technoligies"** विषय पर एक स्मारिका भी प्रकाशित कर रहा है।

अभियंता राष्ट्र के विकास की आधारशिला होते हैं। जल संसाधन, सिंचाई, आधारभूत संरचना, ऊर्जा, परिवहन, नगरीय विकास तथा तकनीकी क्षेत्रों में अभियंताओं का योगदान देश एवं प्रदेश को प्रगति के पथ पर अग्रसर करने में अत्यंत महत्वपूर्ण है। बदलते समय में हमारी जिम्मेदारी और भी बढ़ गई है कि हम नवाचार, आधुनिक तकनीक, गुणवत्ता, पारदर्शिता तथा पर्यावरणीय संतुलन को अपनी कार्यप्रणाली का अभिन्न अंग बनाएं।

इस वर्ष अभियंता दिवस की थीम **"Engineering Excellence for a Sustainable and Technologically Sovereign India"** हमें यह संदेश देती है कि तकनीकी उत्कृष्टता के साथ-साथ सतत एवं आत्मनिर्भर भारत के निर्माण में अभियंताओं की महत्वपूर्ण भूमिका है। हमें अपने ज्ञान एवं कौशल का उपयोग समाज के अंतिम व्यक्ति तक विकास का लाभ पहुँचाने तथा जल एवं प्राकृतिक संसाधनों के संरक्षण के लिए करना चाहिए।

मुझे विश्वास है कि प्रदेश के अभियंता अपनी प्रतिभा, समर्पण और कर्तव्यनिष्ठा से उत्तर प्रदेश के विकास को नई गति प्रदान करते हुए विकसित एवं आत्मनिर्भर भारत के निर्माण में अपना महत्वपूर्ण योगदान देते रहेंगे।

अभियंता दिवस पर प्रदेश के समस्त अभियंताओं को हार्दिक शुभकामनाएँ एवं बधाई।

(संदीप कुमार) 9/09/26

प्रमुख अभियंता एवं विभागाध्यक्ष

सिंचाई एवं जल संसाधन विभाग, उत्तर प्रदेश

सिंचनेन समृद्धिं भवति

The Institution of Engineers (India)

AN ISO 9001: 2015 CERTIFIED ORGANISATION
(ESTABLISHED 1920, INCORPORATED BY ROYAL CHARTER 1935)

Er Manish Mahendra Kothari, FIE
President

Headquarters : 8 Gokhale Road, Kolkata 700020
Contact : 91- 33-40106202 / 40106204
E-mail : president@ieindia.org



A Century of Service to the Nation

Message

It gives me immense pleasure to extend my warm greetings to The Institution of Engineers (India), Uttar Pradesh State Centre, for celebration of 166th Birth Anniversary of the eminent engineer-statesman Bharat Ratna Sir M. Visvesvaraya on 15th September 2026. This day, serves as a solemn reminder of the transformative role of engineers playing in nation-building and technological advancement.

The chosen theme of this year, *"Engineering Excellence for a sustainable and technologically Sovereign India"*, is both timely and inspiring, underscoring the vital role of engineers in steering the nation through an era of rapid innovation and global challenges. Engineering excellence remains the cornerstone of national progress, while technological sovereignty is not merely an aspiration but an imperative — ensuring that India remains self-reliant, resilient, and capable of leading in critical domains such as infrastructure, energy, digital transformation, defence, and sustainable development.

I am confident that the souvenir to be released in this occasion for celebration of 59th Engineers' Day will spark fresh ideas, foster collaboration, and strengthen the resolution of the engineering fraternity to advance India's journey toward technological sovereignty. The Uttar Pradesh State Centre deserves high commendation for its dedicated efforts in promoting professional excellence and nurturing the spirit of innovation among engineers.

On this auspicious occasion, I extend my best wishes for the resounding success of Engineer's Day 2026 celebrations and for the continued advancement of the engineering fraternity in building a self-reliant, resilient, and technologically empowered India.

Er. Manish M. Kothari, FIE
President
The Institution of Engineers (India)

MAPA, D-5, Street No.10, MIDC, Satpur, Nashik 422007, Maharashtra
Mobile: 9422247911, Email:mmkotharister@gmail.com

The Institute of Marine Engineers (India)

HEADQUARTERS & TRAINING CENTRE: IMEI HOUSE, SECTOR 19, PLOT NO- 94, NERUL, NAVI MUMBAI - 400706.
TEL.: + 91 22 27701664 ! 27706749 / FAX: + 91 22 2771J663 / URL: www.imare.in
ADMIN: administration@imare.in ! MEMBERSHIP: membership@imare.in / TRAINING : training@imare.in



Message

It gives me immense pleasure to extend my warmest greetings to the engineering fraternity on the occasion of the **59th Engineers' Day**, being celebrated on 15th September 2026.

Engineers have played an indispensable role in shaping the progress of our nation. From infrastructure and industry to energy, technology, transportation and maritime development, the contributions of engineers have been central to India's journey of transformation. Engineers' Day is therefore not merely a celebration of a profession; it is an occasion to recognise the spirit of innovation, problem-solving, dedication and service that defines engineering.

This year's celebrations hold a special significance for the **Institute of Marine Engineers (India)** with the inauguration of the **IMEI Lucknow Chapter**. I am particularly delighted that this important milestone is being marked alongside Engineers' Day and through an association with the **Institution of Engineers (India), Uttar Pradesh State Centre**. The initiative represents an opportunity to strengthen professional engagement, knowledge sharing and collaboration between the wider engineering community and the maritime engineering fraternity.

The maritime sector is undergoing a profound transformation. Decarbonisation, alternative fuels, autonomous and smart ships, digitalisation, artificial intelligence, advanced automation and emerging technologies are redefining the way ships are designed, operated and maintained. At the same time, the industry must ensure that safety, environmental responsibility and human competence remain at the heart of this transformation.

This changing landscape places an even greater responsibility on engineers. The engineer of the future must be more than technically competent. We must be adaptable, innovative, ethical and conscious of the wider social and environmental impact of our decisions. We must also ensure that our young engineers are given the knowledge, mentorship and opportunities necessary to lead this transformation.

The establishment of the IMEI Lucknow Chapter is therefore much more than the opening of another professional chapter. It is a step towards taking the maritime engineering profession closer to new communities, institutions and aspiring engineers. I hope the Chapter will become a vibrant platform for professional development, interaction with academia and industry, technical exchange and, most importantly, for inspiring young people to explore the exciting opportunities offered by the maritime sector.

I sincerely appreciate the efforts of all those who have contributed to bringing this initiative to fruition. I am confident that the partnership between the engineering and maritime communities will grow stronger in the years ahead.

On this auspicious occasion, let us reaffirm our commitment to **engineering excellence, innovation with purpose, professional integrity and sustainable development**.

My best wishes to all engineers on Engineers' Day, and my heartfelt congratulations to the IMEI Lucknow Chapter on its inauguration.

Kaushik Seal
President

The Institution of Engineers (India)

AN ISO 9001 : 2015 CERTIFIED ORGANISATION

(ESTABLISHED 1920, INCORPORATED BY ROYAL CHARTER 1935)

Er.V B Singh, FIE		**Headquarters**	: 8 Gokhale Road, Kolkata 700020
Immediate Past President		**Contact**	: 91- 33-40106202 / 40106204
		E-mail	: president@ieindia.org



A Century of Service to the Nation

MESSAGE

It gives me immense pleasure to extend my warm greetings to The Institution of Engineers (India), Uttar Pradesh State Centre, on the occasion of the 165th Birth Anniversary of the eminent engineer-statesman and Bharat Ratna Sir M. Visvesvaraya, celebrated as Engineers' Day on 15th September 2026.

The theme, **"Engineering Excellence for a Sustainable and Technologically Sovereign India"**, is both relevant and inspiring. It highlights the pivotal role of engineers in shaping a self-reliant, resilient and technologically empowered nation. Engineering excellence, coupled with innovation and indigenous technological capabilities, is essential for strengthening India's position in critical sectors such as infrastructure, energy, digital technologies, defence and sustainable development.

Engineers have a vital responsibility to develop solutions that are technologically advanced, economically viable and environmentally sustainable. Their expertise, creativity and commitment will be instrumental in addressing emerging challenges and advancing the vision of a technologically sovereign India.

I am confident that the souvenir being brought out on this occasion will provide a meaningful platform for exchange of ideas, knowledge and experiences, while further strengthening the professional spirit of the engineering fraternity.

I convey my best wishes to the Uttar Pradesh State Centre for the successful celebration of Engineers' Day 2026 and for its continued efforts towards promoting engineering excellence and contributing to the nation's progress.

(V B Singh)
Immediate Past President, IEI

4/125, Vishal Khand, Gomti Nagar, Lucknow 226 010, **Mobile**: 8004288301, **E-mail:** vbsingh51@gmail.com

The Institution of Engineers (India)

UTTAR PRADESH STATE CENTRE, ENGINEERS BHAWAN, RIVER BANK COLONY, LUCKNOW-226018

दि इन्स्टीट्यूशन ऑफ इंजीनियर्स (इण्डिया)

उत्तर प्रदेश स्टेट सेन्टर, इंजीनियर्स भवन, रिवर बैंक कालोनी, लखनऊ–226018

ER. VIJAYA PRATAP SINGH, FIE
CHAIRMAN

Telephone : +91 7839572369;
+91 0522-3512499
E-mail : upsc@ieindia.org
Website : www.ieiup.org.in

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"A Century of Service to the Nation"



MESSAGE

It gives me immense pleasure to extend my warmest greetings to the engineering fraternity on the occasion of the 59th Engineers' Day.This year's theme, "Engineering Excellence for a Sustainable and Technologically Sovereign India," perfectly reflects our nation's current trajectory. As we honor the enduring legacy of Bharat Ratna Sir M. Visvesvaraya, we are reminded that true engineering prowess lies in balancing rapid technological growth with ecological responsibility.

On this momentous occasion, I also extend my heartiest congratulations and best wishes to The Institute of Marine Engineers (India) on the auspicious inauguration of their Lucknow Chapter. The expansion of marine engineering expertise into this vibrant region will undoubtedly strengthen our collective efforts toward maritime innovation and self-reliance.I congratulate the editorial team and organizers for bringing out this official souvenir and wish the celebrations every success.

VP Singh

(Er. Vijaya Pratap Singh, FIE, FIMARE)
Member, Marine Division Board IEI
&
Chairman

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Life Sketch of Bharat Ratna Sir M. Visvesvaraya

BHARAT RATNA Sir M. Visvesvaraya was one of the few of the twentieth century engineers who have risen to become top national figures. He reached to such achievements owing to his discipline and devotion to profession. His masterly achievements in the field of engineering and administration outclassed the best of engineers. Visvesvaraya was born on September 15, 1861 at Chikkaballapur in Kolar District of Mysore State. He took the Bachelor of Arts Degree of Madras University in 1880 from Central College, Bangalore and then entered the College of Science, Poona in 1881 to pursue engineering education. Topping the list of engineering candidates in 1883 he joined Bombay P.W.D. as an Assistant Engineer. In his early career he was entrusted with direct execution of some important works like the design of Water Supply System for Dhulia in Khandesh Distt., Water Supply and Drainage Schemes for Sukkur in Sind (present day Pakistan) and Water Works for Surat. The successful handling of these schemes established him as an executive of Zeal and ability. His prominence procured him an invitation from Indian Irrigation Commission of 1901-1993 to prepare a memorandum of the Irrigation Works in Bombay Presidency. He designed and patented a system of automated floodgates at rise and fall of water in the reservoir to raise the storage level of Lake at Khadakvasla permanently without raising the dam.These gates installed in 1903 are still working successfully. In 1906 he was deputed to Aden to prepare schemes for sanitary, water supply and roads. Sept. 28, 1908, struck headlines as a day of terrible disaster in the history of Hyderabad due to devastation and deluge caused by the rivers Musi and Easi overflowing their banks and leaving behind a iismal trail of death and destruction. At the invitation in behalf of his Exalted Highness the Nizam, Visvesvaraya consented to act as Special Consulting Engineering from April, 15, 1909. After a thorough nvestigation into the engineering aspect of the problem i.e. set out his scheme for reconstruction of the city and came out with the proposals for construction of two reservoirs.

Subsequently he assumed office as Dewan of Mysore State in November 1912. The farseeing leadership of this Great Man ushered in an era of industrial revolution and community development in the State of Mysore. The Krishnarajasagar, perhaps the first multipurpose project in India, and Visvesvaraya Canal, are living proofs of his creative genius and restless desire to make use of ingenuity, conviction, faith in science and technology for translating vision into reality. A number of Engineering Colleges and Schools were opened in Banglore during his period. He voluntarily laid down the office as Dewan in 1919, where after a new phase of his life began. At an age when most men will content to retire and take life easy, he took numerous assignments for the benefit of the the society. The chronicle of his activities in this period would be too numerous and lengthy to enumerate. He was decorated with C.I.E. and K.C.I.E. by the British Empire in the years 1911 and 1916 respectively. He was honoured by Eight Universities who conferred on him with the Degree of Honorary Doctorate. Finally Sir Visvesvaraya was honoured by the President of India in 1955 and was decorated with the highest Award of the Land-BHARAT RATNA. This Great Engineer Administrator of our land passed away in 1962. Engineers of the land pay a modest homage to this Great Genius who is a torch to the Indian Engineers for all times to come by observing September, 15 as the "Engineers' DAY". Sir M. Visvesvaraya was the pioneer in bringing Autombile industry in the Country. By meeting the then magnates of the fields like Lord Austin

and the Henry Ford, he met the engineers working at FIAT, Italy. His daunted efforts resulted in the establishment of Premier Automobile Company at Bombay in 1939 by M/s Walchand and Hirachand.

Britishers were initially opposed to the idea of Aircraft manufacturing in India but by his support the Government of Mysore was succeeded in starting the industry of Aircrafts in 1940 at Bangalore. He was the main person for sowing the seed for the starting of present HAL. Sir Mokshagundam Visvesvaraya was an Engineering Hero who rose on the Indian scene in the 19th century and continued to serve the country for more than half of the 20th century. His was an all embracing personality to which one could look for guidance in solving India's problems of today and tomorrow . The test of a great life lies really in the worth it retains after it is no longer available to offer guidance, or shed its illumination on the economic landscape. It's greatness would, therefore, be decided by the awareness of the succeeding generations in respect of its capacity to guide them or pilot their course on the uncharted sea of economic problems, with its storms and tempests.

Bharat Ratna Sir M Visvesvaraya belonged to the group of engineering scientist, and inventor, an industrialist, an economic planner, a scientific advisor, and statesman. He was the key person in formulating the right direction of Indian engineering temper.

At this he has advised in-

1. Village planning to contain their population.
2. Compulsory primary education.
3. Free meals, free transport for school going boys and girls.
4. Adopting block system of Irrigation & Role of village tank.
5. Additional occupation of farmers.
6. Need for specialization.
7. Religion is science.
8. Vitalize the youth of the country.
9. Need for more Universities.
10. Industrialize the knowledge.
11. Control of population.
12. Scientific Research.
13. Electrical power grid essential for the development of the country.
14. Engineers should get incentives.
15. Starting of engineering consultancy services.
16. Starting of Automobiles & Aircrafts Industry.

With regards to the position of an engineer in the country's administration he was sorry to say: "The engineer, whether in the service of government, a municipal corporation or a large industrial undertaking does his work unobserved. He may inspire but cannot shape policies. In the course of his daily routine he usually does a vast amount of designing and constructional work, standing behind a ruler, administrator, financier, or business syndicate. The majority of engineers in this country have no independent status. His books "Reconstructing India" and "Planned Economy for India" are examples of his vision and dedication.

On celebration of his 100th birthday in 1961 at Bangalore the then Prime Minister of India Shri Jawaharlal Ji has rightly said: "We have gathered here on a memorable occasion, and I have come here to have the privilege of joining on this occasion. I would have come, anyhow to honour the great son of India. But, it so happen that I occupy a position granted to me by the goodwill and confidence of the people of India, and so without any arrogance I may say that in offering my homage to this distinguished son of India. I do so on behalf of the people of India". This simple & strong disciplined person lived for 101 years. We bow to him on this 52nd Engineers Day.

59th ENGINEERS' DAY

THEME: *"Engineering Excellence for a Sustainable and Technologically Sovereign India"*



Bharat Ratna Sir M Visvesvaraya

September 15 is celebrated every year in the country since the year 1967 as "Engineers' Day" to commemorate the birthday of the legendary engineer Sir Mokshagundam Visvesvaraya. Sir Visvesvaraya, an eminent Indian engineer and statesman was born in a remote village of Karnataka, the State that is incidentally now the Hi-tech State of the country. Due to his outstanding contribution to the society, Government of India conferred "Bharat Ratna" on this legend in the year 1955. He was also called the precursor of economic planning in India. His learned discourse on Economic Planning in India, Planned Economy for India and Reconstructing India, was the first available document on the planning effort of the country and it is still held as the parent source matter for economic planners. A theme of national importance is chosen every year by the Council of the Institution and deliberated at its various State/Local Centres to educate the engineering fraternity in general and the society in particular. This year the 58th Engineers' Day will be celebrated all over the country on the theme "Engineering Excellence for a Sustainable and Technologically Sovereign India".

As we celebrate the 59th Engineers Day and reflect on our journey of engineering excellence, we reaffirm our commitment to sustainability and national development. Engineering for sustainability is not merely an aspiration—it is a responsibility to create infrastructure that drives progress while safeguarding our planet for future generations. From infrastructure and petrochemicals to process industries, information and data security, automation, and digital transformation, our contributions have consistently supported nation-building through responsible and sustainable engineering practices. Today, the urgency of climate change and the growing demand for cleaner, smarter infrastructure have redefined our priorities.

Sustainability is no longer a choice; it is an engineering mandate. Across projects worldwide, we are integrating energy efficiency, environmental stewardship, and circular economy principles into every stage of design and execution. Our focus is now on advancing pioneering technologies such as green hydrogen, advanced bio fuels, AI-driven solutions, and carbon-conscious design. From underground crude storage systems to future-ready data centres, our engineering solutions are designed to serve both industry and the environment in a balanced and sustainable manner

About the Institution of Engineers (India)

Er. Nirendra Kumar Nishad FIE
Hony. Secretary

ADVANCING KNOWLEDGE

The Institution of Engineers (India), the IEI, is a national organization for engineers in India. It has more than eight million members in 15 engineering disciplines in 125 centers or chapters in India and 6 overseas, and is the world's largest multi-disciplinary engineering professional society.

The IEI was established in 1920 in Madras,with Sir Thomas R. J. Ward being the founding president. It was formally inaugurated in 1921 by Lord Chelmsford, the then-Viceroy of British India. On 19 December 1930, the then Viceroy Lord Irwin, laid the foundation for the IEI's building at 8 Gokhale Road, in Calcutta. The organisation moved into the building on 1 January 1932.

In September 1935, following a successful petition by Sir Thomas Guthrie Russell (President 1933-34), the IEI obtained a Royal Charter of Incorporation from King George V 'to promote and advance the science, practice, and business of engineering'.

IEI with its presence in 5 Overseas Countries, is also the first professional body to represent India in several international Forums like World Federation of Engineering Organisations (WFEO). Commonwealth Engineer Council (CEC). Federation international du Beton (Fib) Federation of Engineering Institutions of Asia and the Pacific (FEIFIC), and Federation of Engineering Institutions of South and Central Asia (FEIAP), besides a host of strategic tie-ups with professional societies across the globe.

IEI functions with and amongst the professional engineers, academicians and research workers and provides a vast array of technical value-added professional services to the Government, Industries, academic and engineering communities.

IEI had been conducting it's well recognized non-formal engineering education programme since pioneering the same in 1928, acknowledged to be equivalent to a degree in engineering by the Government of India, the Union Public Service Commission, the state Governments and many Public/Private Sector organizations in the country. Though matter is under legal dispute for students registered after 31st May 2013.

IEI Headquarters in Kolkata, India and administered by a National Council led by its President operates through 125 State and Local Centres, located at the capital cities and towns of industrial and academic importance all over the country, along with 6 Overseas Chapters. The Secrrtary & Director General is the Chief Executive Officer of the Institution.

IEI SERVICE SPECTRUM FOR ENGINEERING COMMUNITY

The range of services offered by the Institution of Engineers (India) to their Members includes:

Dissemination of engineering and technological knowledge to all members, planning and organizing activities that impact engineering such as continuation of education courses, seminars, symposia, workshops, conventions, conferences, etc at both national and international levels.

- Providing access to R & D activities and engineering practices across multitude of engineering and

technological disciplines.

- Focusing on new developments, techniques, products, processes and other issues of topical interest to boost professional growth.
- Communicating emerging engineering and technological scenario through IEI News, the institutional Journal published monthly.
- Providing advanced library services as well as knowledge interfaces at the IEE Headquarters and State and Local Centres.
- Fostering national and international cooperation to promote new age excellence in engineering and technology.
- Acting as an accreditation body for courses in engineering.
- Acting as qualifying body and conducting examinations for its non-formal education programme catering to aspirations of prospective entrants to the profession.
- Supporting and rewarding individual pursuits and achievements in furthering the art and science of engineering and technology.

INTERNATIONAL PROFESSIONAL ENGINEERS' CERTIFICATION

By virtue of being a member of the International Professional Engineers Agreement (IPEA) since 2009. The Institution of Engineers (India) represents India and has been empowered to establish and maintain the India section of the International Professional Engineers (IntPDE) Register.

Details are available at https/www.ieindia.org/inter_prof.aspx.

PROFESSINAL ENGINEERS' CERTIFICATION

The Institution of Engineers (India) renders Certificate of Competence to engineers by way of Professional Engineers Certification known as P.Eng.(India), Professional Engineers (PE) Certification not only enhances the engineering professionals stature , but also makes them suitable in maintain higher levels of authority and responsibility, enabling an engineer to become an independent consultant, government engineer or an academician.

Details including the Guidelines, application Form, etc. are available at IEI website: www.ieindia.org.

IEI MEMB ERSHIP

The Corporate Members of the Institution is open to any person with an accredited engineering degree with required professional experience. The membership portfolio based on accumulated professional experience and level of responsibilities includes Associate Member, Member and fellow grades, subjecting to strict scrutiny by a nominated high level Committee at IEI HQ, Kolkata. For details and onlines application for IEI membership, visit http:/www.ieindia.org.

IEI MEMBERSHIP GRADE

Corporate

Non Corporate

Student Member (SMIT)

Member Technologist (MTIE)

Associate Member Technologist (AMTIE)

Senior Technician (Sr. Tech.IE)

Technician (Tech.IE)

Fellow(FIE)

Member (MIE)

Associate Member (AMIE)

Institutional Member

KEY BENEFITSS

- CORPORATE MEMBERSHIP -
- Corporate Members are entitled to receive Chartered Engineer certificate on payment of requisite fee.
- Eligible for exemption from appearing in Section A and may appear directly in Section B in additional branch examination of IEI.
- Provided with e-access to 5 series of journals of The Institution of Engineers (India) covering 15 engineering division, published in partnership with globally renowned journal publishing house SPRINGER.
- Given the monthly ;IEI NEWS' and IEI Epitome.
- Entitled to participate in technical events e.g. Seminar, Symposia, Conventions, Workshops etc. organized by IEI Centres at State. National and International Levels at a concessional rate of 20%.
- Given preference for grant-in-aid on R&D activities to the Corporate Members. engaged in academic.
- Eligible to participate contest in IEI elections as per Bye-laws of the Institution.
- Empanelled as internal project guide in AMIE Examination conducted by IEI as per norms.
- PROVIDED WITH THE FACILITY OF STAYING IN THE iei Guest Houses spread over all important locations in India. A list of all the guest houses is available at IEI website.

हिमालयी क्षेत्र में बढ़ती आपदाएँ: केदारनाथ से चमोली, जोशीमठ और धराली तक—क्या हमने समय रहते चेतावनियों को समझा?

प्रो. (डॉ.) भारत राज सिंह
पर्यावरणविद् एवं महानिदेशक (तकनीकी),
स्कूल ऑफ मैनेजमेंट साइंसेज, लखनऊ, उत्तर प्रदेश, भारत
ईमेल:brsinghlko@yahoo.com मोब:9415025825
डॉ. आशा कुलश्रेष्ठ
विभागाध्यक्ष, सिविल इंजीनियरिंग,
स्कूल ऑफ मैनेजमेंट साइंसेज, लखनऊ, उत्तर प्रदेश, भारत

सारांश
हिमालय भारत सहित दक्षिण एशिया की जल, जैव-विविधता, कृषि, ऊर्जा और आजीविका की जीवनरेखा है। इसकी तीव्र ढाल, कमजोर भूगर्भीय संरचना, सक्रिय विवर्तनिकी, मानसूनी प्रभाव तथा बढ़ता मानवीय दबाव इसे अत्यधिक आपदा-संवेदनशील बनाते हैं। **केदारनाथ (2013), चमोली (2021), जोशीमठ (2022–23) और धराली (2025)** की घटनाओं ने इस संवेदनशीलता को स्पष्ट किया है। इनके तात्कालिक कारण अलग थे, लेकिन प्राकृतिक पर्वतीय अस्थिरता, जलवायु एवं जलवैज्ञानिक चरम घटनाओं, हिममंडलीय परिवर्तन और मानवीय जोखिम-उद्भासन के बीच अंतर्संबंध समान रूप से दिखाई देता है।
यह अध्ययन इन घटनाओं को अलग-अलग दुर्घटनाओं के बजाय **परस्पर जुड़े चेतावनी संकेतों** के रूप में देखता है। हिमनद क्षय, परमाफ्रॉस्ट, जमाव–पिघलाव, अस्थिर शैल-पिंड, अत्यधिक वर्षा, हिमनदीय झीलें, नदी-मार्ग, ढाल कटान, सड़क निर्माण और जोखिमपूर्ण बस्तियाँ मिलकर श्रृंखलाबद्ध आपदा जोखिम उत्पन्न कर सकती हैं। अतः हिमालयी विकास का आधार केवल निर्माण क्षमता नहीं, बल्कि **भू-वैज्ञानिक उपयुक्तता, पारिस्थितिक वहन क्षमता और वैज्ञानिक जोखिम आकलन** होना चाहिए।

मुख्य शब्द: हिमालय, जलवायु परिवर्तन, हिमनद क्षय, शैल–हिम हिमस्खलन, GLOF, मलबा प्रवाह, जोशीमठ, धराली, प्रारंभिक चेतावनी, वहन क्षमता।

1. प्रस्तावना
हिमालय विशाल हिम एवं बर्फ भंडार, प्रमुख नदी-तंत्र, वन, जैव-विविधता, कृषि, पर्यटन और जलविद्युत का आधार है। साथ ही तीव्र ढाल, सक्रिय विवर्तनिकी, कमजोर चट्टानी संरचना और प्रबल मानसून इसे प्राकृतिक रूप से जोखिमपूर्ण बनाते हैं।
हिंदूकुश–हिमालय क्षेत्र में तापमान वृद्धि, हिमनद द्रव्यमान में कमी, हिम-आवरण परिवर्तन और परमाफ्रॉस्ट क्षरण जैसी प्रवृत्तियाँ चिंता बढ़ा रही हैं। फिर भी प्रत्येक आपदा को केवल जलवायु परिवर्तन से जोड़ना वैज्ञानिक रूप से उचित नहीं है। प्राकृतिक भूवैज्ञानिक प्रक्रियाओं के साथ सड़क निर्माण, ढाल कटान, नदी-तट विकास और जोखिमपूर्ण बस्तियाँ आपदा के प्रभाव को बढ़ा सकती हैं।

मुख्य प्रश्न यह है:

क्या वैज्ञानिक चेतावनियों को सुरक्षित और जोखिम-सचेत विकास में बदला गया है?
उत्तर आंशिक है। वैज्ञानिक निगरानी में प्रगति हुई है, पर विकास-निर्णयों में जोखिम की जानकारी का पूर्ण समावेश अभी आवश्यक है।

2. आपदा जोखिम का प्रणालीगत दृष्टिकोण

र्वतीय आपदाओं की सटीक तिथि और स्थान की भविष्यवाणी कठिन है; इसलिए प्राथमिकता **जोखिम-पथों की समय रहते पहचान** होनी चाहिए। तापमान वृद्धि हिम, हिमनद और परमाफ्रॉस्ट को प्रभावित कर सकती है, जबकि अत्यधिक वर्षा ढीले अवसादों और खंडित चट्टानों को गतिशील कर सकती है।
अधिक वैज्ञानिक मॉडल है:
जलवायु परिवर्तन + भू-वैज्ञानिक अस्थिरता + जलवैज्ञानिक चरम घटनाएँ + भू-आकृतिक प्रक्रियाएँ + मानवीय जोखिम-उद्भासन = श्रृंखलाबद्ध आपदा जोखिम।

3. प्रमुख हिमालयी आपदाएँ

3.1 केदारनाथ, 2013

अत्यधिक वर्षा, तीव्र अपवाह, अवसाद परिवहन और उच्च-ऊर्जा जल-प्रवाह ने संकरी घाटी में भारी तबाही मचाई। तीर्थस्थल पर बड़ी मानवीय उपस्थिति ने जोखिम बढ़ाया। मुख्य सीख यह है कि **प्राकृतिक खतरा तब आपदा बनता है जब मनुष्य और अवसंरचना प्राकृतिक जल एवं मलबा-प्रवाह मार्गों में स्थित हों।**
पर्यटन नियोजन में सड़क और होटल क्षमता के साथ जल, अपशिष्ट प्रबंधन, ढाल स्थिरता, जल-निकासी और आपातकालीन क्षमता को शामिल करना आवश्यक है।

3.2 चमोली, 2021

7 फरवरी 2021 की ऋषिगंगा–धौलीगंगा आपदा में विशाल **शैल–हिम हिमस्खलन** हुआ। वैज्ञानिक अध्ययन में लगभग **2.7 करोड़ घन मीटर** विफल द्रव्यमान तथा घटना से पहले भूकंपीय संकेतों की पहचान की गई। इसके बाद जल, मलबा और अवसाद का तीव्र प्रवाह हुआ।
इससे स्पष्ट हुआ कि निगरानी केवल हिमनदों और GLOF तक सीमित नहीं होनी चाहिए, बल्कि अस्थिर शैल–हिम द्रव्यमान, लटके हिमनद और हिमनद-विहीन ढाल भी शामिल होने चाहिए। संभावित श्रृंखला हो सकती है:
शैल-विफलता → शैल–हिम हिमस्खलन → तीव्र प्रवाह → मलबा → नदी अवरोध/मार्ग परिवर्तन → बाढ़।

3.3 जोशीमठ, 2022–23

जोशीमठ में संकट धीरे-धीरे विकसित हुए भू-विरूपण और भू-धँसाव के रूप में सामने आया। NRSC/ISRO आकलन में अप्रैल–नवंबर 2022 के बीच लगभग **9 सेंटीमीटर** भू-धँसाव दर्ज किया गया, जिसके बाद दिसंबर 2022–जनवरी 2023 में स्थिति तेजी से बिगड़ी।
पुराने भूस्खलन निक्षेप, जल-निकासी, असंपिंडित भू-सामग्री, ढाल स्थिति और बढ़ता निर्माण भार महत्वपूर्ण कारक रहे। इसलिए जोशीमठ को केवल हिमनद पिघलने से जोड़ना उचित नहीं है।

"जहाँ भू-वैज्ञानिक सीमाएँ ज्ञात हों, वहाँ विकास को भू-भाग के अनुरूप ढलना चाहिए।"

3.4 धराली, 2025

5 अगस्त 2025 को धराली–हर्षिल क्षेत्र में विनाशकारी मलबा-युक्त आकस्मिक बाढ़ आई। ISRO/NRSC के उपग्रह विश्लेषण में लगभग **20 हेक्टेयर** क्षेत्र में मलबा एवं पंखाकार निक्षेप तथा नदी-मार्ग में महत्वपूर्ण परिवर्तन दर्ज हुए।

घटना को केवल "क्लाउडबर्स्ट" या "ग्लेशियर बर्स्ट" कहना पर्याप्त नहीं है। संभावित संयुक्त तंत्र में **तीव्र वर्षा, अस्थिर अवसाद, तीव्र ढाल, परिवर्तित जल-निकासी, नदी-मार्ग और मानवीय बस्तियाँ** शामिल हो सकते हैं।

4. हिमालय का बदलता हिममंडल और संयुक्त जोखिम

"हिमालय नीचे से गर्म हो रहा है" को वैज्ञानिक रूप से पृथ्वी के आंतरिक ताप के अर्थ में नहीं, बल्कि पर्वतीय पर्यावरण में फैलते **तापीय एवं जलवैज्ञानिक प्रभावों के रूपक** के रूप में समझना चाहिए। परमाफ्रॉस्ट के पिघलने और हिमनद पीछे हटने से ढाल स्थिरता, जल-प्रवाह और चट्टानी सतहों की स्थिति प्रभावित हो सकती है।

हिमनद पीछे हटने पर उजागर चट्टानों में जल अंतःप्रवेश, जमाव–पिघलाव, गुरुत्वीय भार और पूर्ववर्ती दरारें मिलकर अस्थिरता बढ़ा सकती हैं। हिमनदीय झीलों के विस्तार से अवरोध टूटने पर GLOF का खतरा भी बढ़ता है।

निगरानी में हिमनद द्रव्यमान, झील क्षेत्रफल/आयतन, मोरेन बाँध, अस्थिर चट्टान, लटके हिमनद, परमाफ्रॉस्ट, भू-तापमान, चरम वर्षा, नदी प्रवाह और तलछट भार शामिल होने चाहिए।

हिमालयी जोखिम का समेकित मॉडल है:

विवर्तनिकी + भूविज्ञान + हिममंडल + जलविज्ञान + चरम मौसम + भू-आकृति विज्ञान + मानवीय हस्तक्षेप = सम्मिलित पर्वतीय जोखिम।

5. नेपाल कनेक्शन

16 अगस्त 2024 को नेपाल के खुम्बू क्षेत्र के थामे में विनाशकारी GLOF हुआ। ICIMOD के अनुसार इसमें चट्टानी हिमस्खलन और क्रमिक झील-विफलताओं की जटिल श्रृंखला शामिल थी तथा लगभग **4,59,000 घन मीटर जल** का संयुक्त निर्गमन और **135 लोगों का विस्थापन** हुआ।

यह घटना दिखाती है कि हिमालयी आपदाएँ सीमापार हैं। **26 अगस्त 2026** को लांगटांग लिरुंग क्षेत्र में रिपोर्ट की गई बर्फ–चट्टान हिमस्खलन एवं आकस्मिक बाढ़ की घटना ने इस जोखिम की गंभीरता को फिर रेखांकित किया।

"राजनीतिक सीमाएँ भू-भागों को विभाजित करती हैं, लेकिन हिमनद, नदियाँ, पर्वत और आपदा के मार्ग राजनीतिक सीमाओं का अनुसरण नहीं करते।"

भारत, नेपाल, भूटान, चीन और पाकिस्तान के लिए हिमनद, GLOF, भूस्खलन, वर्षा और पर्वतीय भू-विकृति की संयुक्त निगरानी आवश्यक है।



6. क्या हमने चेतावनियों को समझा?

उपग्रह, InSAR, भूकंपीय निगरानी, संख्यात्मक मॉडलिंग और उच्च-रिज़ॉल्यूशन DEM ने हिमालयी जोखिमों को समझने की क्षमता बढ़ाई है। समस्या अब अधिकतर **वैज्ञानिक जानकारी को भूमि-उपयोग, अवसंरचना और बस्ती नियोजन में बदलने की है।**

केदारनाथ ने चरम वर्षा और मानवीय जोखिम का प्रभाव दिखाया; चमोली ने उच्च हिमालयी शैल–हिम अस्थिरता; जोशीमठ ने धीमे भू-विकृति संकट; और धराली ने मलबा-युक्त आकस्मिक बाढ़ का खतरा उजागर किया।

इसलिए मुख्य अंतर है:
आपदा प्रतिक्रिया: "घटना के बाद क्या करें?"
जोखिम शासन: "लोगों और अवसंरचना को पूर्वानुमेय खतरे के मार्ग में आने से कैसे रोकें?"

7. हिमालयी प्रारंभिक चेतावनी एवं जोखिम न्यूनीकरण

भविष्य की व्यवस्था को घटना-आधारित प्रतिक्रिया के बजाय **निरंतर जोखिम प्रबंधन** पर आधारित होना चाहिए।

प्रमुख उपाय

1.एकीकृत निगरानी:

उपग्रह, InSAR, भूकंपीय सेंसर, मौसम केंद्र, वर्षा रडार, नदी-जलस्तर सेंसर, GNSS/DGPS, ड्रोन और भूवैज्ञानिक सर्वेक्षण को एकीकृत किया जाए।

2. खतरा-क्षेत्र निर्धारण:
प्रत्येक प्रमुख पर्वतीय बस्ती के लिए वैज्ञानिक Hazard Zonation Map तैयार हो—
लाल: निर्माण निषिद्ध;
नारंगी: कड़े भू-तकनीकी नियंत्रण के साथ निर्माण;
हरा: तुलनात्मक रूप से उपयुक्त क्षेत्र।

3. पर्यटन की वहन क्षमता:
जल, अपशिष्ट, आपातकालीन निकासी, ढाल स्थिरता, पारिस्थितिक संवेदनशीलता और बाढ़ जोखिम को पर्यटन क्षमता में शामिल किया जाए।

4. ढाल कटाई नियंत्रण:
न्यूनतम आवश्यक खुदाई + नियंत्रित इंजीनियरिंग + ढाल स्थिरीकरण + प्रभावी जल निकासी को आधार बनाया जाए।

5. प्राकृतिक जल-निकासी का संरक्षण:
पुराने बाढ़ मार्ग, नदी गलियारे, मलबा-पंख और बाढ़-मैदानों पर निर्माण को नियंत्रित किया जाए।

6. सुरक्षित तलहटी बस्तियाँ:
अत्यधिक अस्थिर बस्तियों के लिए परिवहन, विद्यालय, स्वास्थ्य, जल, ऊर्जा और रोजगार सहित **सुरक्षित तलहटी आवासीय क्लस्टर** विकसित किए जाएँ।

8. प्रस्तावित हिमालयी आपदा न्यूनीकरण संरचना

स्तर	कार्यवाही	उपकरण
खतरे की पहचान	हिमनद, ढाल, झील व नदी गलियारों की पहचान	उपग्रह, InSAR, DEM, ड्रोन
ट्रिगर निगरानी	वर्षा, भूकंपीय व जलवैज्ञानिक परिवर्तन	मौसम केंद्र, रडार, सेंसर
पूर्वानुमान	डाउनस्ट्रीम प्रभावों का आकलन	मॉडल, GIS, AI
चेतावनी	तीव्र जोखिम-संचार	सायरन, मोबाइल, रेडियो
जोखिम न्यूनीकरण	जोखिम-उद्भासन कम करना	जोनिंग, पुनर्वास, लचीला ढाँचा

यह व्यवस्था **पूरे वर्ष** संचालित हो तथा बहुभाषी चेतावनी, निकासी मार्ग, स्थानीय स्वयंसेवक, मॉक ड्रिल और सुरक्षित स्थानों को शामिल करे।

9. चर्चा

चारों घटनाओं से एक स्पष्ट पैटर्न सामने आता है:

घटना	मुख्य खतरा	प्रमुख सीख
केदारनाथ, 2013	वर्षा, बाढ़, मलबा	जोखिमपूर्ण क्षेत्रों में मानवीय उपस्थिति आपदा बढ़ाती है
चमोली, 2021	शैल–हिम हिमस्खलन	उच्च हिमालय के लिए उन्नत निगरानी आवश्यक
जोशीमठ, 2022–23	भू-धँसाव	धीमे खतरे भी बड़े शहरी संकट बन सकते हैं
धराली, 2025	मलबा-युक्त बाढ़	नदी गलियारों और मलबा-पंखों में कड़ा नियंत्रण आवश्यक

इन घटनाओं के भौतिक तंत्र अलग हैं, लेकिन समान कमजोरियाँ हैं—**जोखिमपूर्ण स्थानों पर बस्तियाँ, अपर्याप्त निगरानी, भू-आकृतिक सीमाओं की अनदेखी और पर्यावरण एवं अवसंरचना नियोजन का अलग-अलग होना।**

इसलिए हिमालयी नीति का लक्ष्य केवल आपदा के बाद प्रतिक्रिया नहीं, बल्कि **पूर्वानुमेय जोखिम के सामने लोगों और अवसंरचना के अनावश्यक जोखिम-उद्भासन को रोकना** होना चाहिए।

10. निष्कर्ष

केदारनाथ, चमोली, जोशीमठ और धराली की घटनाएँ अलग-अलग प्राकृतिक दुर्घटनाएँ नहीं, बल्कि हिमालयी जोखिम की बदलती प्रकृति की चेतावनियाँ हैं। वैज्ञानिक प्रमाण हिमालयी हिममंडल में तीव्र परिवर्तन दर्शाते हैं, लेकिन हर आपदा को केवल जलवायु परिवर्तन से जोड़ना उचित नहीं है। जलवायु परिवर्तन के साथ **भूविज्ञान, जलविज्ञान, भू-आकृति विज्ञान और मानवीय हस्तक्षेप** मिलकर जोखिम को आकार देते हैं।

भविष्य का विकास **Risk-Informed Development** पर आधारित होना चाहिए। सड़क, होटल, पुल, जलविद्युत परियोजनाएँ और बस्तियाँ केवल तकनीकी रूप से संभव स्थानों पर नहीं, बल्कि भूवैज्ञानिक स्थिरता, जल-निकासी, पारिस्थितिक संवेदनशीलता, बाढ़ जोखिम और वहन क्षमता को ध्यान में रखकर बनाई जानी चाहिए।

इसके लिए स्थायी **हिमालयी प्रारंभिक चेतावनी नेटवर्क**, वैज्ञानिक खतरा-मानचित्रण, ढाल कटाई का नियमन, प्राकृतिक जल-निकासी का संरक्षण, पर्यटन की वहन-सीमा और आवश्यकतानुसार नियोजित पुनर्वास अनिवार्य हैं।

"हिमालय को जीतने की नहीं, समझने की आवश्यकता है।"

हिमालयी अस्थिरता का प्रभाव जल सुरक्षा, जलविद्युत, कृषि, जैव-विविधता, पर्यटन, खाद्य प्रणालियों और राष्ट्रीय लचीलेपन तक पहुँचता है। इसलिए अब प्रश्न यह नहीं है कि **चेतावनियाँ उपलब्ध हैं या नहीं—वे उपलब्ध हैं। वास्तविक प्रश्न है कि क्या हम उन्हें समय रहते वैज्ञानिक नीति और ठोस विकास-निर्णयों में बदलेंगे?**

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El Niño Affecting India's Ecology: Impacts, Ecological Responses and Climate-Resilient Strategies

Prof. (Dr.) Bharat Raj Singh1, FIE and Sanjeev Pandey2
1Director General (Technical), 2Asst. Professor-II, Civil Engineering Deptt
School of Management Sciences, Lucknow-226501

Abstract:

El Niño is the warm phase of the El Niño-Southern Oscillation (ENSO) and represents one of the major climate phenomena capable of producing widespread changes in weather and natural environmental conditions. The unusual warming of the central and eastern tropical Pacific Ocean modifies atmospheric circulation, pressure systems, convection and oceanic processes, which in turn can influence the Indian Summer Monsoon. In general, El Niño episodes are often associated with weaker monsoon rainfall over India; however, the strength of this relationship is variable and depends on several other oceanic and atmospheric factors. Its ecological influence is much broader than a reduction in rainfall and may result in drought conditions, higher temperature, loss of soil moisture, changes in river discharge and groundwater recharge, forest degradation, agricultural stress, biodiversity loss, increased forest-fire risk and disturbances in freshwater as well as marine ecosystems.

India is comparatively more vulnerable to such climatic variations because a major share of its annual precipitation is received during the southwest monsoon period, while considerable agricultural activity still depends directly on rainfall. The 2026 El Niño episode and associated monsoon behaviour provide an important example of this climate-ecology connection, particularly because rainfall conditions during the later part of the monsoon season can have significant implications for soil moisture, agriculture, water resources and ecosystem health.

The present paper reviews the major pathways through which El Niño can influence India's ecological systems and examines its possible consequences for agriculture, forests, wetlands, rivers, groundwater, biodiversity, Himalayan ecosystems and coastal and marine environments. An integrated ecological resilience approach is also proposed, incorporating improved early-warning mechanisms, water conservation, climate-resilient agricultural practices, ecosystem restoration, landscape-level management and better prediction of ENSO and Indian Ocean Dipole (IOD) interactions.

The study emphasizes that El Niño should not be considered only as a periodic meteorological disturbance; rather, it should be viewed as a **multi-dimensional ecological risk multiplier** capable of creating interconnected pressures on India's water resources, food production, energy requirements, biodiversity and human livelihoods. Strengthening ecosystem resilience and local adaptive capacity can therefore play an important role in reducing the long-term environmental consequences of El Niño-related climatic variability.

Keywords: El Niño, ENSO, Indian Monsoon, Ecology, Climate Variability, Biodiversity, Drought, Water Security, Agriculture, Marine Ecosystems, Indian Ocean Dipole, Climate Resilience

1. Introduction

El Niño-Southern Oscillation, commonly known as ENSO, is a natural interaction between the ocean and atmosphere which mainly develops over the tropical Pacific region. El Niño is considered as the warm phase of this phenomenon. During an El Niño episode, the surface water temperature over the central and eastern equatorial Pacific becomes higher than its normal condition. This abnormal warming produces changes in atmospheric circulation, pressure distribution, cloud activity and movement

of moisture. As a result, its influence is not restricted to the Pacific region but can also be observed in the climate and rainfall pattern of far away regions including South Asia.

India is highly dependent on the behaviour of the southwest monsoon and therefore it is sensitive to major changes in ENSO conditions. In most parts of the country, a very large proportion of yearly rainfall is received during the monsoon months from June to September. This rainfall is directly connected with agricultural production and also plays an important role in filling reservoirs, recharging groundwater, maintaining river flow, supporting forests and sustaining natural ecosystems. Any significant departure from normal monsoon rainfall can therefore create a chain of environmental and socio-economic problems.

It is generally observed that El Niño years are more often related with weak or deficient southwest monsoon over India, while La Niña conditions may support normal or comparatively higher rainfall. But this connection is not fixed for every year. The response of Indian monsoon to ENSO may differ from one region to another and also changes with the timing and intensity of the event. Studies have indicated that many El Niño events do not always result in a deficient monsoon in India. Other climatic influences, such as the Indian Ocean Dipole (IOD), snow conditions over Eurasia, monsoon circulation, Madden-Julian Oscillation and short-term atmospheric variations, can either increase or reduce the effect of ENSO on Indian rainfall.

Thus, the environmental importance of El Niño should not be understood only in terms of less rainfall. Its influence may extend through a much wider sequence of interconnected changes involving **climate, water availability, soil moisture, vegetation growth and biodiversity.** A prolonged rainfall deficiency can increase temperature and evaporation, reduce water availability, weaken vegetation, affect agricultural productivity and place additional pressure on wildlife and natural habitats. Therefore, El Niño may act as an important **climatic stress multiplier for India's ecological systems,** particularly when it occurs together with rising background temperatures and other extreme weather conditions.

2. El Niño and the Indian Monsoon: Physical Mechanism

During a strong El Niño event, warming of the central and eastern tropical Pacific modifies the Walker circulation. Enhanced convection over the Pacific is accompanied by changes in atmospheric subsidence and circulation over the Indian Ocean and South Asian region. These changes can suppress monsoon circulation and reduce moisture transport toward India. The IPCC has documented a tendency toward reduced Indian summer monsoon rainfall during El Niño years and above-normal rainfall during La Niña years, while also noting that the ENSO-monsoon relationship has changed over time.

The Government of India similarly reports that El Niño generally weakens the Indian summer monsoon and that the intensity of El Niño influences the magnitude of its impact, as shown in Fig.1. Since 1950, 16 El Niño years have been identified, of which seven were associated with below-normal Indian monsoon rainfall. The inverse relationship is particularly pronounced during the latter part of the monsoon season, especially September.

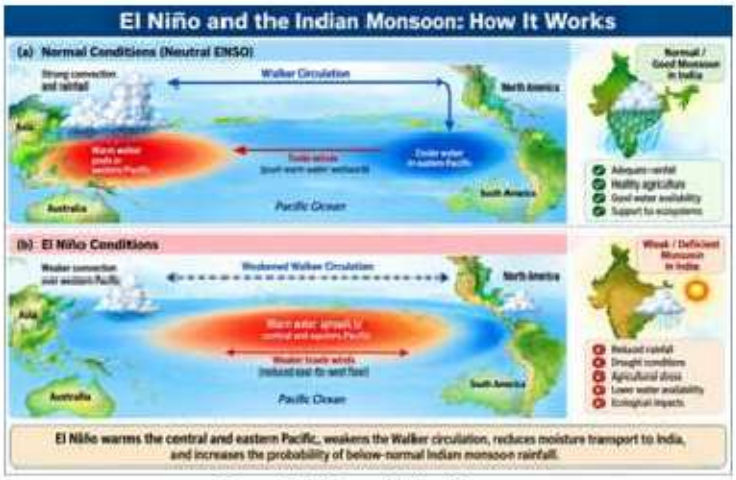


Figure 1: El-Nino and indian Mansoon

Major physical pathways

El Niño →Pacific warming → altered Walker circulation→ weakened monsoon circulation→ rainfall variability → soil-moisture stress→ ecological consequences

However, the actual outcome depends upon interactions with other climate modes.

3. Interaction between El Niño and the Indian Ocean Dipole

The Indian Ocean Dipole (IOD) is another major climate mode affecting the Indian monsoon. It is characterized by a difference in sea-surface temperatures between the western and eastern tropical Indian Ocean.

A positive IOD can partially compensate for the rainfall-reducing influence of El Niño, whereas a negative IOD can reinforce monsoon deficiency. Recent Indian satellite-based climate assessments emphasize that ENSO and IOD interactions play a major role in determining Indian Summer Monsoon Rainfall.

Therefore:

Climate condition	Expected broad influence on Indian monsoon
El Niño + neutral IOD	Increased probability of deficient rainfall
Strong El Niño + negative IOD	Greater drought risk
El Niño + positive IOD	El Niño impact may be partially moderated
La Niña + positive/neutral IOD	Increased probability of above-normal rainfall
Strong ENSO + climate warming	Greater potential for compound heat and rainfall extremes

This interaction explains why every El Niño event does not produce an identical ecological response.

4. Ecological Impacts of El Niño on India



Fig 2- Ecological impact of El-Nino on India

4.1 Agriculture and Agro-Ecosystems

Agriculture is one of the first ecological systems affected by monsoon variability.

Reduced rainfall can cause:

- delayed sowing;
- reduced soil moisture;
- crop-water stress;
- reduced germination;
- lower crop productivity;
- increased irrigation demand;
- groundwater depletion;
- increased pest and disease vulnerability;
- livestock fodder shortages; and
- Increased food-price pressure.

The impact becomes especially serious in rainfed agricultural regions. In 2026, below-normal rainfall has already raised concerns for crops including cotton, soybean, maize, rice and pulses, while declining soil moisture may affect subsequent winter-crop sowing, Ecological impact as shown in **Fig. 2..**

El Niño therefore creates a cascading ecological sequence:

Rainfall deficit → soil-moisture decline → vegetation stress → agricultural productivity decline → livestock/fodder stress→ livelihood vulnerability.

4.2 Soil and Land Degradation

Persistent moisture deficiency reduces biological activity in soils and can accelerate land degradation.

Vegetation cover normally protects soil against:

- wind erosion;
- water erosion;
- surface runoff;
- nutrient loss;
- excessive evaporation; and
- temperature extremes.

During drought conditions, declining vegetation cover exposes soil surfaces. When intense rainfall subsequently occurs after a prolonged dry period, the hardened or degraded soil can generate rapid runoff rather than infiltration.

Thus, El Niño can produce a drought-flood ecological paradox:

prolonged dry conditions followed by short-duration intense rainfall. This is particularly significant for semi-arid and degraded landscapes.

4.3 Forest Ecosystems

Forest ecosystems depend strongly on temperature, precipitation and soil moisture.

El Niño-associated drought and heat can cause:

1. reduced tree growth;
2. premature leaf shedding;
3. reduced regeneration;
4. increased forest-fire probability;
5. water stress in wildlife;
6. changes in flowering and fruiting;
7. pest outbreaks; and
8. habitat fragmentation.

Dry forests and forest edges are especially vulnerable.

A prolonged moisture deficit can also reduce the resilience of forests to subsequent extreme events. Repeated climate stress may gradually shift species composition toward drought-tolerant species while reducing moisture-dependent species.

4.4 Biodiversity and Wildlife

Ecological communities respond to changes in water availability, vegetation productivity and temperature.

During prolonged El Niño-related dry periods:

- natural waterholes may dry earlier;
- wildlife may move toward human settlements;
- competition for water may increase;
- breeding cycles may be disrupted;
- food availability may decline;

- migration routes may change; and
- Human-wildlife conflict may increase.

The effects are particularly important in protected areas where wildlife populations depend on seasonal water bodies. Ecological corridors should therefore be treated as climate-resilience infrastructure.

5. Impact on Rivers, Wetlands and Groundwater

India's rivers and wetlands are closely connected to monsoon rainfall. Reduced monsoon precipitation can lead to:

- lower river discharge;
- reduced wetland inundation;
- declining reservoir levels;
- reduced groundwater recharge;
- deterioration of water quality;
- increased concentration of pollutants; and
- loss of aquatic habitat.

Groundwater becomes particularly important during El Niño years because communities compensate for reduced surface-water availability through increased pumping.

This can create a feedback loop:

Rainfall deficit → increased groundwater extraction → reduced aquifer storage → declining groundwater table → greater irrigation dependence → ecological water stress.

The solution must therefore move beyond emergency groundwater pumping toward **aquifer recharge and watershed restoration.**

6. Himalayan Ecosystems and El Niño

Although the Himalaya are not directly controlled by El Niño alone, large-scale climate variability interacts with warming temperatures, glacier retreat, changing precipitation patterns and extreme rainfall.

Potential consequences include:

- reduced snow accumulation in some periods;
- increased glacier melt;
- changes in spring discharge;
- seasonal water shortages;
- vegetation shifts;
- increased wildfire susceptibility in dry periods; and
- increased vulnerability to landslides and flash floods when intense rainfall follows prolonged dryness.

The Himalayan ecological system should therefore be evaluated using a **compound-risk framework** rather than attributing individual disasters solely to El Niño.

The interaction of climate warming, cryospheric change, extreme precipitation and human development can increase vulnerability even when seasonal rainfall totals are not exceptionally low.

7. Coastal and Marine Ecosystems

One of the less widely discussed consequences of El Niño is its influence on ocean temperature.

INCOIS has noted that El Niño can contribute to stronger and prolonged marine heatwaves in the northern Indian Ocean, potentially damaging coral reefs and affecting fisheries and marine ecological balance.

Marine heatwaves may cause:

- coral bleaching;
- changes in fish distribution;
- reduced fisheries productivity;
- changes in plankton communities;
- stress on mangroves and coastal organisms; and
- disruption of marine food webs.

Coastal ecosystems are particularly important because mangroves, coral reefs, seagrass beds and estuaries function as natural protection against storms, erosion and sea-level-related hazards.

8. El Niño and Extreme Heat

Rainfall deficiency and increased atmospheric stability can contribute to elevated temperatures over parts of India.

Heat stress affects:

- humans;
- livestock;
- crops;
- forests;
- wetlands;
- urban ecosystems; and
- Freshwater organisms.

The ecological significance of heatwaves increases when they occur simultaneously with water shortages.

This creates a compound climate hazard:

El Niño → rainfall deficiency + heat → evaporation increase → soil moisture decline→ vegetation stress → increased fire risk.

Urban areas may experience additional stress through the urban heat-island effect.

9. El Niño and the 2026 Indian Ecological Situation

The 2026 situation provides a contemporary example of why El Niño requires ecological preparedness.

The Ministry of Earth Sciences reported that IMD had forecast below-normal southwest monsoon rainfall for 2026, initially estimating seasonal rainfall at 92% of the Long Period Average and subsequently revising the estimate to 90% of LPA. IMD also indicated the likely development of El Niño during the southwest monsoon season.

By late August 2026, IMD expected September rainfall to remain below normal following a 16% rainfall deficit in August.

The ecological significance of a deficient late monsoon is particularly important because September rainfall contributes to:

- late-season crop development;
- soil-moisture storage;
- groundwater recharge;
- reservoir recovery;
- preparation for winter crops; and
- Maintenance of seasonal wetlands and vegetation.

The current situation demonstrates that the ecological consequences of El Niño should be monitored at **district, watershed and ecosystem levels,** rather than only through national seasonal rainfall averages.

10. Why El Niño Does Not Always Produce Drought in India

It is scientifically important to avoid a simplistic equation:

El Niño = Indian drought

Historical evidence shows that the relationship is probabilistic rather than deterministic. Research by the India Meteorological Department has demonstrated that while most severe Indian droughts are associated with El Niño, fewer than half of El Niño events necessarily result in deficient Indian rainfall.

Regional variability is also substantial. Studies have found that the ENSO-monsoon relationship varies across northern, central and southern India and has changed over historical periods.

Consequently, ecological risk assessment should incorporate:

- ENSO intensity;
- ENSO phase timing;
- IOD;
- monsoon onset and withdrawal;
- intraseasonal oscillations;
- sea-surface temperatures;
- atmospheric circulation;
- antecedent soil moisture;
- land-use change; and
- global warming.

11. Ecological Risk Matrix

Ecological component	El Niño related risk	Potential consequence	Priority response
Agriculture	High	Yield reduction	Climate-smart agriculture
Soil moisture	High	Land degradation	Mulching, watershed management
Groundwater	High	Aquifer depletion	Managed aquifer recharge
Forests	Moderate–High	Fire and regeneration stress	Fire management and restoration
Biodiversity	Moderate–High	Habitat and food stress	Wildlife water planning
Rivers	High	Reduced seasonal flow	Environmental-flow management
Wetlands	High	Drying and habitat loss	Wetland restoration
Himalaya	Moderate–High	Water and ecosystem stress	Catchment-based planning
Coral reefs	High	Marine heat stress	Reef monitoring/restoration
Fisheries	Moderate–High	Distribution/productivity changes	Climate-resilient fisheries
Urban ecology	High	Heat and water stress	Blue-green infrastructure

12. Climate-Resilient Ecological Strategies for India

12.1 Strengthening ENSO Early-Warning Systems

India already receives regular ENSO and monsoon assessments from IMD and climate information from national institutions. The next step should be to translate climate forecasts into **ecosystem-specific risk advisories.**

For example:

ENSO forecast → district rainfall forecast→ watershed water balance → crop advisory → groundwater advisory → biodiversity/wildlife advisory.

12.2 Water Security through Local Recharge

India should strengthen:

- rainwater harvesting;
- check dams;
- recharge ponds;
- traditional tanks;
- wetlands;
- watershed restoration;
- aquifer recharge structures; and
- revival of traditional water systems.

The objective should be to retain rainfall locally rather than allowing intense rainfall to rapidly leave the watershed as runoff.

12.3 Climate-Smart Agriculture

Farmers in vulnerable regions should be encouraged to adopt:

- drought-resistant crop varieties;
- short-duration crops;
- crop diversification;
- micro-irrigation;
- precision irrigation;
- soil-moisture conservation;
- agroforestry;
- weather-based crop advisories; and
- integrated crop-livestock systems.

12.4 Forest and Landscape Restoration

Ecological restoration should focus on native

species, soil moisture conservation and watershed connectivity.

A landscape approach should integrate:

forest + agriculture + wetlands + rivers + groundwater + biodiversity corridors.

Such integrated ecological planning can increase resilience to both drought and intense rainfall.

13. Proposed Integrated "El Niño Ecological Resilience Framework"

A national framework may be developed around five pillars:

Pillar 1 - Prediction

Continuous monitoring of ENSO, IOD, monsoon and ocean conditions.

Pillar 2 - Translation

Convert climate forecasts into district- and ecosystem-specific risk maps.

Pillar 3 - Preparation

Prepare water, agriculture, forest, biodiversity and disaster-management plans before peak ecological stress.

Pillar 4 - Restoration

Restore degraded watersheds, wetlands, forests and groundwater systems.

Pillar 5 - Resilience

Develop local communities capable of adapting to repeated climate variability.

The framework can be represented as:

Climate Monitoring → Early Warning → Ecological Risk Mapping → Local Action→ Ecosystem Restoration → Climate Resilience

14. Policy Recommendations

The following measures are recommended:

1. Establish an India El Niño Ecological Risk Observatory integrating IMD, IITM, ISRO/NRSC, INCOIS, agricultural, forestry and water-resource datasets.
2. Prepare district-level El Niño ecological vulnerability maps.
3. Integrate ENSO forecasts into district disaster-management plans.
4. Develop seasonal groundwater budgets for drought-prone districts.
5. Establish ecological thresholds for rivers, wetlands and protected-area water bodies.
6. Expand climate-resilient agriculture and drought-tolerant crops.
7. Strengthen forest-fire early-warning and prevention systems.
8. Monitor marine heatwaves and coral ecosystems in the Indian Ocean.
9. Protect and restore wetlands as natural water-storage systems.
10. Promote traditional water-harvesting systems alongside modern infrastructure.
11. Develop climate-resilient urban planning using blue-green infrastructure.
12. Strengthen public communication so that El Niño forecasts are translated into practical local advisories.

15. Conclusion

El Niño is not limited to the Pacific Ocean; its atmospheric effects can influence India's monsoon, temperature, water resources, agriculture, forests, wildlife and marine environment. Although it generally increases the chance of weak monsoon rainfall, its impact can vary due to the Indian Ocean Dipole and other climate factors.

Its ecological effect can be viewed as a connected chain:

El Niño ? weak/variable monsoon ? water shortage ? soil and vegetation stress ? crop loss ? biodiversity pressure ? livelihood risk.

A dry period may also be followed by sudden heavy rainfall, creating both drought and flood hazards. Therefore, rainfall quantity alone is not enough for ecological planning.

India needs to prepare before the climatic stress becomes severe through rainwater harvesting, groundwater recharge, ecosystem restoration, climate-resilient farming, biodiversity protection and improved early warning systems. The 2026 experience again shows the importance of such preparedness, particularly during the later monsoon period.

In future, India's approach should change from reacting to climate events towards early preparation, ecological resilience and integrated landscape management. This will help to reduce environmental damage and strengthen the capacity of communities and ecosystems to face El Niño related climate variability.

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Future-Ready Engineers: Addressing the Challenges of Technical Education through Deep-Tech Innovation

Dr.Neelam Srivastava,
EC Member ET Division,
UP State Center Lucknow

Abstract

Engineering education is standing at a decisive crossroads. Artificial Intelligence (AI), Generative AI, semiconductor technology, quantum computing, robotics, autonomous systems, 6G communication, cybersecurity, digital twins, advanced materials and green technologies are rapidly changing the nature of engineering practice. The challenge before technical institutions is therefore not simply to add a few new subjects to an existing curriculum, but to fundamentally transform the way engineering is taught, learned, researched and applied.

For Uttar Pradesh, this transformation is particularly important. The State is emerging as an important destination for semiconductor, electronics, defence, manufacturing, digital infrastructure and emerging technology investments. Its Semiconductor Policy 2024 explicitly emphasises curriculum enhancement, industry-academia linkages, faculty training, internships, research centres and Centres of Excellence.

This article argues for a transition from **conventional engineering education to Deep-Tech-oriented, problem-driven and innovation-led education.** The future engineer must possess strong fundamentals, specialised technological depth, AI and digital competence, interdisciplinary thinking, research capability, entrepreneurial orientation and a strong sense of ethics and sustainability.

Keywords: Future-ready engineers, Deep Tech, AI, Generative AI, semiconductor, VLSI, Industry 4.0, engineering education, innovation, Uttar Pradesh

Introduction: Engineering Education at a Turning Point

For decades, the conventional engineering education model has broadly followed:

Syllabus → Lecture → Laboratory → Examination → Degree → Placement

This model produced generations of competent engineers and must not be discarded completely. Mathematics, physics, engineering sciences, programming, circuit theory, mechanics, materials and core engineering principles will remain essential.

However, the technological environment has changed dramatically.

Today's engineer may work with AI models, semiconductor devices, autonomous robots, digital twins, quantum algorithms, photonic systems, intelligent sensors, cyber-physical systems or renewable-energy technologies. Consequently, merely completing a prescribed curriculum is no longer sufficient.

The new model should become:

Problem → Knowledge → Experiment → Prototype → Validation → Patent/IP → Industry/Startup → Societal Impact

This represents a change not merely in curriculum but in institutional mindset.

The fundamental question should change from:

"What subjects have we taught?"

to:

"What problems have our students learned to solve?"

2. From Emerging Technology to Deep Technology

The expression Deep Tech refers to technologies based on substantial scientific and engineering knowledge and capable of creating long-term technological and economic value. AI, quantum technologies, semiconductors, robotics, advanced materials, biotechnology, photonics, advanced communication systems and clean-energy technologies are representative areas.

Deep-Tech education cannot be created simply by introducing a one-semester course titled "Artificial Intelligence" or "Quantum Computing".

It requires a layered educational architecture:

↓Mathematics + Science + Engineering Fundamentals

↓Domain Specialisation

↓AI + Data + Digital Competence

↓Interdisciplinary Deep-Tech Skills

↓Research + Innovation + Entrepreneurship

At every level, the engineer must develop **ethics, sustainability, communication, creativity and lifelong-learning capability.**

Thus, the objective should not be to produce students who merely use technology, but engineers capable of understanding, designing, validating and creating technology.

3. What Does Research Tell Us?

Recent engineering-education research provides a strong warning as well as an opportunity. A 2024 IEEE Transactions on Engineering Management study identified 65 important Industry 4.0 skills for engineering students-17 technological, 12 digital, 5 computational and 31 soft skills-and reported a gap between university education and the skills expected in smart-industry environments. This is significant. The future engineer is not simply a technical specialist. He or she must combine:

- technological expertise,
- digital competence,
- computational thinking,
- problem-solving,
- communication,
- teamwork,
- adaptability,
- creativity and leadership.

Table1. Industry 4.0 Skill Distribution

Skill category	Number of skills
Technological	17
Digital	12
Computational	5
Soft skills	31
Total	**65**

The message is clear: technical depth and human capability must develop together.

4. AI and Generative AI: Do Not Ban It-Teach It Properly

Artificial Intelligence is perhaps the most immediate disruption facing engineering education. A 2025 systematic review of 161 studies identified seven major applications of AI in engineering education, including virtual experiments, learning analytics, intelligent tutoring systems, engineering-education robots, automatic assessment and assisted learning.

Another 2025 IEEE Access scoping review analysed 146 studies on Generative AI in engineering and computing education and highlighted the need to integrate GenAI with curriculum, AI literacy and prompt-engineering skills while addressing associated risks.

Therefore, the question for engineering colleges should not be:

"How can we stop students from using AI?"

The better question is:

"How can we teach students to use AI without allowing AI to replace their thinking?"

For example, instead of assigning:

Design a digital circuit.

a future-ready assignment could be:

Design and simulate the circuit using AI-assisted tools; independently verify the output, identify errors or limitations, compare alternative designs and document how AI was used.

This changes AI from a shortcut into a learning and engineering tool.

Students must learn to:

Prompt→ Generate → Verify → Test → Critique → Improve

The principle should be:

AI-assisted engineering, not AI-dependent engineering.

5. The Semiconductor Opportunity: A Wake-Up Call for Uttar Pradesh

One of the most compelling examples of why engineering colleges must change is the semiconductor sector.Uttar Pradesh has established a dedicated Semiconductor Policy 2024 with the objective of developing a semiconductor ecosystem. The policy supports semiconductor manufacturing, ATMP/OSAT, compound semiconductors, silicon photonics, sensor fabs and chip-design activities. It also provides support for faculty training, internships, Centres of Excellence and R&D infrastructure.

The policy specifically recognises the importance of stronger industry-academia connections, curriculum enhancement and regular updating of electronics education.

This creates a major opportunity-and a major responsibility-for engineering institutions.

If Uttar Pradesh wants to become a semiconductor destination, its colleges must not continue producing only conventional electronics graduates.

They must produce:

Semiconductor Engineers

with knowledge of:

Digital Electronics → FPGA →Embedded Systems → VLSI Design → Semiconductor Devices → IC Design → Verification → AI Hardware → Advanced Packaging → Photonics

This can become one of the most important engineering-education transformations for the State.

6. Future Engineering Specialisations

Engineering institutions should anticipate technology demand rather than react to it.

Table 2: High-Potential Deep-Tech Domains

Domain	Emerging Engineering Opportunities
AI & GenAI	AI engineering, foundation models, edge AI
Semiconductor	VLSI, chip design, verification, packaging
Quantum	Quantum computing, sensing and communication
Robotics	Autonomous robots, industrial robotics, drones
6G & Photonics	Intelligent networks, optical/photonic systems
Cybersecurity	Cyber-physical security, zero-trust systems
IoT & Digital Twins	Smart manufacturing, predictive maintenance
Green Technology	Green hydrogen, batteries, smart grids
Advanced Materials	Nanotechnology, functional materials
Biomedical Engineering	Medical AI, biosensors, wearable systems

The purpose should not be to create dozens of narrowly defined degrees.Instead, colleges can create **flexible interdisciplinary pathways, minors, specialisations, laboratories and Centres of Excellence.**

7. A Proposed 70:20:10 Model for Future Engineering Education

A practical institutional framework could be as per need of future is:

70% - Core Engineering Fundamentals

Mathematics, science, programming, engineering principles and domain fundamentals.

20% - Emerging Deep-Tech Specialisation

AI, VLSI, robotics, quantum, cybersecurity, 6G, green technology, etc.

10% - Innovation and Entrepreneurship

Hackathons, prototypes, patents, startups, industry projects and societal problem-solving.

The **70:20:10 ratio is a proposed strategic framework rather than a universal prescription.** Individual institutions should adapt it according to discipline, resources and regional industry needs.

The central idea is that **fundamentals should never be sacrificed for fashionable technology.**

8. From Engineering Laboratory to Innovation Laboratory

Many engineering laboratories continue to operate primarily as places where students perform predefined experiments.Future laboratories must become places where students **design experiments and build solutions.**

A modern engineering institution should progressively establish:

- AI and Data Science laboratories
- Semiconductor/VLSI laboratories
- Robotics and Autonomous Systems laboratories
- IoT and Digital Twin laboratories
- 5G/6G and Photonics laboratories
- Cybersecurity laboratories
- Renewable Energy and Green Hydrogen laboratories
- Advanced Manufacturing laboratories
- Biomedical and Healthcare Technology laboratories

More importantly, laboratories should be interconnected. For example in figure 3

Diagram 1: Agriculture Problem-Interdisciplinary Approach

→	IoT	Sensors
→	AI	Analytics
→	Drone	Imaging
→	Communication	Network
→	Edge	Computing
→	Automated Decision System	

One problem thereby becomes a multidisciplinary engineering project.

9. The University as a Deep-Tech Ecosystem

Engineering colleges in Uttar Pradesh should increasingly function as **regional innovation engines.**

A possible model is:

Local Problem

↓

Engineering College

↓

Deep-Tech Centre of Excellence

↓

Industry + Startup + Government

↓

Prototype

↓

Patent/IP

↓

Commercialisation

↓

Societal Impact

This model can be applied to the State's major sectors.

Agriculture

AI + drones + sensors + IoT → **AgriTech**

Defence

Robotics + sensors + AI + communication→ DefenceTech

Healthcare

AI + biomedical sensors + data analytics→ **HealthTech**

Manufacturing

Robotics + AI + digital twins → **Industry 4.0**

Electronics

VLSI + embedded systems + AI hardware→ Semiconductor Technology

Thus, the engineering college becomes more than a teaching institution-it becomes a technology-development institution.

10. Faculty Transformation is Equally Important

Curriculum reform will fail if faculty development does not accompany it.The role of a faculty member is evolving from:

Teacher

to

Teacher + Researcher + Mentor + Innovator + Industry Collaborator

Faculty members need regular exposure to:

- emerging technologies,
- industrial tools,
- AI-assisted engineering,
- interdisciplinary research,
- patents and intellectual property,
- startup ecosystems,
- technology transfer,
- industry projects.

UP's Semiconductor Policy already provides support for faculty training, workshops and awareness activities, creating an opportunity for institutions to systematically build semiconductor capability.

A strong institutional mechanism would be:

Annual Faculty Deep-Tech Development Plan

with measurable targets for certification, industrial training, research publications, patents, sponsored projects and technology prototypes.

11. Research Must Begin Earlier

Research should not remain restricted to Ph.D. scholars.

Undergraduate students should experience research through:

- first-year problem-solving projects,
- literature reviews,
- simulation studies,
- design challenges,
- mini research projects,
- industry problems,
- hackathons,
- patent-oriented projects,
- undergraduate research publications.

A student who learns to ask **"Why?", "Can this be improved?"** and **"Can I design something better?"** has already begun developing a research mindset.

Project evaluation should therefore move beyond:

"Did the prototype work?"

to:

"What problem does it solve?"

"What is novel?"

"What evidence validates it?"

"Can it be patented?"

"Can it be scaled?"

12. Measuring the Future-Ready Institution

Placements remain important, but they cannot be the only indicator of institutional success.

A future-ready engineering college should track:

- patents filed and granted,
- prototypes developed,
- startups incubated,
- industry-sponsored projects,
- research grants,
- technology transfers,
- student publications,
- interdisciplinary projects,
- international collaborations,
- faculty industry training,
- technology commercialisation,
- societal impact.

The institutional dashboard should therefore evolve from:

Placement Rate

to:

Innovation + Research + Entrepreneurship + Employability + Societal Impact

13. Five Immediate Actions for Engineering Colleges in Uttar Pradesh

1. Establish Deep-Tech Centres of Excellence

Begin with regional strengths-semiconductors, AI, robotics, defence technology, agriculture technology, healthcare technology or green energy.

2. Introduce Interdisciplinary Minors

Allow an electronics student to study AI; a mechanical student to study robotics; a civil student to study digital twins; and an electrical student to study energy storage and smart grids.

3. Convert Conventional Labs into Innovation Labs

Provide open-ended projects, prototyping facilities, simulation tools and industry challenges.

4. Build Industry as a Co-Creator

Industry should participate in curriculum design, laboratories, internships, projects, faculty development and assessment.

5. Create an Innovation-to-Industry Pipeline

Idea → Prototype → Patent → Incubation→ Funding → Industry → Product

This is how technical education can contribute directly to regional economic development.

14. Conclusion: From Job-Ready to Future-Ready

The greatest challenge before technical education today is not technological-it is institutional mindset.

If engineering colleges continue to operate with yesterday's curriculum, yesterday's laboratories and yesterday's assessment systems, students will enter tomorrow's industries with yesterday's capabilities.

The transformation must therefore begin now.

We need to move:

From Skill to Deep Skill

From Digital Literacy to Technology Creation

From Classroom Learning to Problem Solving

From Projects to Prototypes

From Publications to Translational Research

From Placement-Centric Education to Innovation-Centric Education

From Job-Ready Engineers to Future-Ready Engineers

For Uttar Pradesh, the opportunity is particularly significant. The State's semiconductor and broader technology policies provide an emerging ecosystem in which engineering institutions can connect education with advanced manufacturing, R&D, entrepreneurship and technology development.

The engineering college of tomorrow must therefore not merely prepare students for the future.

It must enable students to create the future.

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ग्रामीण क्षेत्रों में आजीविका के अच्छे अवसर पैदा करना एक गैर पारंपरिक दृष्टिकोण

डॉ. रमेश चंद्र श्रीवास्तव
पूर्व कुलपति, डॉ राजेंद्र प्रसाद केंद्रीय कृषि विश्वविद्यालय, पूसा, समस्तीपुर, बिहार

हाल के वर्षों में भारत और दुनिया भर में विकास नीति पर बहस के केंद्र में आजीविका के अच्छे अवसर प्रदान करने का सवाल रहा है। भारतीय संदर्भ में, बढ़ती मजदूरी और सामाजिक सुरक्षा तक पहुंच के संदर्भ में रोजगार की गुणवत्ता में सुधार को राज्य की नीति की एक महत्वपूर्ण चिंता माना जाता था। ऐसी चिंताओं के बावजूद, रोजगार सृजन के मोर्चे पर प्रगति मिश्रित रही है। भारत में रोजगार परिणामों में महत्वपूर्ण अंतर-क्षेत्रीय और अंतर-क्षेत्रीय अंतर मौजूद हैं, विशेष रूप से आर्थिक विकास की लगातार उच्च दर के साथ। अवसर के अलावा, रोजगार की गुणवत्ता एक बड़ी चुनौती है, जो देश के विभिन्न क्षेत्रों में आर्थिक और सामाजिक विकास को प्राप्त करने में महत्वपूर्ण है। ग्रामीण क्षेत्रों से शहरी क्षेत्रों में नैमित्तिक रोजगार की तलाश में अकुशल और अर्धकुशल व्यक्तियों का पलायन ग्रामीण क्षेत्रों में सामाजिक समस्या के साथ-साथ शहरी अवसंरचना पर बढ़ते भार दोनों की एक बड़ी समस्या बन गया है। ग्रामीण क्षेत्रों में अच्छे आजीविका के अवसरों की कमी के कारण गरीबी अधिक है, जो शहरी क्षेत्रों की तुलना में लगभग 25: अधिक है। अन्य क्षेत्रो के मुकाबले पूर्वी उत्तर प्रदेश और बुंदेलखंड क्षेत्र में अंतर अधिक है। इस लिए यह आवश्यक है कि ग्रामीण क्षेत्रों में ही आजीविका के अच्छे अवसर पैदा हों। ग्रामीण क्षेत्रों में अच्छे आजीविका के अवसर पैदा करने की एक बड़ी चुनौती ग्रामीण कार्यबल में कौशल का निम्न स्तर है यदि हम बड़े पैमाने पर आजीविका के अवसर पैदा करने के लिए पारंपरिक विनिर्माण क्षेत्र पर निर्भर करते हैं। इस प्रकार रोजगार पर ध्यान देने के साथ विकास को बढ़ावा देने के लिए, गैर-पारंपरिक गैर-कृषि रोजगार के अवसरों पर ध्यान केंद्रित करने और उद्यमिता को प्रोत्साहित करने की आवश्यकता है।

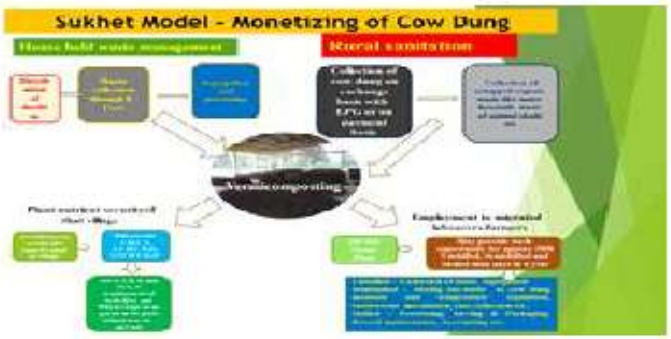
इसे ध्यान में रखते हुए, तत्कालीन कुलपति डॉ. आर सी श्रीवास्तव के नेतृत्व में ड२. राजेंद्र प्रसाद केंद्रीय कृषि विश्वविद्यालय, पूसा, समस्तीपुर, बिहार द्वारा एक मॉडल की अवधारणा की गई थी। मूल रूप से इस अवधारणा को उज्ज्वला कार्यक्रम के लाभार्थियों को विशेष रूप से एलपीजी गैस रिफिल प्रदान करने और विशेष रूप से ग्रामीणों को प्रतिदिन 20 किलोग्राम गाय का गोबर के बदले प्रदान करने के लिए कल्पना की गई थी। इस अवधारणा की एक

विशिष्ट विशेषता कोई नकद हस्तांतरण नहीं थी, बल्कि एलपीजी गैस की रिफिल के साथ एक वस्तु विनिमय था। इस अवधारणा को निम्नलिखित चित्र में समझाया गया है।

इस मॉडल को लागू करते समय यह पाया गया कि यह मॉडल केवल एक के बजाय चार उद्देश्यों को पूरा करता है जिसके बारे में शुरू में सोचा गया था। (1) अंशदान करने वाले परिवार को प्रत्येक दूसरे महीने एलपीजी रीफिल उपलब्ध कराना, (2) ग्रामीण क्षेत्रों में स्वच्छता सुनिश्चित करना क्योंकि परिवार के घर के दरवाजे पर गाय के गोबर का संग्रहण जैविक घरेलू अपशिष्ट भी एकत्र करता है, (3) जैविक खेती करने वाले किसानों को घर पर जैविक खाद उपलब्ध कराना, और (4) अकुशल युवाओं और एक शिक्षिता युवाओं को रोजगार प्रदान करना। इस मॉडल को स्थानीय और राष्ट्रीय मीडिया दोनों में स्थान मिला। इस पर माननीय पीएम का भी ध्यान गया, जिन्होंने 29 अगस्त, 2021 को 80वें एपिसोड में अपने मन की बात में इसका उल्लेख किया था। कुछ लिंक।

http://www.outlookinida.com/outlook-spotlight/monetization -of-cow-dung-a-novel-initiative-of-rpcau-news-390483 ; What is the 'Sukhet Model' of Madhubani praised by PM Modi during Mann Ki Baat? Find out here! (youtube.com)

माननीय प्रधानमंत्री ने सुझाव दिया था कि प्रत्येक पंचायत को इस मॉडल को अपनाना चाहिए। अगर उत्तर प्रदेश के संदर्भ में इसकी क्षमता की जांच करें, जिसमें लगभग 2.38 करोड़ किसान परिवार हैं, जिनमें से लगभग 2 करोड़ किसान परिवारों ने

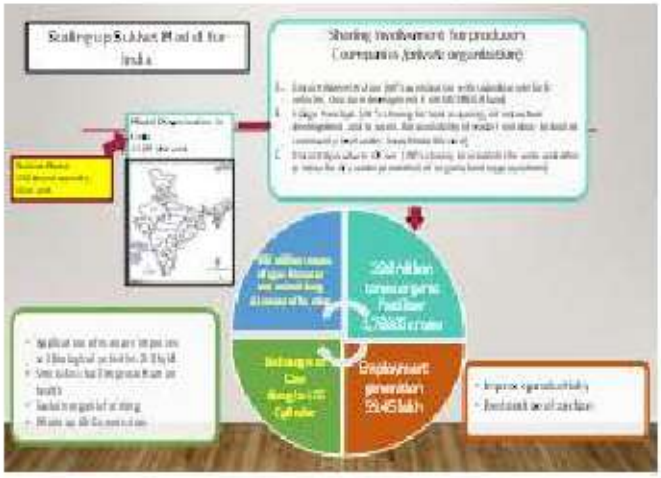


किसान सम्मान निधि के लिए पंजीकरण कराया है। मवेशियों की आबादी 8.33 करोड़ होने के साथ, प्रति परिवार मवेशियों की औसत संख्या चार है, जो इस मॉडल के लिए आवश्यक एक से बहुत अधिक है। संचालन को आसान रखने के लिए, यह प्रस्तावित किया गया है कि 100 किसान परिवारों के लिए एक इकाई होनी चाहिए। इस प्रकार पूरे राज्य को कवर करने के लिए लगभग 2 लाख इकाइयों की आवश्यकता होगी। यदि इसे पूरे राज्य में लागू किया जाता है, तो यह 8 लाख अकुशल नौकरियां और लगभग 40000 कुशल रोजगार पैदा करेगा, यह मानते हुए कि लेखांकन और बिक्री के लिए आवश्यक कुशल व्यक्ति 5 इकाइयों को कवर करेगा।

वर्मीकम्पोस्ट यार्ड, गारबेज यार्ड, चौफिंग, छलनी, हाथ गाड़ी आदि के लिए कुछ छोटी मशीनों वाली एक इकाई को स्थापित करने की अनुमानित पूंजी लागत लगभग 15 लाख प्रति यूनिट होगी और वार्षिक परिचालन व्यय लगभग 14 लाख होगा जिसमें 7.7 लाख का वेतन बिल (चार अकुशल कर्मचारियों के लिए 15000/- रूपये प्रति माह और कुशल कर्मचारियों का 15 वां हिस्सा / 20000/- प्रतिमाह) शामिल है। 100 कृषक परिवारों के लिए

वार्षिक रूप से 6 एलपीजी सिलिंडरों की लागत के लिए 6 लाख रूपए/-रू.1000/- प्रति सिलिंडर (बिना किसी सब्सिडी के) और शेष आकस्मिक व्यय के रूप में । वार्षिक रिटर्न 250 टन वर्मीकम्पोस्ट होगा जिसे 6000/- रूपये से 8000/- रूपये प्रति टन की दर से बेचा जा सकता है (वर्मीकम्पोस्ट की खुदरा दर 30 किलोग्राम बैग के लिए 12 रूपये से 10 किलोग्राम बैग के लिए 15 रूपये प्रति किलोग्राम तक भिन्न होती है)। इस प्रकार अपेक्षित राजस्व 15 लाख से 20 लाख प्रति यूनिट प्रति वर्ष के बीच होगा। इस प्रकार यह उद्यम आर्थिक रूप से व्यवहार्य होगा। राष्ट्रीय स्तर पर इस अवधारणा को आगे बढ़ाने का तरीका नीचे प्रस्तुत किया गया है।

स्तर पर इस अवधारणा को आगे बढ़ाने का तरीका



नीचे प्रस्तुत किया गया है।

इस योजना के कार्यान्वयन के लिए रोडमैप

यदि इसे पूरे राज्य में लागू किया जाता है, तो इसके लिए 30,000 करोड़ रूपये के पूंजी निवेश और कम से कम पहले वर्ष के लिए 28,000 करोड़ रूपये के परिचालन व्यय के प्रावधान की आवश्यकता होगी। पूरे राज्य को कवर करने के लिए पूंजीगत व्यय 3 या 5 वर्षों में फैल सकता है। यह निवेश दो मार्गों से आ सकता है। (1) मनरेगा, स्वच्छ भारत मिशन और जैविक खेती परियोजना से पूलिंग बजट । पूंजीगत व्यय के लिए लगभग 70% धन मनरेगा से दिया जा सकता है क्योंकि लगभग 60% सामग्री लागत पर और शेष श्रम लागत के रूप में अनुमत है। इसका 20% मुख्य रूप से ठेला, कूड़ेदान और अन्य छोटे उपकरणों पर स्वच्छ भारत मिशन के लिए सोर्स किया जा सकता है और बाकी 10% मुख्य रूप से केंचुओं और अन्य आकस्मिक वस्तुओं पर खर्च जैविक खेती मिशन एवं परंपरागत कृषि विकास योजना एवं राष्ट्रीय कृषि विकास योजना से दिया जा सकता है है। परिचालन व्यय नाबार्ड से 2 साल के अधिस्थगन के साथ कम लागत वाले ऋण से आ सकता है और पहले दो वर्षों के दौरान राज्य सरकार द्वारा ब्याज का भुगतान किया जा रहा है। वर्तमान में एलपीजी सिलेंडर को दी जाने वाली सब्सिडी का उपयोग कम से कम 3-5 वर्षों के लिए वर्मीकम्पोस्ट के मूल्य पर सब्सिडी देने के लिए किया जा सकता है जिससे बिक्री आकर्षक हो जाएगी। दूसरा मार्ग एमएसएमई के माध्यम से हो सकता है, जहां प्रत्येक इकाई को पूंजीगत लागत पर 25% सब्सिडी दी जाएगी और अन्य 25% मालिक का योगदान होगा और शेष 50% सॉफ्ट लोन होगा। पहले दो वर्षों के

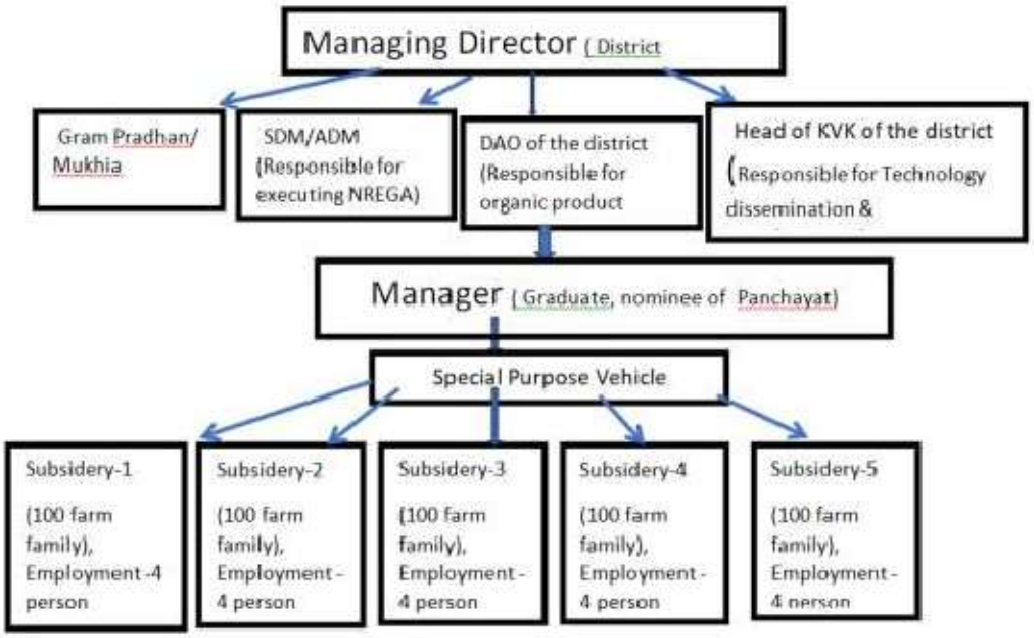
लिए परिचालन लागत नाबार्ड से कम लागत पर ऋण होगी, जिसे सरकार द्वारा दो वर्ष के अधिस्थगन के साथ सुरक्षित किया जाएगा, जिसके दौरान ब्याज का भुगतान सरकार द्वारा किया जाएगा. इस पैसे का भुगतान एलपीजी सिलेंडर के लिए सब्सिडी पर बचत या जैविक खेती पर सब्सिडी से किया जा सकता है।

गुणवत्ता नियंत्रण

गुणवत्ता मानकों का रखरखाव इस कार्यक्रम की सफलता के लिए महत्वपूर्ण होगा। यह जिला स्तर पर याद्दच्छिक नमूना संग्रह और इसके परीक्षण द्वारा प्राप्त किया जा सकता है। इसके लिए दो विकल्पों का उपयोग किया जा सकता है, 1) ऐसा करने के लिए जिला स्तरीय मृदा परीक्षण प्रयोगशालाओं को मजबूत करना और 2) जिला केवीके में मौजूदा मृदा परीक्षण सुविधा की स्थापना/सुदृढ़ीकरण। प्रयोगशाला के पास अपने निपटान में एक वाहन होना चाहिए जिसके माध्यम से नमूने स्वेच्छिक रूप से एकत्र किए जाएंगे और सख्ती से परीक्षण किए जाएंगे ताकि उपयोगकर्ताओं का उत्पाद में विश्वास हो। इस पर होने वाले खर्च को कृषि विभाग के नियमित बजट से पूरा किया जा सकता है

प्रशासनिक सेटअप

जिला स्तर पर निगम बनाकर पूरी प्रणाली को कॉर्पोरेट फैशन में प्रबंधित किया जा सकता है। कार्यक्रम के कार्यान्वयन के लिए प्रशासनिक व्यवस्था का रेखा आलेख निम्नलिखित है। उपर्युक्त से यह स्पष्ट है कि यह प्रणाली आर्थिक रूप से व्यवहारीय है और इसमें रोजगार की अपार संभावनाएं हैं साथ ही मौजूदा योजनाओं से ही व्यय लिया जा सकता है।



3D Printed Check Dams: A Digital Revolution in Check Dam Construction

Pratik Ranjan Chaurasia
Water Resources and Management expert, water conservation and protection activist, writer & peer reviewer, Ex-HOD & Chief Engineer, Department of Minor Irrigation, Government of UP, Ex-Director, Groundwater Department, Government of UP

The construction of masonry check dams has been a primary focus for water conservation and groundwater recharge, particularly in the drought-prone Bundelkhand and Vindhyan regions. The Minor Irrigation Department is a pioneer agency for constructing masonry check dams in the state of UP. The department has constructed over 6000 masonry check dams across the state. These check dams are constructed using stone and cement-sand mortar, as well as plain concrete. Associated problems with such technology include leaks due to numerous weak mortar joints, high wastage (resulting from stone cutting), slow work speed, difficulty in constructing curved or tapered structures, piping from the sides of the wing wall, and challenges in ensuring quality.

3D Printing is a cutting-edge technology, and its use has surged in every field due to its numerous advantages, including speed, accuracy, quality assurance, and flexibility, particularly in rugged terrain. Constructing masonry check dams via 3D printing represents a shift from traditional labour-intensive "wet trade" masonry to Digital Additive Manufacturing. Instead of manually laying stones and mortar, a robotic system deposits material layer-by-layer based on a precise digital model. There are two approaches in practice; one is the "Digital Masonry Approach (Modular)" in which a 3D printer is used to create complex, interlocking masonry blocks off-site. Another is "Monolithic On-site Printing (The Seamless Dam)", which is more commonly known as the "Construction 3D Printing (C3D P)" method. In it, a robotic arm or gantry is brought directly to the gully or stream bed. The robot extrudes a specialised concrete or geopolymer mix in a continuous loop to form the dam's perimeter. To mimic the weight and stability of a heavy masonry dam, the printer creates a hollow double-wall shell which is then filled with local rubble, earth, or a secondary concrete pour.

Why 3D Print a Check Dam

- **Complex Hydraulics:** Traditional masonry is limited to simple flat or arched walls. 3D printing enables energy-dissipating textures, which reduce downstream erosion.
- **Speed in Remote Areas:** A 3-meter check dam that might take a crew a month to build manually can be printed in less than 12 hours of active run-time.
- **Engineering for Resilience:** Traditional masonry dams often fail at the mortar joints. 3D printing enables topological optimisation, creating shapes that distribute stress more naturally.
- **The "Double-Skin" Wall:** The robot prints two parallel walls with an internal "zigzag" lattice. This creates a massive structure that uses less material than a solid stone dam but provides higher shear resistance.
- **Variable Layer Thickness:** To handle the "impact" of rolling boulders during a flood, the printer can thicken the layers at the base (the "toe") of the dam and use more fibre-dense material in the "spillway" section.
- **Material Optimisation:** By using hollow-core designs for wing walls, core wall and aprons, material consumption can be reduced by 30-50% while maintaining structural stability through geometry.

✦ **Preventing Piping along the Wing Wall:** 3D printers are programmed to extend the "beads of concrete mix" directly into a pre-excavated trench in the riverbank, creating a keyed connection that is much tighter than the usual earth fill after constructing a stone masonry wing wall and prevents water from bypassing.

Constructing wing walls and aprons via 3D Concrete Printing (3DCP) replaces traditional construction formwork with a robotic extrusion process. In this workflow, a 6-axis robotic arm or gantry system follows a digital path to deposit high-performance concrete layer-by-layer.

Wing Walls: Design and Tie-ins

Wing walls are typically vertical or canted structures designed to funnel water and protect stream banks. 3D printing allows these to be monolithic extensions of the dam body.

✦ Curved Geometry: Unlike flat formwork, 3D printers can easily create logarithmic curves or tapered profiles. These shapes are hydraulically superior as they reduce turbulence and prevent "dead zones" where sediment might collect.

✦ "Keying" into Banks: To prevent water from bypassing the wall (piping), the printer can be programmed to extend the "beads" of concrete directly into a pre-excavated trench in the stream banks. This creates a "keyed" connection that is much tighter than a poured-against-earth joint.

✦ Internal Reinforcement: Since wing walls face lateral earth pressure, the printer typically creates a hollow-core wall (two parallel "skins" with a zig-zag infill). Steel rebars or vertical tie-rods can be inserted into these cavities and grouted manually after the print is complete.

Upstream and Downstream Aprons

Aprons are horizontal or slightly sloped slabs that protect the gully bed from erosion. In C3DP, they are constructed using "Pavement-Style" or "Hybrid" methods.

A. The "Waffle" or Ribbed Method

Instead of printing a solid block of concrete (which is slow and uses excess material), the robot prints a ribbed "waffle" structure.

✦ Energy Dissipation: The downstream apron can be printed with an intentional surface roughness or "stepped" texture. These "teeth" act as micro-baffles to break the water's velocity.

✦ Infilling: The printed "cells" are often filled with local stone or gravel, and then topped with a final "skin" of printed concrete to create a robust, heavy armour layer.

B. Non-Planar Printing

For transition areas where the apron meets the dam toe, a 6-axis robotic arm can use non-planar slicing. This means the robot doesn't just print in flat layers; it can move the nozzle in 3D curves to follow the slope of a spillway bucket or the curvature of the gully floor, ensuring a seamless transition between the vertical dam and the horizontal apron.

The Construction Workflow

A typical 3D-printed check dam project follows these steps:

Step	Action	Description
1. Site Preparation	Excavation	The stream or riverbed is cleaned and trenched to receive the printed layers.
2. Base Print	Apron first	The robot first prints the downstream and upstream aprons to provide a stable, level working surface.
3. Core & Wings	Monolithic print	The printer builds the main dam body and wing walls simultaneously in one construction path to avoid cold joints.
4. Finishing	Reinforcement	Steel bars are inserted into the printed voids, and a high-strength grout is poured to solidify the structure.

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4. Finishing Reinforcement Steel bars are inserted into the printed voids, and a high-strength grout is poured to solidify the structure.

First, a drone performs a LiDAR survey of the stream's topography to create a digital twin of the site. CAD software generates a dam shape optimised for the stream's specific flow. A specialised mix is loaded into a circular mixer. The robot extrudes the material in horizontal layers. The layers are printed perpendicular to the flow to maximise shear resistance. If the dam is high head, the robot may pause to allow for the insertion of vertical steel bars or fibre mesh layers between the masonry beads. The printer follows these "Digital Masonry" rules:

1. Foundation Keying: The robot prints the first 5 layers into a pre-dug trench to "key" the dam into the bedrock.
2. Horizontal Reinforcement: Every10th layer, the robot pauses for a human (or second arm) to lay a galvanised steel mesh or carbon fibre grid across the path.
3. Tapering: The width of the print path narrows as the height increases.

If the pump fails and the concrete hardens before the next layer is printed, a "cold joint"-a massive weak point is created. Authentic 3D printing requires a "non-stop" toolpath to ensure the dam acts as one monolithic stone.

Material

Constructing a masonry check dam with 3D printing requires a specialised material palette designed to balance pumpability (flowing through the hose) and buildability (holding its shape without moulds). Standard concrete used in traditional dams is too "soupy" for 3D printing. Instead, a High-Performance Fibre-Reinforced Mortar (HPFRM) comprising Portland Pozzolana Cement (PPC) type II, silica fume, fly ash, graded sand, and polypropylene or cellulose is used. PCC acts as a primary binder, fly ash improves flow and reduces heat (preventing cracks), silica fume increases "stickiness", for high-layer stacking, fine sand acts as a bulk aggregate, polycarboxylate acts as a superplasticiser, and polypropylene fibre provides strength to prevent sagging.

The Companies and Technology & Service Providers

The primary players or companies that manufacture, supply, or provide the machinery (the actual 3D printers) or technology and services in India, capable of building hydraulic structures like check dams, are:

- AJAX Engineering
- MiCoB Private Limited
- Simpliforge Creations
- Cretebots
- Tvasta Construction
- L&T Construction
- Apsuja Infratech

पंजाब की चावल-गेहूं प्रणाली में पराली जलाने और भूजल की कमी का एक लीक से हटकर समाधान

डॉ. रमेश चंद्र श्रीवास्तव
M. Tech., Ph.D. (IIT, Kgp),
FNAAS, FIE, FISAE, FIASWSC, FCHAI
पूर्व कुलपति, डॉ राजेंद्र प्रसाद केंद्रीय कृषि विश्वविद्यालय, पूसा, बिहार

पराली जलाना आजकल खबरों में है क्योंकि यह राष्ट्रीय राजधानी क्षेत्र में प्रदूषण के परिदृश्य को प्रभावित कर रहा है और अधिकांश प्रतिक्रियाओं में, किसानों को इसके लिए दोषी ठहराया जा रहा है। चावल- गेहूं की फसल प्रणाली को इसके साथ-साथ भूजल स्तर में गिरावट के लिए दोषी ठहराया जा रहा है। कोई भी किसानों की मजबूरी के बारे में बात नहीं कर रहा है कि वे चावल-गेहूं की फसल प्रणाली की लाभप्रदता और मशीनीकरण के कारण इसे अपना रहे हैं। साथ ही ये हमारे खाद्या सुरक्षा के लिए भी जरूरी है। कुछ दिन पहले, यहां तक कि सुप्रीम कोर्ट ने भी किसानों को उपदेश देने के लिए कठोर शब्दो का उपयोग करते हुए कहा था कि पराली जलाने वाले किसानों को न्यूनतम समर्थन मूल्य का लाभ नहीं दिया जाना चाहिए। सुप्रीम कोर्ट ने यहां तक सुझाव दिया कि घटते भूजल को देखते हुए पंजाब और हरियाणा में चावल का रकबा कम किया जाना चाहिए। हालांकि, इनमें से कोई भी कदम पंजाब में चावल की खेती की समस्या पर विचार नहीं करता है और एक स्थायी समाधान की तलाश करता है। ड२. राजेन्द्र प्रसाद केन्द्रीय कृषि विश्वविद्यालय के कुलपति के रूप में मेरे कार्यकाल के दौरान,मैंने एक मॉडल की संकल्पना की जो माननीय प्रधान मंत्री द्वारा अगस्त, 2021 में मन की बात में उल्लेख किए जाने के बाद प्रसिद्ध सुखेत मॉडल बन गया। इस मॉडल में किसानों से उनके दरवाजे पर सभी घरेलू कचरे और गोबर का संग्रह, वर्मी कम्पोस्ट बनाना, इसे बेचना और हर 2 महीने में एक बार एलपीजी सिलेंडर भरवाना शामिल था। जो लोग इसके बारे में अधिक जानना चाहते हैं, वे इसे गूगल कर सकते हैं। इसी तरह मैंने बिहार के जलभराव वाले क्षेत्रों के लिए एक भूजल पुनर्भरण सह जल निकासी मॉडल तैयार किया जो उत्तर बिहार के मैदानी इलाकों में मानसून के अतिरिक्त पानी को कम करने और जलभृतों के पुनर्भरण के लिए इसका उपयोग करने में बहुत सफल रहा जहां भूजल स्तर गिर रहा है। सुखेत मॉडल और भूजल पुनर्भरण सह जल निकासी संरचना के मेरे अनुभव के आधार पर, पराली और घटते जल स्तर की दोहरी समस्याओं को हल करने के लिए मेरा प्रस्ताव निम्नानुसार है।

उपलब्ध आंकड़ों के अनुसार, पराली की मात्रा जिसे हटाया जाना है वह लगभग 185 लाख टन अर्थात

लगभग 6 टन/हेक्टेयर है। प्रति गांव चावल का औसत क्षेत्रफल 250 हेक्टेयर है, जिसकी गणना गांवों की कुल संख्या और चावल के क्षेत्र को विभाजित करके निकाली गई है, इसलिए प्रति गांव कुल पराली उत्पादन 1500 टन है। प्रति गांव औसत गोबर उत्पादन 7 टन प्रति दिन है, अर्थात, राज्य की मवेशी आबादी को गांवों की संख्या से विभाजित करते हुए प्रति वर्ष लगभग 2500 टन है। पराली की कटाई और इसे केंद्रीकृत स्थान पर ले जाने का काम इसके लिए नियुक्त एजेंसी द्वारा किया जा सकता है या किसानों को ऐसा करने के लिए कहा जा सकता है। यह एजेंसी या किसान पराली की कटाई करेंगे, उसे भूसे में परिवर्तित और इसे वर्मीकम्पोस्ट केंद्रों तक पहुंचाएंगे। इस ऑपरेशन के लिए, एजेंसी या किसान को 2000 रूपये प्रति टन भुगतान किया जा सकता है, यानी लगभग 12000 रूपये प्रति हेक्टेयर। 31 लाख हेक्टेयर के लिए कुल लागत 3720 करोड़ रूपये होगी और एक गांव के लिए यह 29.76 लाख यानी 30 लाख होगी। गोबर के लिए जो किसानों के दरवाजे पर एकत्र किया जा सकता है, उन्हें रू. 1 प्रति किलोग्राम का भुगतान किया जा सकता है। इस प्रकार एक गांव के लिए वर्मीकम्पोस्ट की इनपुट लागत गोबर के लिए 25 लाख और पराली के लिए 30 लाख होगी, जिससे प्रति गांव कुल वार्षिक इनपुट लागत 55 लाख रूपये होगी। इस प्रकार प्रत्येक गांव 2400 टन वर्मीकम्पोस्ट (इनपुट सामग्री का 60%) का उत्पादन करेगा जो 24 टन नाइट्रोजन, 19.2 टन फास्फोरस और 19.2 टन पोटाश (1% एन, 0.8% पी, 0.8% के) के बराबर होगा, जिससे यह 96 किलोग्राम N 48 किलोग्राम और K48 किलोग्राम प्रति हेक्टेयर खेती क्षेत्र होगा। जो मिट्टी में कार्बनिक कार्बन और पोषक तत्वों की आवश्यकता को पूरा करेगा जो मिट्टी के स्वास्थ्य के लिए एक बड़ी समस्या है। सुखेत मॉडल के पूर्व अनुभव के अनुसार श्रम की आवश्यकता 250 टन यूनिट के लिए 5 जनशक्ति की आवश्यकता होगी, जिसका अर्थ है कि 2400 टन उत्पादन के लिए 35 जनशक्ति (लेखांकन आदि के लिए सफेदपोश श्रम की आवश्यकता केवल एक हो सकती है) लगभग 63 लाख रूपये के वार्षिक व्यय के बराबर होगी। इसके अलावा, खाद बनाने के लिए बुनियादी ढांचे के निर्माण में लगभग 120 लाख की आवश्यकता होगी। इसलिए 120 लाख रूपये के पूंजीगत व्यय और लगभग 118 लाख रूपये के राजस्व व्यय के साथ, प्रत्येक गांव में प्रति वर्ष 2400 टन खाद उत्पादन होगा, जो केवल राजस्व व्यय पर विचार करने के साथ 4.91 रूपये प्रति किलोग्राम होगा। यदि उर्वरक सब्सिडी वर्मीकम्पोस्ट में स्थानांतरित की जाती है, और वर्मीकम्पोस्ट को किसानों को 33% सब्सिडी पर बेचा जाता है, तो किसान इसे आसानी से @Rs 3.25 प्रति किलोग्राम पर खरीद लेंगे। क्योंकि यह घर पर उपलब्ध होने के अलावा मिट्टी के स्वास्थ्य में मदद करेगा। शेष राजस्व घाटा 39.84 लाख रूपये प्रति गांव यानी लगभग 4980 करोड़ रूपये है, जिसे एनसीआर में चलने वाले

वाहनों के साथ-साथ निर्माण गतिविधियों पर वार्षिक उपकर से पूरा किया जा सकता है। विभिन्न प्रकार के वाहनों के लिए अलग-अलग स्लैब वाले 2.5 करोड़ वाहनों पर प्रति वाहन औसत 1000 रूपये का उपकर और 1 ट्रिलियन रूपये मूल्य की निर्माण गतिविधियों पर 2% उपकर लगाने से लगभग 4500 करोड़ रूपये का राजस्व उत्पन्न किया जा सकता है। और शेष उर्वरक सब्सिडी निधियों से आएगा। 15000 करोड़ रूपये की पूंजीगत लागत @12500 गांवों के लिए प्रति गांव 1.2 करोड़) को राज्य सरकार के खजाने से पूरा किया जा सकता है, इससे किसानों की आय में वृद्धि के अलावा गांव में ही अर्धकुशल युवाओं के लिए रोजगार के बड़े अवसर पैदा होंगे, जो पराली और गोबर की बिक्री के साथ प्रति वर्ष 5000 करोड़ रूपये से अधिक होंगे। कार्यक्रम का कार्यान्वयन पंचायतों को सौंपा जा सकता है जो इसे लगभग 1.2 करोड़ निवेश के रूप में लागू करने में प्रसन्न होंगे।

इसी तरह भूजल की समस्या के लिए लीक से हटकर समाधान निकालने की कोशिश की जा सकती है। आंकड़ों से पता चला है कि चावल का क्षेत्र 31 लाख हेक्टेयर है, जिसमें से लगभग 27% क्षेत्र नहर सिंचित है और शेष टयूबवेल सिंचित है। इसी प्रकार गेहूं का रकबा लगभग 32 लाख हेक्टेयर है। इस प्रकार यह सुरक्षित रूप से माना जा सकता है कि चावल-गेहूं का क्षेत्र लगभग 31 लाख हेक्टेयर है, जिसमें से लगभग 22.5 लाख हेक्टेयर टयूबवेल सिंचित (27% नहर सिंचित) है। चावल के लिए 1000 मिमी और गेहूं के लिए 300 मिमी सिंचाई आवश्यकता मानते हुए, चावल-गेहूं के लिए पंप किया गया कुल पानी लगभग 29.25 लाख हेक्टेयर मीटर (1 हेक्टेयर मीटर = 10000 मीटर^3) यानी 29.25 ×109 m^3 (29.25 ×105 ×104) है। भारत सरकार की रिपोर्टों के अनुसार, वार्षिक भूजल पुनर्भरण 18.94 बीसीएम अर्थात 18.94 ×109 m^3 है। भूजल स्तर को कम होने से सुरक्षित रखने के लिए, लगभग 10.31 × 109 m^3 को हर साल अतिरिक्त रूप से जलभृत में रिचार्ज करने की आवश्यकता होती है। पंजाब के हाइड्रो जियोलॉजी के बारे में एकत्र की जा सकने वाली सीमित जानकारी से पता चला है कि दो सीमित जलभृत हैं जिनके बीच एक मिट्टी की परत है। पानी को इन जलभृतों में रिचार्ज करने की आवश्यकता है।

सतलज डाउनस्ट्रीम भाखड़ा बांध और रावी डाउनस्ट्रीम थीन बांध के बाढ़ प्रवाह के आंकड़ों की जांच से पता चला है कि सामान्य मानसून के मौसम के दौरान सतलज में प्रवाह 2000 क्यूमेक यानी 70000 क्यूसेक और रावी में 267.5 क्यूमेक यानी 9400 क्यूसेक है। इसमें से ज्यादातर पानी बहकर पाकिस्तान चला जाता है जबकि सिंधु संधि के अनुसार इन जल पर हमारा पूरा अधिकार है। यदि हम मानसून के दौरान सुतलज से 400 क्यूमेक (20%) और रावी से 150 क्यूमेक (56%) को मोड़ते हैं और इसे नदी के मार्ग के साथ बनाई गई रिचार्ज प्रणालियों में मोड़ते हैं, तो यह 550 क्यूमेक होगा,

यानी 1950000 m3 प्रति घंटा जिसका अर्थ है 468 लाख क्यूबिक मीटर प्रति दिन। यदि यह प्रणाली 100 दिनों अर्थात मानसून अवधि तक चलती है, तो यह भूजल जलभृतों को 4.68 × 109 m^3 यानी आवश्यकता के 35-72% के बराबर रिचार्ज करेगी। तथापि, यदि हम सतलज से अपवर्तन को 50% अर्थात 1000 क्यूमेक तक और रावी के लिए 75% अर्थात 200 क्यूमेक तक बढ़ाते हैं, तो पुनर्भरण राशि हमारी आवश्यकता का लगभग 72% बढ़कर 936× 109 m^3 हो जाएगी। यह डायवर्जन एक स्थान पर नहीं किया जाना होगा बल्कि इन दो मुख्य नदियों की विभिन्न सहायक नदियों के पूरे मार्ग में फैलाया जाना होगा। इस प्रकार यह एक स्थान पर प्रवाह को प्रभावित नहीं करेगा और न ही इसके लिए, एक स्थान पर बड़ी मात्रा में भूमि की आवश्यकता होगी। लेखक द्वारा विकसित डिजाइन प्रत्येक इकाई के लिए 0.5 लाख प्रति हेक्टेयर मीटर की लागत से लगभग 5 हेक्टेयर मीटर रिचार्ज करता है। इस प्रकार पानी की इतनी मात्रा की देखभाल करने के लिए लगभग 5000 करोड़ रूपये के निवेश पर लगभग 2 लाख इकाइयों की आवश्यकता होगी।

ऊपर से यह स्पष्ट है कि पराली जलाने और भूजल में गिरावट की दोहरी समस्याओं का समाधान किया जा सकता है, यदि हम फसल प्रणाली में विविधता लाने या बिजली चार्ज करने के दृष्टिकोण, जिसमें किसी भी तत्काल ठोस लाभ के बिना प्रत्येक किसान की भागीदारी की आवश्यकता होती है पर निर्भर रहने के बजाय समस्या से निपटने के लिए एक सक्रिय दृष्टिकोण अपनाते हैं। । पंचायतों को इस पूरे प्रयास में शामिल किया जा सकता है जिसे वे खुशी से लेंगे क्योंकि प्रत्येक गांव को लगभग दो करोड़ रूपये का निवेश मिलेगा। किया गया निवेश प्राकृतिक संसाधन परिदृश्य को बदल देगा और संरक्षण के हमारे प्रयासों में एक लंबा रास्ता तय करेगा।

Road Safety and Highway Construction: Building Safer Roads for a Safer India

Masarrat Noor Khan, FIE
Chief Engineer, U.P. PWD (Retd.)

Introduction

Roads are the lifelines of a modern nation. They connect villages with towns, cities with markets, industries with ports, and people with opportunities. India has witnessed remarkable growth in the construction of National Highways, Expressways, bridges and other transport infrastructure during the last few decades.

However, road development cannot be measured only by the length of roads constructed or the speed at which vehicles can travel. The real measure of a successful highway is how safely and efficiently it carries people and goods. Road safety must therefore be treated as an integral part of highway planning, design, construction, operation and maintenance.

India continues to face a serious road-safety challenge. A large number of crashes occur every year, resulting in deaths, serious injuries, loss of family income and considerable economic loss. Many of these accidents can be reduced through better engineering, disciplined construction practices, effective enforcement and responsible road-user behaviour.

The Human Cost of Road Accidents

Road Category	Number of Accidents	Persons Killed
National Highways, including Expressways	1,50,177	63,112
State Highways	1,05,662	39,439

The seriousness of India's road-safety challenge becomes clear from the casualty figures. During the decade from 2015 to 2024, nearly 16 lakh people lost their lives in reported road accidents in India. The number of fatalities was 1, 46,133 in 2015 and increased to 1, 50,785 in 2016. It was 1, 47,913 in 2017 and 1, 57,593 in 2018. In 2019, 1, 51,113 persons were killed. During the COVID-19 affected year 2020, fatalities declined to 1, 38,383. However, they increased thereafter to 1, 53,972 in 2021, 1, 68,491 in 2022 and 1, 72,890 in 2023. The figure for 2024 was approximately 1.80 lakh. These figures are not merely statistics. Every fatality represents a human life lost, a family affected and a social and economic burden created. They underline the need to make road safety an essential component of highway planning, design, construction, maintenance and operation. Fatalities on National and State Highways

The distribution of fatalities also highlights the particular responsibility of highway engineers. According to the Ministry of Road Transport & **Highways, in 2023 there were:**

Thus, National and State Highways together accounted for nearly 60 per cent of all road-accident fatalities in 2023. This is a strong indication that highway safety must receive the same importance as capacity, speed and connectivity.

Road Safety Begins at the Planning Stage

Road safety should not be considered an additional facility to be provided after a highway has been constructed. It must be incorporated from the very beginning of the project.

During planning and feasibility studies, engineers should carefully examine traffic volume and composition, future traffic growth, speed characteristics, accident-prone locations, pedestrian

and cyclist movement, schools and markets, junctions and intersections, terrain and climatic conditions, flood-prone and landslide-prone locations, and the requirement for service roads and pedestrian facilities.

A proper Road Safety Audit at different stages of a project can identify potential hazards before they result in accidents.

Highway Design and Safety

A well-designed highway should be forgiving. This means that even when a driver makes a minor mistake, the road environment should minimise the possibility of a serious crash.

Important safety features include: Proper geometric design: Horizontal and vertical curves should provide adequate sight distance and should be compatible with the design speed.

Safe intersections: Junctions are among the most accident-prone locations and require appropriate channelisation, signs, markings, lighting and, where necessary, grade separation.

Median and crash barriers: Properly designed medians and safety barriers can prevent vehicles from crossing into opposing traffic.

Shoulders and emergency areas

Adequate shoulders provide space for vehicles that have broken down and reduce obstruction to moving traffic. Pedestrian facilities: Footpaths, pedestrian crossings, foot-over bridges and underpasses should be provided wherever pedestrian movement is significant. Service roads: In built-up areas, service roads can separate local traffic from high-speed through traffic.

Drainage

Water accumulation on the carriageway reduces skid resistance and can damage the pavement. Efficient drainage is therefore an important safety feature.

Quality of Construction

Safety is closely connected with quality of construction. Poor-quality pavement, uneven surfaces, inadequate compaction, defective drainage, weak shoulders and improperly constructed road furniture can create serious hazards. Highway construction should strictly follow approved specifications and quality-control procedures. Materials should be properly tested, construction stages adequately supervised and quality assurance carried out effectively. Particular attention should be given to:

- Pavement thickness and material quality
- Proper compaction
- Surface evenness
- Skid resistance
- Drainage arrangements
- Bridge approaches
- Expansion joints
- Road markings
- Crash barriers
- Delineators and signboards.

A road constructed cheaply but requiring frequent repairs is ultimately more expensive-not only financially but also in terms of safety.

Construction Zones

A Major Safety Concern

Ironically, a road improvement project intended to make a highway safer can temporarily become a major source of accidents. Construction zones should therefore have a properly prepared Traffic Management Plan. Drivers must receive adequate warning well before reaching the work zone. There should be advance warning signs, clearly marked diversion routes, reflective barricades, adequate lighting at night, proper lane markings, speed restrictions, safe pedestrian movement and trained flagmen where required. Workers themselves must be provided with helmets, reflective jackets, safety shoes and other

appropriate personal protective equipment.

No construction activity should be allowed to compromise the safety of road users or workers.

The Human Factor

Engineering alone cannot eliminate road accidents. The behaviour of road users is equally important.

Common causes of serious crashes include:

- over speeding
- Drunken or impaired driving
- Driving on the wrong side
- Distracted driving and mobile-phone use
- Failure to wear seat belts
- Failure to wear helmets
- Dangerous overtaking
- Fatigue and drowsy driving
- Violation of traffic signals.

The principle should be simple

Better roads + safer vehicles + responsible drivers + effective enforcement = safer transportation. Road users must understand that traffic rules are not merely legal requirements; they are measures designed to protect human life.

Highway Maintenance

Construction of a highway is only the beginning. Maintenance is a continuous responsibility. A well-designed highway can become unsafe if potholes, damaged barriers, faded markings, blocked drains, vegetation, broken signs or defective lighting are not attended to promptly. Routine inspection should be undertaken, particularly after heavy rainfall, floods, landslides and other extreme weather events. Modern technologies such as drones, GPS-based inspection, pavement-monitoring systems and artificial intelligence can increasingly help authorities identify defects before they become dangerous.

Climate Change and Resilient Highways

Climate change is creating new challenges for highway infrastructure. Extreme rainfall, flash floods, landslides, heat waves and other unusual weather events can damage roads and bridges. Highway planning must therefore move towards climate-resilient infrastructure.

This requires

- Proper hydrological and drainage studies
- Adequately designed culverts and bridges
- Protection of slopes and embankments
- Bio-engineering and appropriate retaining structures
- Avoidance of construction in highly vulnerable areas
- Regular monitoring of hill roads
- Early-warning and emergency-response systems.

In mountainous regions, particularly the Himalayan areas, indiscriminate cutting of slopes and poorly planned construction can increase vulnerability. Development must be balanced with the carrying capacity and ecological sensitivity of the region.

Technology and Intelligent Highways

The highways of the future will increasingly depend on technology. Intelligent Transport Systems can provide real-time traffic information, automatic incident detection, variable message signs, weather and visibility warnings, electronic tolling, emergency communication and real-time monitoring of traffic conditions. Connected vehicles and advanced driver-assistance technologies may further reduce human error in the future.

However, technology should support good engineering and responsible driving, not replace them.

The Way Forward

For safer highways, India needs an

integrated approach based on the "4 Es" of road safety: Engineering - safer planning, design, construction and maintenance. Education - continuous road-safety awareness among drivers, pedestrians, students and the public. Enforcement - strict and fair enforcement of traffic rules. Emergency Care - rapid medical assistance and trauma care after a crash. A fifth element- Evaluation-should also become an integral part of the system. Accident data must be scientifically analysed so that recurring hazards can be identified and corrected. There is also a need for greater coordination among highway authorities, police, transport departments, local bodies, engineers, contractors and emergency medical services. Road safety is a shared responsibility and cannot be achieved by one department alone.

Conclusion

Highway construction is essential for economic development, but development must never be achieved at the cost of human lives. The objective of modern highway engineering should not merely be to construct wider and faster roads. It should be to create roads that are safe, sustainable, resilient, accessible and efficient. Every bridge, every kilometre of highway, every junction and every road project should ultimately serve one fundamental purpose-to take people safely to their destination. The engineering profession has a special responsibility in this regard. As engineers, planners, contractors and administrators, we must remember that behind every traffic statistic is a human being and a family. The ultimate objective should be to move from a system that merely responds to accidents to one that anticipates risks and prevents crashes before they occur. A highway is not truly successful because it carries more traffic; it is successful when it carries that traffic safely.

Predictive Modelling of Yamuna River Water Quality Using Multispectral Remote Sensing and Regression Techniques

Vikas Pandey[1], K. K. Singh2*, and M. B. Chetti3
1,2,3 School of Agriculture, Sanskriti University, Mathura, 281401, Uttar Pradesh, India
* Corresponding Author Email: dean.soa@sanskriti.edu.in

Abstract

Monitoring surface-water degradation in heavily polluted tropical rivers requires efficient and spatially continuous assessment methods. This study developed and compared empirical models for predicting key water-quality parameters along a 28 km stretch of the Yamuna River between Devraha Baba Temple and Chintaharan Ghat, Mathura, Uttar Pradesh, India. Water samples were collected from 46 sampling stations during the pre-monsoon period (March 2024) and analyzed for Total Suspended Solids (TSS), Total Dissolved Solids (TDS), turbidity, chlorophyll-a, Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) using standard analytical procedures. Spectral information extracted from IRS LISS-III multispectral imagery (Bands 2-5) and derived band-ratio indices was used as predictor variables in Multiple Linear Regression (MLR), Stepwise Regression (SWR), and Support Vector Regression (SVR) models. MLR provided moderate predictive performance, with R^2values ranging from 0.44 (TSS) to 0.78 (chlorophyll-a). SWR improved prediction accuracy for several parameters, achieving the highest cross-validated performance for TSS (R^2=0.63), TDS (R^2=0.74), chlorophyll-a (R^2=0.79), and BOD (R^2=0.79). SVR, using a radial basis function kernel, captured nonlinear spectral relationships most effectively for COD, attaining the highest model fit (R^2=0.85) and the best cross-validated performance (R^2=0.77). The results demonstrate that the optimal modelling approach is parameter-dependent and that combining IRS LISS-III imagery with regression and machine-learning techniques provides a practical, non-destructive framework for spatially distributed river-water-quality monitoring to support pollution management and river-restoration planning

Keywords: Surface water quality, Remote sensing, IRS LISS-III, Support Vector Regression, Yamuna River, Water quality modelling.

Introduction

Surface-water bodies are essential for domestic supply, agriculture, industry, and ecological sustainability; however, rapid population growth, urbanization, industrialization, and intensive agricultural activities have substantially degraded river-water quality. The discharge of untreated sewage, industrial effluents, agricultural runoff, and solid waste introduces diverse pollutants into river systems, adversely affecting their physicochemical and ecological conditions and posing risks to human health [1]. Therefore, systematic monitoring of surface-water quality is essential for pollution assessment, water-resource management, and ecological restoration. The Yamuna River, a major tributary of the Ganga, originates from the Yamunotri Glacier and flows approximately 1,376 km before joining the Ganga at Prayagraj. Water quality deteriorates considerably along densely populated urban and industrial stretches. The Mathura reach is particularly important because of its cultural and religious significance and associated anthropogenic pressures. Previous studies have reported considerable variations in turbidity, Total Dissolved Solids (TDS), Biochemical Oxygen

Demand (BOD), Chemical Oxygen Demand (COD), dissolved oxygen, and other water-quality parameters at different locations along the Yamuna in Mathura [2-4]. Conventional water-quality assessment depends primarily on field sampling and laboratory analysis of parameters such as Total Suspended Solids (TSS), TDS, turbidity, chlorophyll-a, BOD, and COD. Although standardized laboratory procedures provide reliable measurements [5], their cost, labour requirements, limited sampling frequency, and point-based nature restrict their ability to represent spatially heterogeneous river conditions. Satellite remote sensing provides a complementary approach by enabling rapid, non-destructive, and spatially distributed water-quality assessment. Spectral information in the visible and near-infrared regions can be related to optically active constituents such as suspended sediments, chlorophyll-a, turbidity, and dissolved organic matter [6,7]. The Linear Imaging Self-Scanning Sensor-III (LISS-III), onboard India's Resourcesat satellite series, provides multispectral observations in the green (B2: 0.52-0.59 μm), red (B3: 0.62-0.68 μm), near-infrared (B4: 0.77-0.86 μm), and shortwave-infrared (B5: 1.55-1.70 μm) regions, with approximately 23.5 m spatial resolution [8]. Its spectral and spatial characteristics make it suitable for environmental and inland-water monitoring. The application of LISS-III imagery integrated with field observations for river-water-quality assessment has previously been demonstrated in the Gomti River, Uttar Pradesh [9]. Regression-based techniques provide an effective means of relating satellite-derived spectral variables to in-situ water-quality measurements. Multiple Linear Regression (MLR) provides an interpretable baseline, while Stepwise Regression (SWR) facilitates predictor selection and reduces redundancy among spectral variables. However, water-quality-spectral relationships can be nonlinear because of interactions among suspended sediments, algal matter, and dissolved substances [10]. Support Vector Regression (SVR), through kernel-based learning, can model such nonlinear relationships and has been applied to satellite-based water-quality estimation [11]. Despite the increasing application of remote sensing and machine-learning techniques, comparative evaluations of MLR, SWR, and SVR using IRS LISS-III data for multiple water-quality parameters in polluted inland rivers remain limited. Therefore, this study evaluates MLR, SWR, and SVR for predicting TSS, TDS, turbidity, chlorophyll-a, BOD, and COD in the Yamuna River at Mathura using field observations and LISS-III imagery acquired during the pre-monsoon season of March 2024. The objectives are to develop predictive models using LISS-III spectral bands and derived indices and compare the accuracy, stability, and generalization performance of MLR, SWR, and SVR. The study provides a practical framework for integrating field observations, satellite remote sensing, and statistical/machine-learning techniques for spatially distributed river-water-quality assessment.

2 Materials and Methods

2.1 Field Sampling and Laboratory Analysis

A field sampling campaign was conducted during the pre-monsoon period on 10-11 March 2024. A total of 46 sampling sites were systematically distributed along approximately 28 km of the Yamuna River to capture spatial variations in pollution conditions, including relatively less-impacted upstream sections, urban and religious zones near major ghats, sewage-discharge locations, and downstream reaches (Figure 1). Geographic coordinates of each sampling site were recorded using a handheld GPS. Water samples were collected approximately 10-20 cm below the water surface using pre-cleaned high-density polyethylene (HDPE) bottles. Prior to collection, each bottle was rinsed three times with river water. Samples were immediately stored in an ice-filled cooler and transported to the University Chemistry Laboratory for analysis within 24 h. Sample collection, preservation, handling, and analytical procedures were conducted following the relevant procedures of Standard Methods for the Examination of Water and

Wastewater [5]. Six water-quality parameters were analyzed: Total Suspended Solids (TSS), Total Dissolved Solids (TDS), turbidity, chlorophyll-a, Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). TSS was determined gravimetrically by filtering a well-mixed water sample through a pre-weighed glass-fibre filter (Whatman GF/C), followed by drying at 103-105 °C and reweighing. TDS was measured in situ using a TDS meter. Turbidity was measured in Nephelometric Turbidity Units (NTU) using a calibrated nephelometric turbidimeter. Chlorophyll-a was determined following solvent extraction with 90% acetone, with absorbance measured at 665 and 750 nm using a double-beam spectrophotometer. BOD was determined from the change in dissolved oxygen concentration following a 5-day incubation at 20 °C, with dissolved oxygen measured using the prescribed analytical procedure. COD was determined by the closed-reflux method, in which samples were digested with potassium dichromate in an acidic medium and subsequently titrated using ferrous ammonium sulfate with ferroin as the indicator [1].

2.2 Satellite Data Acquisition and Radiometric Processing

A multispectral IRS LISS-III satellite scene covering the study area was acquired for March 2024 through the ISRO Bhuvan platform. The LISS-III sensor provides observations in four spectral bands: Band 2 (green; 0.52-0.59 µm), Band 3 (red; 0.62-0.68 µm), Band 4 (near-infrared; 0.77-0.86 µm), and Band 5 (shortwave infrared; 1.55-1.70 µm) [8]. The georeferenced field-sampling locations were overlaid on the satellite imagery in ArcGIS, and the corresponding pixel values for Bands 2-5 were extracted at each sampling location using the Extract Multi Values to Points tool. To improve the representation of spectral information at the sampling locations, the extracted band values were subsequently used to derive spectral ratios and indices. These included ratios among the LISS-III bands (e.g., B2/B3, B4/B3, B5/B3, and B4/B2) and selected spectral indices such as the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Turbidity Index (NDTI). Such band combinations and spectral indices have been widely employed as predictor variables in remote-sensing-based water-quality assessment because they can enhance spectral sensitivity to water constituents and reduce some effects associated with absolute reflectance variation [6,7].

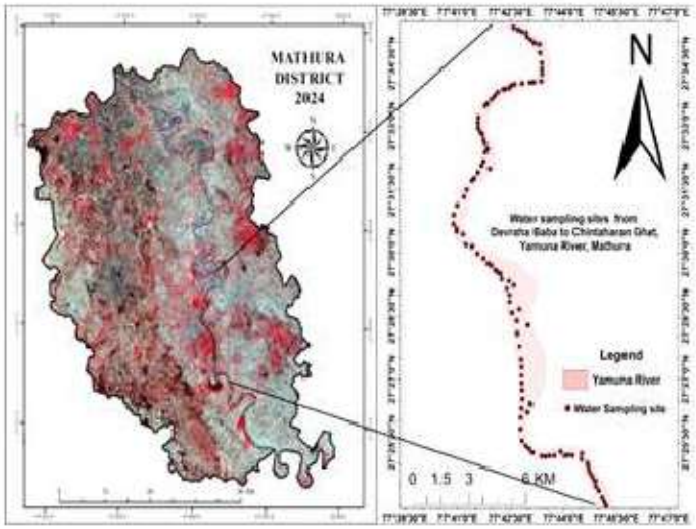


Figure 1: Location map of Mathura District and water sampling sites from Devraha Baba to Chintaharan Ghat, Yamuna River.

2.3 Predictive Regression Models

Three distinct modeling approaches were formulated and evaluated: (1) Multiple Linear Regression (MLR), which establishes a linear functional relationship between target parameters and spectral bands; (2) Stepwise Linear Regression, which automatically selects statistically significant combinations of bands and band ratios based on an F-test threshold ($p < 0.05$); and (3) Support Vector Regression (SVR), a non-linear machine learning algorithm that maps input vectors into a high-dimensional feature space using a Radial Basis Function (RBF) kernel. Hyperparameters (regularization parameter C and kernel width ?) were optimized via grid-search optimization combined with 10-fold cross-validation. Model

predictive accuracy was evaluated using the Coefficient of Determination (R^2), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE). Cross-validation performance was verified across all 46 sampling stations to prevent model overfitting.

3 Results and Discussion

3.1 Water Quality Characteristics

The descriptive statistics of the measured water quality parameters across the 46 sampling sites are summarized in Table 1. The ground-truth data reveal significant spatial variability along the Yamuna River during the pre-monsoon season. The concentration of Total Suspended Solids (TSS) ranged from 288 to 394 mg/L, with a high mean of 318.63 mg/L. Total Dissolved Solids (TDS) varied from 623 to 735 mg/L, with a mean of 686.63 mg/L, reflecting a high concentration of dissolved inorganic salts. Turbidity exhibited values between 103 and 120 NTU (mean 112.96 NTU), which correlates with the elevated TSS levels. Chlorophyll-a concentrations ranged from 5.02 to 5.95 µg/L (mean 5.49 µg/L), indicating active algal growth in the warm, nutrient-rich water. BOD and COD concentrations ranged from 11.15 to 17.65 mg/L (mean 14.68 mg/L) and 38.52 to 48.42 mg/L (mean 44.46 mg/L), respectively. These elevated organic parameters highlight severe organic pollution in the river corridor. The low flow conditions and warm climate in March accelerate bacterial degradation of organic waste, leading to dissolved oxygen depletion and ecological stress.

Table: 1. Descriptive statistics of water quality parameters for the study area (n = 46)

Parameter	Min	Max	Mean	Std. Dev.
TSS (mg/L)	288	394	318.63	20.85
TDS (mg/L)	623	735	686.63	28.12
Turbidity (NTU)	103	120	112.96	3.00
Chlorophyll -a (µg/L)	5.02	5.95	5.49	0.24
BOD (mg/L)	11.15	17.65	14.68	1.38
COD (mg/L)	38.52	48.42	44.46	1.88

3.2. Spectral Response and Regression Equation Analysis

The spectral response of the sampled water varied with water-quality conditions. TSS and turbidity showed greater sensitivity to the visible and near-infrared bands, whereas chlorophyll-a was more strongly associated with visible-band information. TDS, BOD, and COD exhibited indirect relationships with combinations of NIR and SWIR variables. Band ratios were considered to enhance relative spectral differences and reduce variability associated with illumination and background effects. The SWR analysis identified parameter-specific predictor combinations: B2/B3 and B3/B2 for TSS; B2/B3 and B4/B3 for TDS; B5/B3, B3/B2, and B3/B4 for turbidity; B5/B3 and B4/B2 for chlorophyll-a; B4/B5, B2/B5, B3/B5, and B3 for BOD; and B2 and B5/B4 for COD (Table 2). These results indicate that the spectral predictors varied among parameters, reflecting differences in their relationships with the optical properties of the river water. The MLR and SWR equations and optimized SVR configurations are presented in Table 2. MLR models incorporated LISS-III Bands 2-5, whereas SWR reduced the predictor set through statistical variable selection. The resulting equations demonstrate that no single spectral combination consistently explained all investigated water-

quality parameters. SVR employed RBF kernels for TSS, TDS, chlorophyll-a, and BOD, with C=100,100,10,and 10, respectively, and ?=0.1,0.1,0.01,and 0.01, respectively. Linear kernels were selected for turbidity and COD, with C=1and ?=0.2for both parameters (Table 2). The parameter-specific kernel selection indicates that the relationship between LISS-III spectral predictors and water-quality parameters varied across the investigated constituents.

Table: 2. Regression equations and optimized SVR configuration for predicting water quality parameters

Parameter	MLR Equation	Stepwise Regression (SWR) Equation	SVR Configuration
TSS	351.78 − 1.54·B2 + 1.25·B3 − 0.25·B4 + 0.53·B5	1901.00 − 702.80·(B2/B3) − 858.27·(B3/B2)	RBF kernel, C = 100, ε = 0.1
TDS	666.16 + 2.79·B2 − 2.46·B3 − 0.24·B4 − 0.26·B5	470.15 + 197.10·(B2/B3) − 23.03·(B4/B3)	RBF kernel, C = 100, ε = 0.1
Turbidity	114.77 − 0.40·B2 + 0.56·B3 + 0.06·B4 − 0.15·B5	110.58 − 12.10·(B5/B3) + 38.13·(B3/B2) − 20.71·(B3/B4)	Linear kernel, C = 1, ε = 0.2
Chlorophyll-a	6.04 − 0.01·B2 − 0.01·B3 − 0.00·B4 + 0.01·B5	4.97 + 0.74·(B5/B3) − 0.26·(B4/B2)	RBF kernel, C = 10, ε = 0.01
BOD	12.91 + 0.08·B2 − 0.05·B3 − 0.04·B4 + 0.05·B5	16.47 − 4.65·(B4/B5) + 11.02·(B2/B5) − 12.42·(B3/B5) + 0.06·B3	RBF kernel, C = 10, ε = 0.01
COD	65.66 − 0.34·B2 + 0.05·B3 − 0.08·B4 + 0.14·B5	49.04 − 0.25·B2 + 21.56·(B5/B4)	Linear kernel, C = 1, ε = 0.2

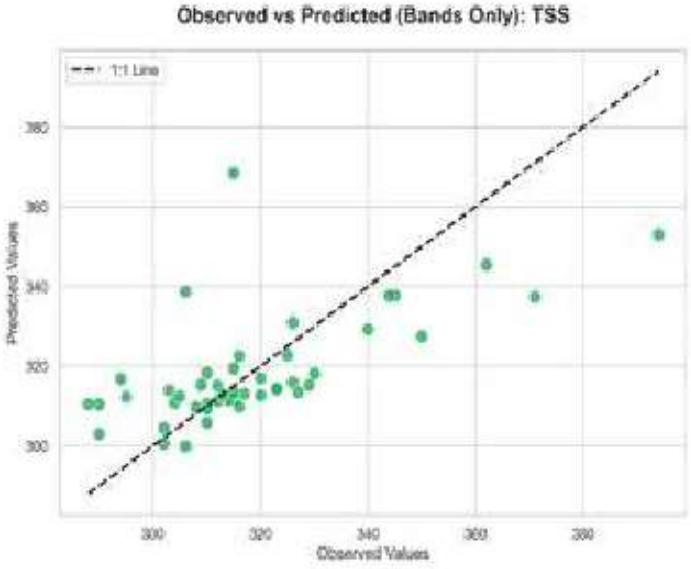
3.3. Comparative Performance Analysis

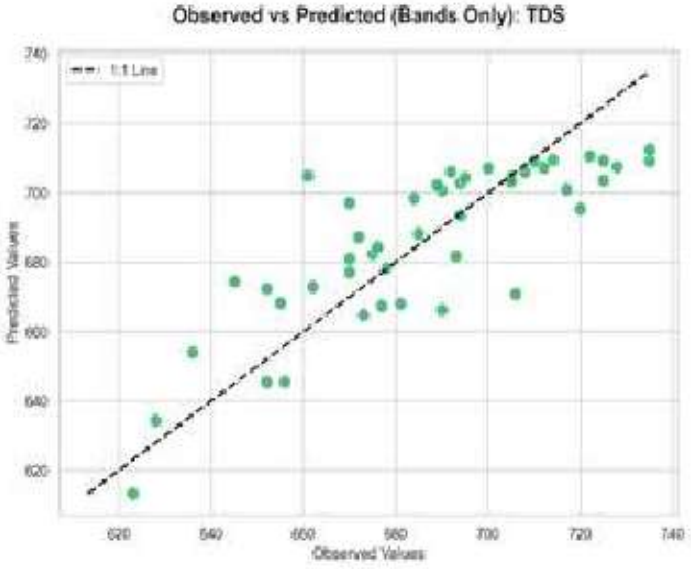
The comparative performance of the Multiple Linear Regression (MLR), Stepwise Regression (SWR), and Support Vector Regression (SVR) models is summarized in Table 3. The observed-versus-predicted relationships for Multiple Linear Regression (MLR), Stepwise Regression (SWR), and Support Vector Regression (SVR) are presented in Figures 2-4, respectively. The model-fit R^2 values for Multiple Linear Regression (MLR), Stepwise Regression (SWR), and Support Vector Regression (SVR) are graphically compared in Figure 5. MLR showed moderate model-fit performance, with R^2 values ranging from 0.4363 for TSS to 0.7767 for chlorophyll-a (Table 3). SWR generally improved model fit for TSS, TDS, chlorophyll-a, and BOD, increasing R^2. In contrast, MLR slightly outperformed SWR for turbidity, while COD showed nearly identical results (Table 3; Figure 5). The observed-versus-predicted relationships for SWR are shown in Figure 3. SVR achieved the highest model-fit R^2 for TSS (R^2 = 0.6510), TDS (R^2 = 0.8171), chlorophyll-a (R^2 = 0.8047), BOD (R^2 = 0.7889), and COD (R^2 = 0.8498), whereas MLR performed best for turbidity (R^2 = 0.6336) (Table 3; Figure 5). Among SVR models, the highest fit was

obtained for COD ($R^2 = 0.8498$), followed by TDS ($R^2 = 0.8171$), chlorophyll-a ($R^2 = 0.8047$), BOD ($R^2 = 0.7889$), and TSS ($R^2 = 0.6510$). SVR was further evaluated using cross-validation to assess model generalization.

Table: 3. Comparative predictive performance of Multiple Linear Regression (MLR), Stepwise Regression (SWR), and Support Vector Regression (SVR) models for predicting water quality parameters.

Parameter	MLR R^2	MLR RMSE	MLR MAE	SWR R^2	SWR RMSE	SWR MAE	SVR Fit R^2	SVR CV R^2	SVR CV RMSE
TSS	0.4363	15.48	10.71	0.6309	12.53	6.39	0.6510	0.4607	15.14
TDS	0.6658	16.08	13.05	0.7416	14.14	11.16	0.8171	0.7213	14.69
Turbidity	0.6336	1.80	1.28	0.6261	1.82	1.27	0.5926	0.5456	2.00
Chlorophyll-a	0.7767	0.11	0.09	0.7860	0.11	0.08	0.8047	0.6871	0.13
BOD	0.5829	0.88	0.59	0.7868	0.63	0.47	0.7889	0.7115	0.73
COD	0.7693	0.89	0.60	0.7680	0.89	0.69	0.8498	0.7724	0.89





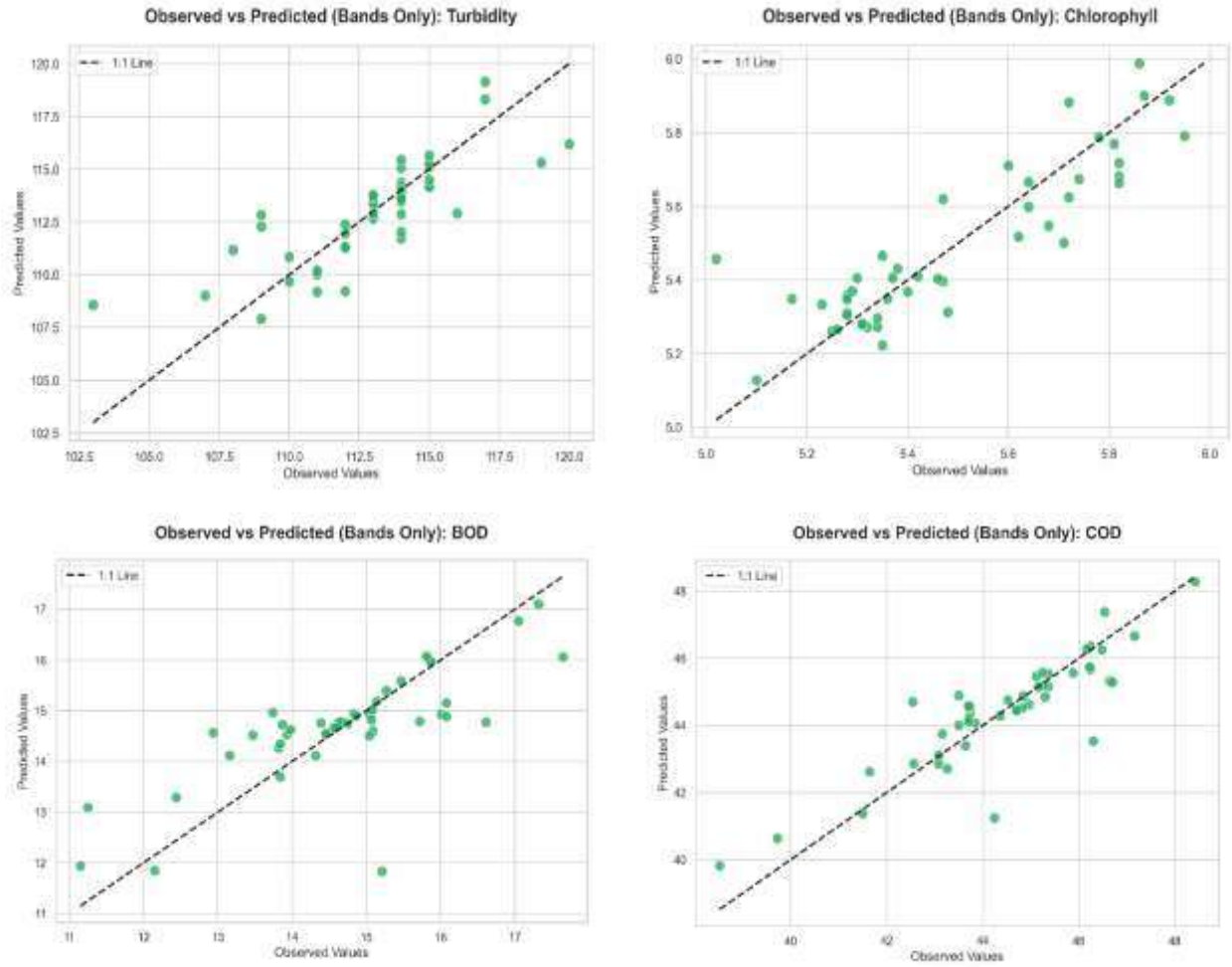


Figure 2. Scatter Plot (Observed vs Predicted values) using a Multilinear regression model.

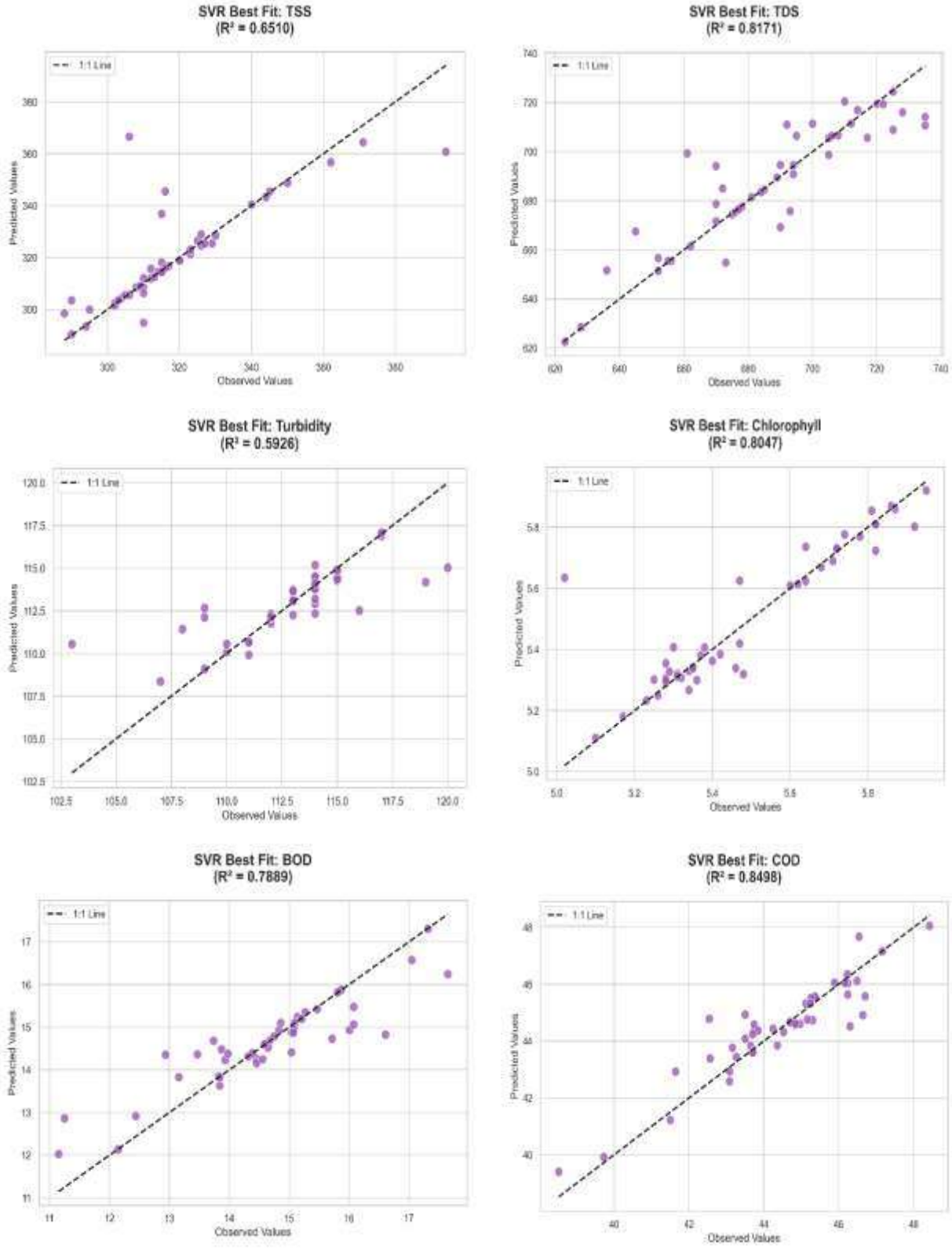


Figure 4. Scatter Plot (Observed vs Predicted values) using a Support Vector Regression model.

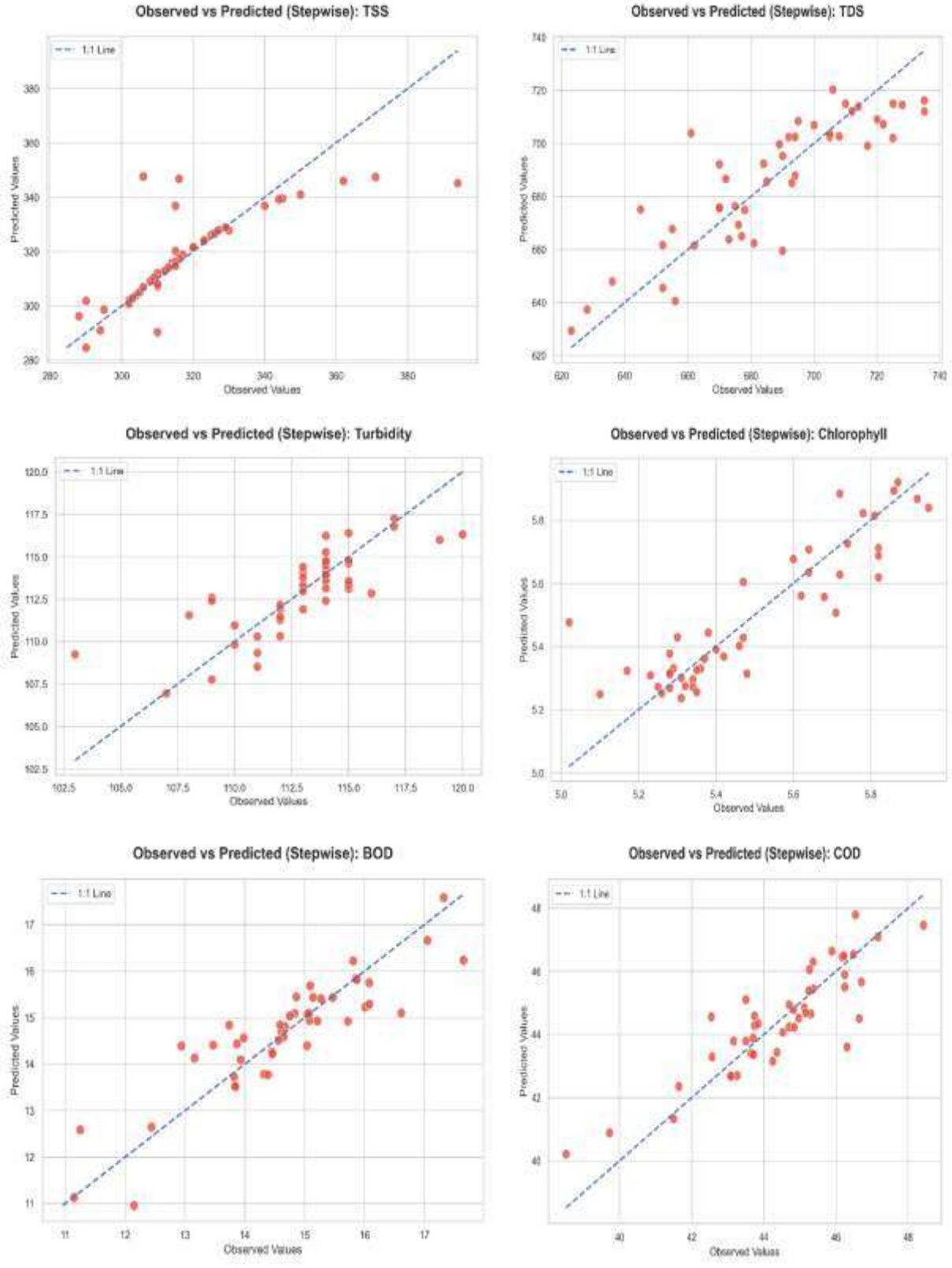


Figure 3. Scatter Plot (Observed vs Predicted values) using a stepwise regression model.

As shown in Table 3, SVR cross-validation (CV) R^2 values were 0.4607 for TSS, 0.7213 for TDS, 0.5456 for turbidity, 0.6871 for chlorophyll-a, 0.7115 for BOD, and 0.7724 for COD. The fit-to-CV R^2 differences were most pronounced for TSS, chlorophyll-a, and BOD, indicating lower performance on cross-validation data and emphasizing the importance of assessing model generalization. Because CV statistics were reported only for SVR, direct cross-validated comparison among MLR, SWR, and SVR is not possible. Overall, SVR showed strong model-fit performance and relatively consistent cross-validated performance, particularly for COD, which achieved a model fit R^2 of 0.8498 and CV R^2 of 0.7724. Thus, model performance was parameter-dependent, with SWR improving the model fit over MLR for several parameters and SVR providing the highest model-fit R^2 for five of the six parameters. These results demonstrate the potential of integrating IRS LISS-III spectral variables with statistical and machine-learning approaches for spatially distributed water-quality assessment, while highlighting the need to consider both model-fit and validation statistics.

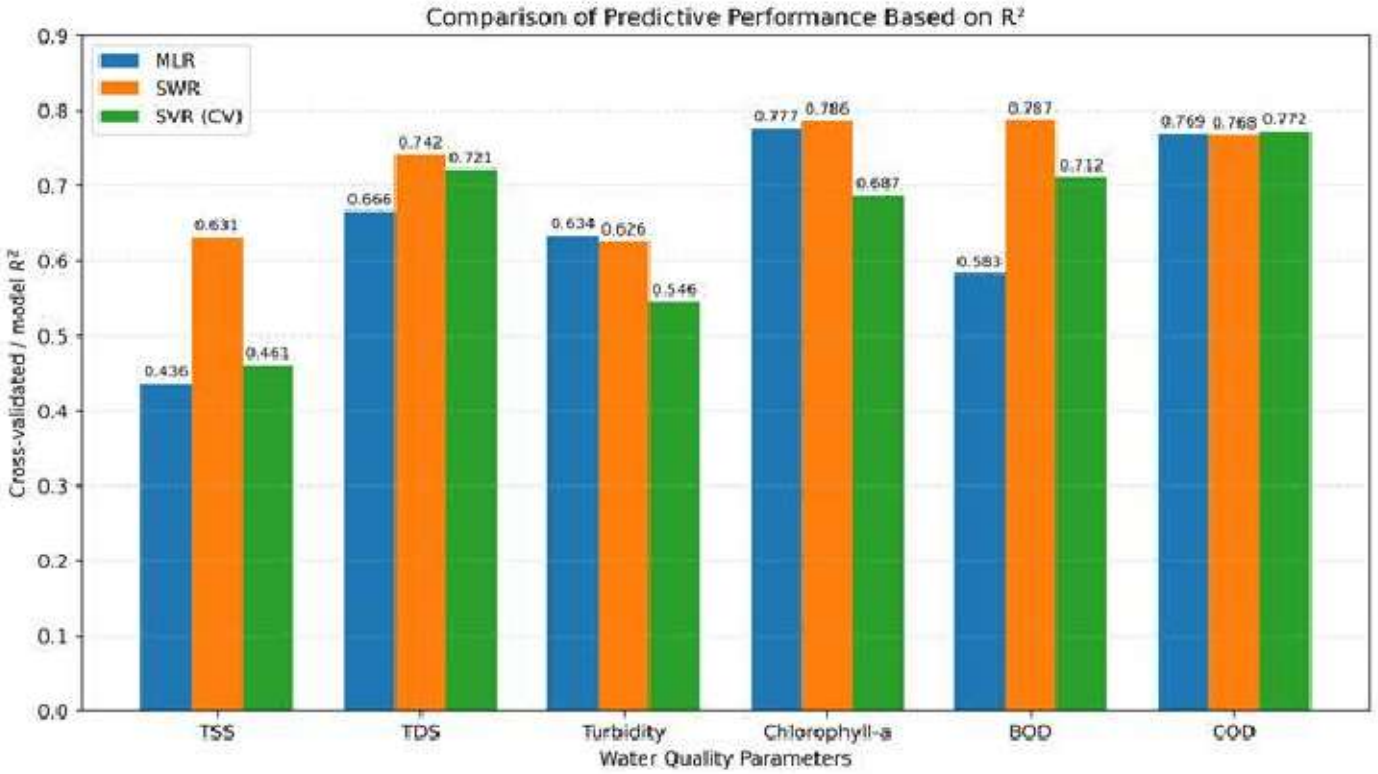


Figure 5. Comparison of MLR, SWR, and cross-validated SVR R^2values for the six investigated water-quality parameters.

4. Conclusions

This study evaluated Multiple Linear Regression (MLR), Stepwise Regression (SWR), and nonlinear Support Vector Regression (SVR) with an RBF kernel for estimating TSS, TDS, turbidity, chlorophyll-a, BOD, and COD in the Yamuna River at Mathura using IRS LISS-III multispectral data. The results demonstrate parameter-dependent model performance, with no single modelling approach consistently outperforming the others. SWR improved model-fit R^2 for TSS, TDS, chlorophyll-a, and BOD, while MLR performed best for turbidity. SVR achieved the highest model-fit R^2 for COD, with a lower cross-validated R^2, highlighting the importance of evaluating model generalization alongside model fit. The results indicate that the relationships between LISS-III spectral variables and

water-quality parameters are parameter-dependent, with both linear and nonlinear approaches providing useful predictive capabilities. SWR demonstrated particular effectiveness by selecting a reduced set of informative spectral predictors, while SVR showed greater potential for modelling the nonlinear relationship associated with COD. Overall, the findings demonstrate that IRS LISS-III imagery combined with regression and machine-learning techniques can provide a practical and spatially distributed approach for river-water-quality assessment. However, the differences between model-fit and cross-validation performance highlight the importance of independent validation and careful assessment of model generalization. Future studies should incorporate larger multi-seasonal datasets and additional environmental and hydrological variables, such as water temperature, river discharge, and flow conditions, to improve model robustness and spatial transferability.

Acknowledgments

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Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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River Revival: Illusion or Reality

Pratik Ranjan Chaurasia

Water Resources and Management expert, water conservation and protection activist, writer & peer reviewer, Ex-HOD & Chief Engineer, Department of Minor Irrigation, Government of UP, Ex-Director, Groundwater Department, Government of UP

Recently, the Kukrail River, a tributary of the River Gomti in Lucknow, was in the news as the government started to demolish houses and shopping complexes in a locality named Akbarnagar, which was built and developed over the last 40 years in its floodplains. Though the Supreme Court of India permitted the demolition of all buildings and encroachments along its course in Lucknow, the first phase started in Akbarnagar, and after completion, it was stopped. Now, a garden has been developed in some part of the recovered area. When the second phase will start in other localities like Kalyanpur, etc., along its course is unknown. The government plans to revive this river, and a demolition exercise was part of it.

The Kukrail River, taking its last breath at present was once an ever-flowing river. People used to bathe in this river. It was a legend that dog bites can be cured by bathing in it. That is why it got its name "Kukrail". It originates from Asti village in Bakshi ka Talab tehsil of district Lucknow and travels about 36 km before merging into the River Gomti upstream of Gomti Barrage in Lucknow. Previously, it used to merge downstream of the Gomti Barrage somewhere near the present Taj Hotel after travelling about 4 km more. But in the name of development, its course was changed to merge near Paper Mill Colony upstream of Gomti Barrage. Over the years its catchment area has witnessed significant changes in land-use patterns, resulting in a sharp increase in sewerage flow from newly developed colonies and human habitats. Apart from this, its floodplains witnessed severe encroachments along residential areas. Lastly, the government pledged to revive it, the first phase of which started by demolishing encroachments in Akbarnagar.

Before discussing its revival plan, some discussion is needed to understand the water dynamics of a river. Any river system is live until it has flowing water. The source of water for any river is precipitation either in the form of rainfall or snow. After the rainy season, most of the rivers originating from the Himalayas are fed by snow and groundwater both of which contribution of snow is only about 15 %. The rivers originating from other mountain ranges or plains are fed by groundwater only after rains. In India, the rainy season is only about three months and after the rainy season, most of the rivers are mainly fed by groundwater. So, groundwater is very crucial for the health of any river system. Groundwater is a part of our hydrological system, and it flows towards the general land slope of the area. It continuously moves through the aquifer system at a very slow velocity and contributes to the river as base flow. After the rainy season, this base flow is the main source of water for a river to remain alive and healthy.

Occurrence of groundwater is an input-output model in which recharge from rainfall and other sources is the input. The output is withdrawal of groundwater for various uses and contribution to rivers in the form of baseflow. If the output is persistently greater than the input for many years, groundwater level starts declining. When groundwater level starts declining, baseflow to the river also reduces, endangering the liveliness of a river. If this situation persists for a longer period, the groundwater levels go so deep that stop contributing to rivers in the form of baseflow, making the rivers die after the rainy season.

Every year the groundwater is replenished by rain. Rainwater passes through soil layers and recharges groundwater. So, the less rain, the less groundwater recharge, and vice-versa. Apart from this, every year rainwater refills natural depressions

and manmade water storage structures like ponds, lakes, tanks, dams, check dams, etc. This stored water replenishes groundwater slowly and slowly, round the year after the rainy season. The basic principle involved here is to increase the contact area and contact time of water with soil to enhance recharge. In-situ practices like farm bunding, marginal bunding, contour bunding, contour trenching, etc., also enhance groundwater recharge. Natural vegetation and forests also retain water and enhance groundwater recharge.

So, increasing the base flow of any river for its sustainable revival should be the highest priority among different measures.

The newspaper reported that the Kukrail River's revival plan envisages removing/demolishing encroachments, renovating five or six lakes/ponds in its catchment, developing green cover along its course, and diversion of water from Sharda canal to keep it flowing. Thus, the plan itself indicates that the measures proposed are insufficient to increase the base flow to a level that will make Kukrail ever-flowing, because diversion of water from the Sharada Canal is proposed. The right approach would have been to adopt comprehensive water management measures in its whole catchment after a detailed survey and choosing the best management options. As stated earlier, the Kukrail River catchment witnessed a significant change in land use patterns in the last few decades. A significant portion of it had been urbanised in the last 40 years, increasing the sewerage flow and groundwater withdrawal and decreasing groundwater recharge. So, to increase the base flow, the ideal solution is to decrease groundwater withdrawals and increase groundwater recharge. The measures to be adopted for these will depend on the present catchment characteristics of Kukrail's catchment, for which a micro-level survey is required. These measures may include:-

1. Launch of a community groundwater recharge scheme in urban areas in which water collected from the roofs of houses and surface pavements is conveyed to a common recharge facility.
2. Treat sewage and wastewater from every drain discharging into the Kukrail River and reuse the treated water for secondary use. After tertiary treatment, it can even be used for drinking water.
3. Implement large-scale water conservation and rainwater storage measures at the farm level in its catchment.
4. Redevelopment of all ponds and lakes in its catchment.
5. Reducing irrigation water use in its catchment by adopting efficient technologies and systems and changing cropping patterns.
6. Increasing forest cover in its catchment by up to 20% in the first phase and up to 33% later. It can be done by declaring a forest area in every village.
7. Reducing groundwater withdrawals in urban areas by providing water from alternative sources like surface water, treated water, etc.
8. Removing/demolishing encroachments and dredging the river.
9. Measuring the municipal water supply of every household and initiating differential water consumption rates.

The proposed revival plan for the Kukkrail River includes only a few of the measures listed above. Furthermore, water diversion from the Sharda Canal is proposed to ensure continuous flow throughout the year. In a true sense, it is not a river revival but a cosmetic exercise, just to demonstrate that the river is flowing.

Hydrogen Based Steel Making - The Future

Narendra Kumar Verma
AM-1921277

Abstract

The energy demand for the automobile, hydrogen-based steel making and industrial sectors is increasing drastically worldwide. Conventional sources will no longer fulfil the growing energy demand and environmental pollution is a serious concern. Thus, an alternative fuel for vehicles, steel plants and other uses is highly required.

The focus is shifted on renewable energy sources like hydrogen, which is abundant in nature. This review examines the continuous progress of hydrogen regarding production and storage techniques in India. Current studies and on-going projects the world over are summarized projecting the status of production, storage, and application of hydrogen. Challenges like infrastructure development, distribution, policies, cost, and public acceptance as obstacles for the commercialization of hydrogen?powered vehicles and hydrogen-based steel making plants in the Indian market are analysed.

This review also focuses on the reduction of iron oxides using hydrogen as a reducing agent. Due to increasing requirements from environmental issues, a change of process concepts in the iron and steel industry is necessary within the next few years. Currently, crude steel production is mainly based on fossil fuels, and emitting of the climate?relevant gas carbon dioxide is integral. One opportunity to avoid or reduce greenhouse gas emissions is substituting hydrogen for carbon as an energy source and reducing agent. Hydrogen, produced via renewable energies, allows carbon?free reduction and avoids forming harmful greenhouse gases during the reduction process. Emphasis has been laid on hydrogen based steel making, advantages & disadvantages and further course of action required to boost up this technology to have a clean & green environment.

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1.Hydrogen - its position in periodic Table:

Hydrogen is the first element of the periodic table as its atomic number is one, which means it has only one electron in its atom and thus only one electron is present in its outermost shell. The placement of elements in the periodic table is based on their electronic configuration.

1.1Dual Nature of Hydrogen:

Hydrogen has the simplest electronic configuration of'one' and hence,

Either loses one electron behaving like electro positive alkali metals[Group 1(IA)]

e.g H- 1e- ? H1+

Gains one electron behaving like electronegative halogens [group 17(VIIA)]

e.g H+1e- ? H1-

Table 1: showing availability of hydrogen

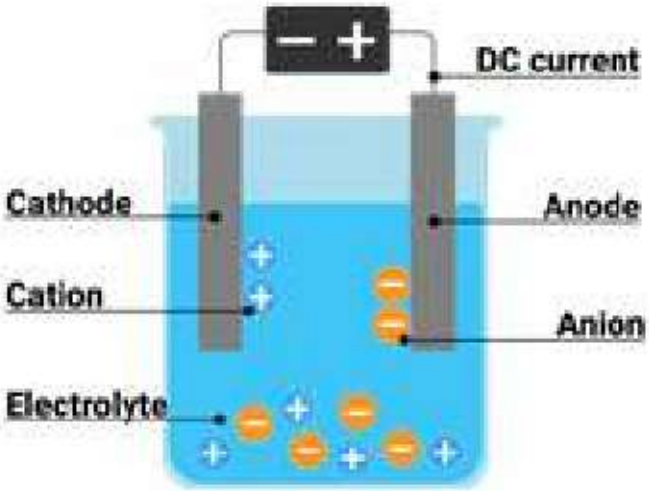
Hydrogen in the free state	Availability in percentage
Earth's crust	0.98
Earth's atmosphere	0.01
Volcanic gases	0.025
Atmosphere- around the sun & the stars	1.1

When hydrogen loses electron, the size of its nucleus decreases and becomes almost 1.5 × 10-3pm, which is very small as compared to the atomic sizes of normal metals and hence hydrogen ion does not exist freely in nature. This unique behaviour of this atom is the reason for it being placed separately in the periodic table.

1.2 Electrolysis:

Electrolysis is defined as a process of decomposing ionic compounds into their elements by passing a direct electric current through the compound in a fluid form. The cations are reduced at cathode and anions are oxidized at the anode.

Electrolysis is usually done in a vessel named 'electrolytic cell' containing two electrodes (cathode and anode) connected to a direct current source and an electrolyte which is an ionic compound undergoing decomposition, in either molten form or in a dissolves state in a suitable solvent.



1.3 Electrolytic Process

In the process of electrolysis, there is an interchange of ions and atoms due to the addition or removal of electrons from the external circuit. Basically, on passing current, cations move to the cathode, take electrons from the cathode (given by the supply source-battery), and is discharged into the neutral atom. The neutral atom, if solid, is deposited on the cathode and if gas, move upwards. This is a reduction process and the cation is reduced at the cathode.

1.4Factors Affecting the Efficiency of Electrolysis:

The efficiency of electrolysis or the electron transfer depends on many factors such as;

i) The number of available cations and anions in the solution.

ii) Mobility rate of the ions to reach the electrode.

iii) Activation energy needed for the electron transfer from the electrode to the electrolyte ions.

iv) The effect of the gas bubble surrounding the electrode on the further electro- transfer etc.

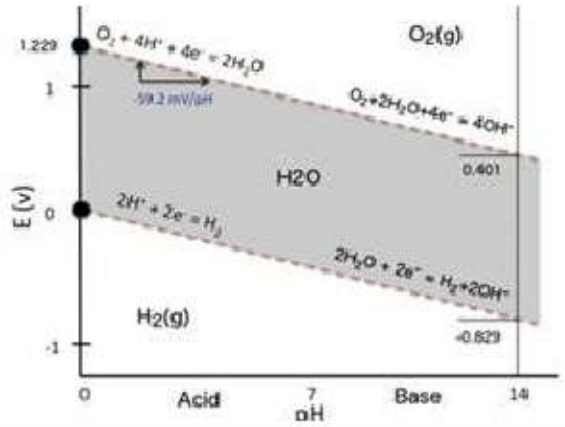
Crossing over of several interfaces (solute- liquid, solute-solid, solid-gas) results in the increase of energy requirements for the electrolysis (overvoltage) than predicted by the thermos-dynamical Gibbs energy.

Because of the low concentration of ions and the interfaces to be crossed electrons an extra voltage (Over voltage) at each electrode is needed to about 0.6V.

In practice, continuous electrolysis of pure water is possible only at an external voltage of 2.4V.

One of the methods is to increase the conductivity by increasing the number of ions available by adding acid, base, or non-reacting salts.

1.4.1 Pourbaix diagram gives the equilibrium regions of water, hydrogen and oxygen at various electrode potentials.



Water Electrolysis in the Presence of Salts

The selection of salts with non-competing ions becomes necessary.

Salts containing lesser standard electrode potentials than hydrogen and hydroxide ions are suitable for the electrolysis of water.

Non-soluble, solid polymeric ionic compounds (Nafion), has been found to help electrolysis of water in less than 1.5V.

1.5 Electrolysis of Water Using Electro Catalysts

Electro-catalysts are substances that accelerate electrochemical reactions without being consumed in the reaction.

The activity of the inert electrode like platinum can be, enhanced by modification of the surface by

i) Increasing the surface area with nanoparticles or alloying with catalytic d-block elements and changing the electronic state coated with other catalytic substance to enhance the electrolysis.

ii) Coating the electrode surface with catalytically active substances, like enzymes.

The electrolytic cell used for the electrolysis of water is the electrolyser. Depending on the transporter of the electrolyte, Electrolyser can be divided into three types;

(i) Polymer Electrolyte Membrane (PEM) Electrolyser

(ii) Alkaline Electrolysers

(iii) Solid Oxide Electrolyser

Key Facts on Global Temperature Rise

(i)Total Increase: The planet is roughly 1.2°C to 1.3°C (2.1°F to 2.4°F) warmer than pre-industrial levels.

(ii) Main Cause: Human activities like burning fossil fuels release greenhouse gases that trap heat in the atmosphere.

(iii) Recent Records: The warmest years in recorded history have all occurred recently, driven by continuous carbon emissions.

1.6 Effect of GHGs (Greenhouse gas):

According to National aeronautics & space Administration, the average global temperature on earth has enhanced by approximately 0.8°C(1.4°F). Accelerating Rate of warming since the early 1980s happens more than twice as fast as the previous century, rising over 0.18°C (0.32°F) per decade which has caused an enormous impact on the environment as a whole. Increase in the concentration of greenhouse gases in the atmosphere is the important factor for rise in temperature.

Methane produced is collected and burnt to produce electricity or heat. Methane is a by-product of the anaerobic respiration of bacteria.

In view of all the above facts, it is more important to reduce the pollution caused by CO2 and CO which is also possible by reducing/avoiding the use of fossil fuel e.g coal etc in steel plants, temperature as it is absorbing heat.

Open burning and disposal of waste on land is an inherent practice. Solid waste plays a vital role in Carbon footprint of the city. Inadequate management of solid waste tends to formation of GHGs like CH? and CO2 which escapes in the atmosphere.

Methane has a global warming potential of 25 times over CO2 for 100 years' time horizon so it is more important to keep the track of these emissions.

The emissions of GHGs i.e. CO2 & CH4 due to decomposition of organic waste is calculated on the basis of following equations;

CO2 emissions (gm/day) =W(Kg/day) x 0.013gm/kg.

CH4 emissions(gm/day) =W(kg/day) x 0.165gm/kg

Where, W is the total organic waste generated.

Co2 emission has increased from 562kg/day to 745 kg/day and CH4 emission has increased from 44.3 kg/day to 58.7 kg/day in 2018-2019 due to increased quantity of MSW. Total CO2 & CH4 emissions accounts to Carbon footprints of 1978.1 kg/day in terms of equivalent of CO2.

(iv)The problem is again compounded by the issues associated with rapid urbanization. (v) A major environmental concern is release of unhealthy gases due to decomposition of garbage.

Global carbon dioxide (CO2) emissions and greenhouse gas levels in 2026 are showing mixed regional trends, with average atmospheric concentrations reaching 432.3 parts-per-million (ppm) by May 2026.

1.7 Global and Atmospheric Status:

Atmospheric Levels: CO2 concentrations rose past 432 ppm in mid-2026, sitting well above pre-industrial levels of 280 ppm.

Global Pace: Global emissions experienced a marginal increase in the first half of 2026, following a slow 0.4% growth rate recorded globally through the end of 2025.

India: Emissions growth is decelerating to roughly 1% to 1.5% in 2026 as non-fossil and renewable energy capacity continues to expand.

United States: Energy-related CO2 emissions are projected by the EIA to decrease by 1.8% in 2026, driven largely by lower coal consumption.

Technologies can be developed to increase the proportion of hydrogen fed into the shaft furnace up to 100%. Where renewable energy is used to produce 'green hydrogen' for use in this way, it directly displaces CO2. However, where insufficient levels of renewable energy are available, industry will need to use 'blue' hydrogen, derived directly from fossil fuels or industrial gases and combined with carbon capture and storage (CCS) to ensure carbon neutrality.

It is apparently evident that we should go ahead for **Hydrogen based Steel making.**

Hydrogen Based Steel making

There are major differences between the steel making process of today and the HYBRIT-process of tomorrow.

1.8 Hydrogen-based metallurgical process

In the HYBRIT- concept, specially developed iron ore pellets are reduced by hydrogen gas in a so-called direct reduction process.

Reduction occurs in a solid state at a lower temperature than in the blast furnace process and produces an intermediate product, sponge iron or direct reduced iron (DRI), with water vapour emitted from the top of the furnace.

Water vapour can be condensed and scrubbed before reuse in the plant. Hydrogen gas is produced by electrolyzing water using renewable electricity (e.g. from hydro or wind power plants), with oxygen gas as a by-product. Hydrogen storage of sufficient capacity is used to balance between the DRI-process and the electricity grid allowing a significant amount of intermittent power generation by e.g. wind or solar power plants to be connected to it. The sponge iron can be used as hot DRI and melted immediately in an electric arc furnace (EAF) together with recycled scrap. The DRI can also be processed into hot briquetted iron (HBI), which can be stored and shipped to another site. The crude steel from the EAF goes through a similar process as in the blast furnace-based route, i.e. alloying and refining before being cast into slabs, ready for rolling and further heat treatment before shipping to customers.

1.9 HYBRIT faces two major challenges

oTo develop an effective process to use 100% hydrogen on an industrial scale.

oTo produce hydrogen in an energy-efficient way so that it is economically justifiable/commercially viable.

HYBRIT - Towards fossil-free steel

(i) HYBRIT aims to replace coking coal, traditionally needed for ore-based steel making, with hydrogen. The result will be the world's first fossil-free steel-making technology, with virtually no carbon footprint.

(ii) The steel industry is one of the highest CO2-emitting industries, accounting for 7% of CO2

emissions globally.

(iii) A growing global population and an expanding urbanization are expected to trigger a rise in global steel demand by 2050. The carbon footprint in the steel industry is thus a challenge for the entire world.

The conclusion is that fossil-free steel, given today's price of electricity, coal and CO2 emissions, would be 20-30% more expensive. With declining prices in electricity from fossil-free sources and increasing costs for CO2 emissions, the pre-feasibility study concludes that in forthcoming future fossil-free steel will definitely be able to compete in the market with traditional steel.

The owners of giant companies have given the green signal for the next phase of HYBRIT and, during summer 2018, work started on the construction of a globally-unique pilot plant for fossil-free steel production at the SSAB site in Lulea, Sweden. A joint-venture, Hybrit Development owned equally by the three partners SSAB, LKAB and Vattenfall was formed during 2017 to carry out the long-term development work.

The pilot phase for pre-feasibility study and a four-year-long research project is planned to last until 2024, after which it will move to the demonstration phase in 2025-2035 in coordination with Swedish Energy Agency.

Already before a solution for fossil-free steel making is in place, SSAB aims to cut its carbon dioxide emissions in Sweden by 25% by as early as 2027, through conversion of the blast furnace in Oxelosund, Sweden, to an electric arc furnace.

The study says reducing costs of electrolysers and renewable generation can push down the cost of green hydrogen generated from renewables to between $0.80 and $1.60/kg by mid-century - its current level is at least $2.50/kg - making it competitive with gas in many markets. The reduction of cost may open the way for hydrogen to meet 24% of the world's energy needs by 2050, and cut up to a third of global emissions from fossil fuels and industry, but if following conditions are fulfilled,

- Infrastructure spending. The study puts an $11trn bill on achieving the production,

storage and transport facilities needed for a hydrogen revolution.

- A carbon price. As per latest study "Hydrogen can enable a switch away from fossil fuels in many of these applications at surprisingly low carbon prices. For example, at $1/kg, a carbon price of $50/t CO2 would be enough to switch to renewable hydrogen in steel making,"

- Storage. "Storing hydrogen in large quantities will be one of the most significant challenges for a future hydrogen economy. Low cost, large-scale options like salt caverns are geographically limited, and the cost of using alternative liquid storage technologies is often greater than the cost of producing hydrogen in the first place."

India's steel industry has relied almost

exclusively on coking coal for the 'reduction' of iron ore so a switch to hydrogen won't be easy.

A new report on India's steel industry warns that the sector's CO2 emissions could quadruple by 2050 to 837 million tonnes. Steel consumption is a key indicator of economic growth, but so far the sector has relied almost exclusively on coking coal for the "reduction" of iron ore. The process releases vast quantities of CO2. Economic growth is good, but in times like these there isn't any room for increased emissions.

1.10 However, the report was released by The Energy and Resources Institute (TERI) and offered a number of solutions. The combination of energy and resource efficiency alone would reduce emissions by 45%, it says, and it recommends imposing penalties on the sector by 2030 to clean up its act.

However, unless the process of manufacturing steel itself is carbon-free, the sector will continue

polluting. Adopting low-carbon technologies and

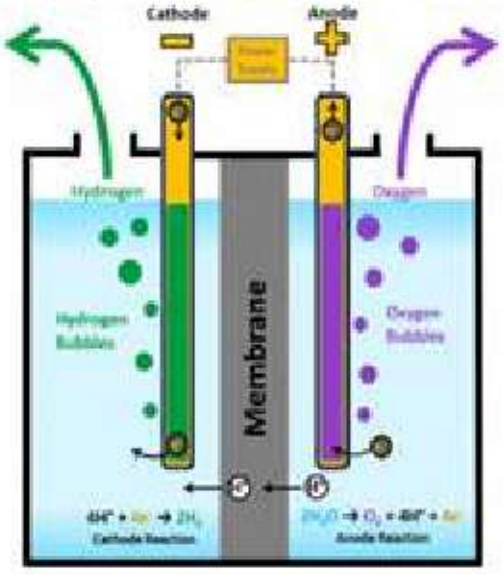
setting standards for low-carbon steel are welcome, but today we're at a point where the country's major industries need to fully de-carbonise.

S.No	Type of furnace	Units /No of plants.
1	Blast Furnace (BF)	60
2	Basic Oxygen Furnace (BOF)	18 units
3	Electric Arc Furnace (EAF)	50
4	Electric Induction Furnace (EIF)	999
5	Direct Reduced Iron	312 units

Here's where the yet another solution of switching to Hydrogen comes in. Using hydrogen instead of coal eliminates the release of CO2, as the process merely produces water as the by-product

1.11 The question is, where will India source hydrogen from?

Splitting water through electrolysis is one route. Powering the process through renewables alone does make for "green steel". But given India's plans to become the world's fastest energy consumer by 2030 - which would involve greater oil and gas consumption - the most likely candidate would be natural gas (which is largely methane).



The country is already expanding its gas grid far and wide, so the opportunity to lower industrial emissions would be a healthy addition to the fuel's reputation. Several new oil fields are being opened as well, making the case for gas even stronger.

Yet in India, the inertia of investing in fossil fuels could prove much harder to shake off, and renewables just aren't coming online fast enough. So if our version of "green steel" is ultimately fuelled by natural gas, it would risk turning a much-touted transition into more of an eyewash. Unless of course, the industry itself decides to innovate and opt for renewables-powered electrolysis. It's not beyond their capabilities, and even presents an enormous opportunity for self-regulation.

Research and Development of Iron & Steel Sector background in India:

Table2 : The structure of the Indian Iron & Steel Sector

1.12 There are primarily two routes of steel production:

" BF/BOF route also called the Oxygen route

" Electric route comprising of Electric Arc Furnace and Electric Induction Furnace.

As per 2017-18 data, about 54% steel is produced through the Electric Furnace route of which about 28% steel is produced through the Electric Induction Furnace (EIF) route and 26% from Electric Arc Furnace (EAF) route.

The Indian steel industry comprises of large producers (= > 1 MTPA) which contribute around 63% of the total production as against smaller producers (< 1 MTPA) which contribute around 37% of the total production in the country.

Government has taken various steps for introduction of National Steel Policy 2017 and allowing 100 per cent Foreign Direct Investment (FDI) in the steel sector under the automatic route. The Government's National Steel Policy 2017 aims to increase the per capita steel **consumption to 160 kgs by 2030-31.In 2019, the Government**

introduced Steel Scrap Recycling Policy with an aim to reduce import.

Technological profile of the Indian Steel Industry has undergone a major & substantial change. With setting up of new large modern steel plants based on state of-the-art technologies and modernization/ expansion of existing steel plants, there is a upward trend in efficiency parameters of operation viz. productivity, energy efficiency, environment friendliness etc.

The Indian Iron & Steel industry needs to pursue research for development & adoption of such technologies which are relevant to natural resource endowment of the country,

(i) which minimize damage to the environment,

(ii) optimize resource utilization,

(iii) Facilitate achievement of global standards of productivity &

(iv) Efficiency and development of front end & strategic steel-based materials.

3 The R&D efforts by the Indian steel companies are basically concentrated on,

(i) Improving internal processes related to saving costs and

(ii) Improving efficiency.

(iii) Process improvements such as beneficiation and palettization of iron ore have received good response in the industry.

Dedicated technologies for harnessing waste heat are drawing the attention of the steel companies to improve productivity and energy efficiency in the Indian steel industries.

1.13 Status of R&D in Iron & Steel sector:

Actually long term technological input with the strenuous R&D efforts are the need of the hour for development of new high performance and value added steel to cover up the gap.

The actual investment on R&D by the large steel companies in India varies from company to company in the range of 0.07-0.58% of their sales turnover.

India needs large outlay of funds earmarked for R&D and should have tie ups with external labs. and academic institutions as compared to R&D scenario in Steel companies across the world. India is also putting their best efforts to achieve R& D investments up to 1% of their sales turn over.

In India also, some of the R&D projects are also being directed towards reduction of energy consumption and Green House Gas Emission (GHG).

1.14 Government Policy framework on R&D:

The National Steel Policy 2017 has set ambitious targets with regard to make Indian Steel globally competitive, to reduce carbon footprint, meeting domestic demand for high performance steel, increasing steel consumption etc. and has identified high end research as one of the focus areas.

Ministry of Steels Initiatives To promote R&D in steel sector:

1. R&D Govt. Budgetary Support:

Ministry of Steel has introduced an R&D scheme viz. "Promotion of R&D in Iron & Steel Sector", for providing financial assistance for the R&D projects identified for funding by Ministry of Steel. The budget allocated for the scheme is around Rs 15 crore per year.

2. A Project Approval and Monitoring Committee (PAMC) under the Chairmanship of Additional Secretary & Financial Adviser and members comprising Joint Secretary, Ministry of Steel, Director IIT Kharagpur, Director IMMT, Director NML and other members, is the decision making body for approval of R&D projects, monitoring of on-going projects and for overall direction.

Process has also been developed in laboratory scale for production of low Phosphorus steel in laboratory scale Induction Furnace, for which industrial trials have also been carried out. The list of the R&D projects funded from Ministry of Steel's budget is given at Annexure1.

As per final annual report 2025-2026 of Ministry of Steel,Govt.of India, it is clarified that;

R&D with financial assistance from Ministry of Steel:

Ministry of Steel is operating a R&D scheme viz. "Promotion of R&D in Iron and Steel Sector", for providing financial assistance for pursuing R&D to address the technological issues faced by the sector and also indigenous development of processes/ technologies.

R&D Project proposals are invited from reputed Academic Institutions/ Research Laboratories and Indian Steel Companies for pursuing R&D projects for the benefit of the Iron and Steel Sector in the country.

In December 2025, the R&D scheme was revised to enhance effectiveness and ensure alignment with strategic objectives. The revised framework incorporates measures to broaden participation from MSMEs and start-ups, and has been extended until FY 2030-31.

R&D thrust areas The thrust areas for providing financial assistance under the R&D Scheme, are development of new alternate processes & technologies to address the burning issues faced by the Iron & Steel Sector such as climate change (green steel production, H2 based steel production, CCUS etc.), waste utilization, resource efficiency, etc. Moving forward, The Ministry of Steel shall regularly organize stakeholder events, including MSMEs, to identify and review thrust areas & larger goals of the R&D scheme

S. No.	Year	Government Funding (in Rs. crore)
1	2021-22	4.81
2	2022-23	4.49
3	2023-24	2.94
4	2024-25	4.99
5	2025-26 (till Dec,2025)	6.0
	Total	**23.23**

The quantum of funding of the R&D projects from Ministry of Steel during the last 5 years and the current FY is given below:

For FY 2025-26, a budget allocation of `6 crore was made for the scheme, against which an expenditure of `6 crore has been incurred up to December 2025. The budget allocation for FY 2026-27 has also been set at `6 crore.

Total Projects Supported: The Ministry historically tracked over 83 major R&D projects backed by an aggregate project cost exceeding ?696 crore.

SDF Share: Out of those projects, the total direct SDF financial assistance accounted for approximately ?389.63 crore.

222MTPA: India's approximate crude steelmaking capacity reached by June 2026.

300 MTPA: The target domestic steel production capacity set for 2030-31 under the National Steel Policy.

1.15 Status of Hydrogen based steel making in the world:

ArcelorMittal is developing a new, innovation project in Germany aimed at the first industrial scale production and use of Direct Reduced Iron (DRI) made with 100% hydrogen as the reductant, with an annual production of 100,000 tonnes of steel.

The process of reducing iron ore with hydrogen will first be tested using grey hydrogen generated from gas separation. It is aimed to achieve the separation of H2 with a purity of more than 97% from the waste gas of the existing plant, using a process known as 'pressure swing absorption'.

Hydrogen gas reduction

1.15.1.In September 2019, M/s ArcelorMittal announced the signing of a Framework Collaboration Agreement (FCA) with Midrex Technologies to design the Hamburg demonstration plant and work on several related R&D and innovation projects.This project, combined with ongoing projects on the use of non-fossil carbon and on carbon capture and use, is key to becoming carbon neutral in Europe by 2050.

The existing Midrex plant in Hamburg is also the

plant with the lowest CO2-emissions for high quality steel production in Europe.

"With the new, hydrogen based DRI plant, it is being planned as part of improving environmental aspects to be carbon neutral by 2050."

1.15.2. ThyssenKrupp Steel Group:

As a Green Initiative ThyssenKrupp Steel Europe reported On November 11, 2019, that the Duisburg-based steel producer had launched a series of tests into the use of hydrogen gas in a working blast furnace.

Major operating conditions for standard case	
Inner volume	4359 m3
Productivity	10400 t/d
RAR (CR)	498 kg/thm
Blast volume	7897 Nm3/min
Blast temp.	1200°C
O2 enrichment	2.50%

RAR (Reducing Agent Ratio, Fuel Ratio)/CR-Coke Ratio

These were path-breaking tests aimed at significantly reducing the Co2 emissions arising from steel-making. This is the first time that a trial has been reported in an operating blast furnace. It is, therefore, a very significant event towards a revolutionary development in making the iron and steel industry environment-friendly.

1.15.3 Hiroshi Nogami undertook studies that performed numerical simulation of blast furnace operation with hydrogen injection through the tuyere. The simulations were carried out under the

- Conditions of constant bosh gas flow rate,
- adiabatic flame temperature (regardless of hydrogen injection ratio by adjusting blast flow rate and oxygen addition) and
- hot metal temperature.

In the study Hiroshi Nogami used a standard all-coke condition as in table 1

The maximum hydrogen content in the blast gas was about 43 mol-%. Simulation results under intensive hydrogen injection operation showed:

(i) The temperature level in the stack part is decreased and it leads the lowering of the top gas temperature and delay in reduction reaction in the stack part.

(ii) The coke rate remarkably decreases with injection while the converted reducing agent rate shows small change.

(iii) Increase in the hydrogen content in the reducing gas decreases the pressure drop in the furnace despite the decrease in higher permeable coke layer.

(iv) In all steps the hydrogen reduction ratio increases with increase in hydrogen injection. For reduction of Fe2O3, most part of Fe2O3 is reduced by the hydrogen even when the hydrogen injection rate is small. The kinetic parameters, namely, the effective diffusivity and chemical reaction rate kept constant, hydrogen reduction for this step is higher by about two orders compared to CO reduction(figure 1)

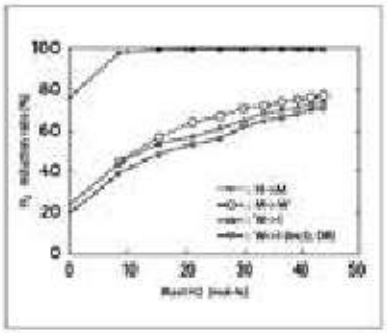


Figure 1 shows the ratio of hydrogen reduction to the total reduction for each step of reduction. (Source: Simulation of blast furnace operation with intensive hydrogen injection by Hiroshi Nogami, Yoshiaki Kashiwaya and Daisuke Yamada)

The hydrogen reduction of iron oxide is an endothermic reaction Therefore, hydrogen iron-making will possibly require more energy to compensate for these endothermic reaction heats.

The findings of Hiroshi Nogami suggest that the potential of hydrogen as a reducing agent in the blast furnace is promising without a doubt. However, the optimum extent of its replacement of carbon needs to be understood through dedicated trial and experience.

1.16 'Green' BF

Evidently, the focus on reduction of CO2 emissions in the iron and steel industry should be through the blast furnace route.

In the Indian scenario, the electric furnace route is dominant, helped by the widespread existence of induction furnaces. Details of India's crude steel production.(Source www.worldsteel.org)

Total Production of Crude Steel in thousand Tonnes (2025)

World	1 850 279
China	960 810
India	165 604
United States	81 937
Japan	80 671
Russia	67 901

As India marches towards the target of 300 MnT per annum of steel production, hot metal production through blast furnaces and coal-based RI production will increase .This will increase CO2 emission from the industry significantly. Development of green processes is thus the need of the day.

Enhancement of energy efficiency: Improvements in energy efficiency have led to reductions of about 50% in energy required to produce a tonne of crude steel since 1975 in most of the top steel producing countries.

Use of steel to create a greener low-carbon world

Across a broad range of industries and applications, the development and use of high-performance steels help to reduce greenhouse gas emissions.

o Steel plays an important role in renewable energy technologies (e.g. wind and solar energy). Steel is the world's most recycled material.

1.17 Co2 Breakthrough Programme:

✦ Research is taking place in: - the EU (ultra-low CO2 steelmaking, or ULCOS) - the US (the American Iron and Steel Institute) - Canada (the Canadian Steel Producers Association) - South America (ArcelorMittal Brazil) - Japan (COURSE50) - Korea (POSCO) - China (Baosteel) and Taipei (China Steel) and - Australia (Bluescope/One Steel and HI smelt)

Five key directions:

- ✦ Coal
- ✦ Hydrogen
- ✦ Electrons
- ✦ Biomass
- ✦ Carbon capture and storage (CCS)

1.17.1 ULCOS (EU)

✦ The four breakthrough technologies identified are:

1) Top Gas Recycling Blast Furnace with CO2 Capture and Storage (CCS)
2) HIsarna with CCS - smelting reduction
3) ULCORED with CCS - new DR concept 4) Electrolysis

✦ ULCOS is also working on… - Biomass and steelmaking - Hydrogen based steelmaking

1.17.2 AISI (US) o Involving: - PPP model between AISI and the US Department of Energy's (Doe), Office of Industrial Technology. Two projects represent significant steps:

- ✦ Suspension Hydrogen Reduction of Iron Oxide Concentrate
- ✦ Molten Oxide Electrolysis (MOE) o In the nearer term, AISI members are also developing… - the Paired Straight Hearth Furnace, a coal based DRI and molten metal process for long range replacement of blast furnaces and coke ovens

1.17.3 POSCO (Korea) o Involving: - POSCO, RIST, POSLAB, POSTECH

✦ Three promising routes of CO2 breakthrough solutions have been identified.

(i) Carbon-lean Steelmaking

- Carbon-lean FINEX process
- Pre-reduction & heat recovery of hot sinter

(ii) Carbon Capture & Storage of Steelmaking

- CO2 absorption using ammonia solution
- CO2 sequestration in ocean gas field

(iii) Hydrogen Steelmaking

- Iron ore reduction of FINEX using hydrogen-enriched syngas
- Hydrogen Enriched Blast Furnace Process

1.17.4 COURSE50 (Japan)

- Involving: - 6 steel and engineering companies, the Japan Iron & Steel Federation, and New Energy and Industrial Technology Development Organization
- Research & development goals:

(i) Reduction of CO2 emissions from Blast Furnaces

- Iron ore reduction with other agents (hydrogen)
- Reforming coke oven gas aiming at a

amplifying H2 content by utilizing waste heat

- High-strength and high reactivity coke for reduction with H2

(ii) Capture of CO2 from Blast Furnace gas

- Chemical and physical absorption to capture, separate and recover CO2
- Reduction of energy requirement for capture, separation and recovery using waste heat from steel plants.

1.17.5 Russia: OMK to build complex to make steel in DRI pellet fed electric arc furnace.

London - Russian steel pipe and railway wheel manufacturer OMK will build a pellet to steel production complex, the first in Russia with iron ore feed and steelmaking facilities to be installed on a single site, with a 70% smaller CO2 footprint than that of a traditional basic oxygen furnace.

The complex is likely to be commissioned in 2024 with a 2.5 million mt/year plant producing metallized pellets using Direct Reduced Iron (DRI) technology and an electric arc furnace (EAF) with up to 1.8 million mt/year of steel capacity.

It is expected to achieve a 70% reduction in CO2 emissions compared with blast furnace-based production and has a 99.5% gas cleaning efficiency, with the output to meet current and future EU requirements for steel goods.

Italian engineering company Danieli will supply a DRI unit based on ENERGIRON technology, a system for feeding hot pellets into an EAF, a 180 mt EAF, a ladle furnace, a vacuum degasser, a gas cleaning system and a continuous casting machine.

"The project is of strategic importance for Russia's economy. This is an example of the best green technology available today and a Gas grid must be adapted to transport hydrogen

1.17.6 'World first' as hydrogen used to power commercial steel production.

Trial at a commercial steel mill in Sweden shows that clean-burning H2 can replace the fossil fuels currently used to produce high-temperature heat. Hydrogen has been used to power commercial steel production for the first time, replacing liquefied natural gas (LNG) as the source of high-temperature heat at a pilot project in Sweden.

1.17.8 : Trial conducted by Swedish steel maker Ovako's at its Hofors steel mill, in conjunction with hydrogen producer Linde Gas.

"It is the first time that hydrogen has been used to heat steel in an existing production environment. Hydrogen can be used simply and flexibly, with no impact on steel quality, which would mean a very large reduction in the carbon footprint."

Røkke discusses many of the technological breakthroughs on the horizon that could help the EU reach its climate goals.



Green hydrogen alone can meet world's H2 needs'

1.18 Five important technologies are enumerated as under,

(1) Modular floating wind

(2) Broad-spectrum solar

"Systems which can utilize the largest spectrum of light give much higher efficiency, hence there is really scope in that area."

This could be achieved by using different materials to silicon, such as perovskite, or by adding lenses that concentrate light or by fitting filters that can capture a wider spectrum of light. Significant work is still ongoing on this aspect.

(3) New battery chemistries

(4) Clean hydrogen - blue, then green

Hydrogen is key for the energy transition but will it be green or blue:

Presently, hydrogen has emerged as a key technology of the energy transition, as it is a versatile zero-carbon fuel.

But there are three methods of producing hydrogen without the emissions,

- By using renewable energy to split water molecules into H2 and oxygen inside an electrolyser.
- By capturing and storing the CO2 from steam methane reforming and Coal gasification and,
- A process known as pyrolysis, where natural gas is heated in the absence of oxygen, giving a by-product of solid carbon, rather than CO2.

But electrolysis, carbon capture and storage (CCS) and pyrolysis are still expensive processes that have yet to be proven at a commercial scale.

Green hydrogen 'can beat fossil-fuel H2 on price by 2030'

Due to the higher capital cost of electrolysers, the levelized cost of green hydrogen gets more expensive when the amount of time it is running is reduced.

"Blue hydrogen is cheaper than [H2 derived from electrolysers]. 95% of hydrogen is produced from fossil [fuel] to 100% [from] renewables without having access to the hydrogen from natural gas with CCS. It is very important for not only Europe, but for the rest of the world to decarbonise."

(5) Carbon-negative technologies

The pyrolysis process could also be used to remove carbon dioxide from the atmosphere, not just methane.

1.19. Challenges

(i) A growing global population and an expanding urbanization are expected to trigger a rise in global steel demand by 2050. The carbon footprint in the steel industry is thus a challenge for the entire world.

(ii) Many technical and practical challenges are still ahead, due to lack of hydrogen infrastructure.

(iii) More than 95% of the world's hydrogen is today derived from natural gas and coal, causing nine to 12 tonnes of CO2 emissions for every tonne of H2 produced. Although hydrogen is a clean gas, releasing only water vapour when burned, there is no point replacing the coke, coal or LNG used in steel production with H2 unless that hydrogen is produced from renewable energy (green) or if the CO2 emitted in its production is captured and stored (blue).

Both green and blue hydrogen are currently

expensive to produce, available in limited quantities and would increase the cost of steel production, so companies are reluctant to make the switch, unless the clean H2 was subsidised in some way.

(iv) The biggest challenge today is system cost. But everybody is predicting that the cost curve will come down, just as it has with solar and wind power.

New pathways have been seen to emerge in some of the projects being worked on, including installing 36GW of electrolyser capacity on an artificial island off the Netherlands and injecting hydrogen into high-pressure natural-gas pipelines in Canada.

There are also concerns about conversion efficiency and the losses in the conversion steps required to produce green hydrogen from electricity.

(v) Storage & transportation:

Once low-carbon hydrogen is produced and stored, it needs to be transported.

By turning that electricity into gaseous hydrogen, we can use the existing gas grid to transport it. There are thousands of kilometres of gas pipelines that are already available.

This is a massive opportunity that will significantly reduce costs in the hydrogen industry. Trump administration is likely to spend $64m to cut cost of green hydrogen.

There should be a firm leadership by every country to go ahead.

(vi) However, there are certain constraints in raw material quality, particularly high Alumina in Indian iron ore and high ash in Indian coal, which adversely affect the techno economic performance of the whole industry

(vii). Product development is yet another challenging area being faced by the steel industry in India. While large varieties of value-added steel products are now being produced indigenously, India is dependent on import for several high performance and value-added steel products like electrical steel, automotive grade steel and steels for specialized use in defence, space and nuclear applications.

1.20 . Advantages of steel making with Hydrogen.

(i) Medium-term energy efficiency improvements are expected through technology transfer, or applying best available technology to out-dated steel plants worldwide.

(ii) it has been established that H2 had no adverse effect on the quality of steel, which would mean a very large reduction in the carbon footprint."

(iii) However, our future lies in green hydrogen; an inexhaustible energy carrier that can be produced using renewable electricity and an electrolyser which splits water into oxygen and hydrogen. There are no emissions from this process.

(iv) Once produced through electrolysis, the hydrogen can be stored, transported and processed for a growing range of applications. Green hydrogen is clean, green and everywhere. It's a perfectly green cycle.

(v) Green hydrogen can also be a tool to deal with variability in electricity systems. When excess solar and wind power floods into the grid, it can be converted into hydrogen which can be used elsewhere or even to produce electricity.

(vi) The German government is already exploring opportunities for hydrogen production and the resulting supply chains in West African countries such as Ghana.

(vii) Between 300-800TWh of clean-energy would need to be fed into electrolysers by 2050, say transmission system operator bodies in Europe.

(viii) Hydrogen is seen as a vital fuel for the energy transition as it can be used to generate electricity and heat with zero greenhouse-gas emissions, and can be used for energy storage, as a long-distance transport fuel, as a replacement for natural gas, and as a feedstock for aviation fuel, ammonia fertilisers and other chemicals.

(viii) "Beyond 2030, after reaching economic competitiveness, the cost of renewable hydrogen will further decrease," says the report. Green

hydrogen production will be cheapest in parts of the world with strong winds and plentiful sunshine, it adds.

"Regions such as Chile, Australia and Saudi Arabia have access to renewables from both wind and solar at low LCOE which enables high load factors for hydrogen production through electrolysis. They thus offer optimal potential for producing renewable hydrogen at minimum costs," says the report. "Under these optimal conditions, hydrogen production could become available at costs of about $2.50 per kg by the early 2020s, declining to $1.90 per kg in 2025 and perhaps as low as $1.20 per kg in 2030. This is well below the average for grey hydrogen.

(viii) Blue hydrogen" produced with CCS will be cheaper and easier to scale up than "green hydrogen" derived via electrolysis.

1.21. Disadvantages:

(I). In the classic blast furnace process, around 300 kilograms of coke and 200 kilograms of pulverised coal are required to produce a tonne of pig iron. The use of hydrogen is the key lever for climate-neutral steel production.

(ii) This CO2 is the major contributor from the iron and steel industry towards generation of greenhouse gases in the world. It is estimated that CO2 emission from the iron and steel industry forms about 7-9% of the global Co2 emissions.

(iii) The hydrogen reduction of iron oxide is an endothermic reaction Therefore, hydrogen iron-making will possibly require more energy to compensate for these endothermic reaction heats.

(iv) The Oxygen Blown Converter route accounted for 72% and 71% of the global crude steel production in 2017 and 2018 respectively. The blast furnace is estimated to contribute 70-80% of the total CO2 emissions by the iron and steel industry. It is, therefore, clear that the focus on reduction of CO2 emissions in the iron and steel industry should be through the blast furnace route.

(v) In manufacturing of Hydrogen, electrolysis, carbon capture and storage (CCS) and pyrolysis are still expensive processes that have yet to be proven at a commercial scale.

1.22. Suggestions and recommendations;

(i) According to the World Steel Association, the steel industry generates 7-9% "of direct emissions from the global use of fossil fuel". We must jointly put our concerted efforts all over the world, for a future where emissions are considerably lower than they are existing today.

(ii). Electrification, renewable energy and energy storage will get us part of the way through the energy transition. However, due to rapid deployment of solar and wind, electrification cannot do everything. Factually, it is likely to meet about half of our expected final energy usage.

(iii) To address the constraints of high alumina in Indian iron and high ash in Indian coal, and also to sustain the projected high growth rate, there is an urgent need for concerted R&D and technology intervention in the iron and steel sector.

1.23. Conclusion

It has been well established that the blue and green hydrogen will be the cheapest options for many types of transport by 2030 - outperforming fossil fuels and battery power.

The Hydrogen Council is a group of 81 companies involved in the hydrogen industry, including Shell, BP, Saudi Aramco, Total, Equinor, Siemens, BMW, Audi, Honda, Toyota, Daimler, GM, Hyundai, Kawasaki, EDF and Engie. It describes itself as a "CEO-led organisation that uses its global reach to promote collaboration between governments, industry and investors, and to provide guidance on accelerating the deployment of hydrogen solutions around the world".

One of Europe's leading experts in emerging low-carbon energy technologies has given an exclusive insight into some of the most promising low-carbon technology developments of the coming years.

EU Commission proposes 50-55% emissions cut by 2030 in Green Deal. EERA plays an important role in the EU's goal of net-zero emissions by 2050 as it oversees the European Commission's Strategic Energy Technology Plan, which aims to accelerate the development and deployment of low-carbon technologies to help the bloc meet its goal. The plan largely consists of 17 research "Joint Programmes" that each cover a different part of the low-carbon energy sector, including wind power, PV, energy storage, hydrogen and carbon capture and storage.

Main issue in India is of the utmost importance i.e the R&D intervention to find out techno-economic solutions to use indigenous raw material resources. Another area that requires attention is the product development to develop and produce high performance steel indigenously.

Not only huge R&D investments to develop high performance and value-added steel technologies are needed but efforts are also required for technological collaborations with such companies for acquiring high-end technologies possessed by them. This may be done by importing the high performance and value-added steel along with transfer of Technology (TOT).

Steel industry across the globe have identified climate change as a major challenge for more than two decades and have been proactive in reducing energy consumption and greenhouse gas emissions by aggressive R&D and technology interventions adopting the clean & green technologies in all areas of production.

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Why AAC Blocks Are the Future of Sustainable Construction

Murgesh Bhustali, FIE
Former Asst. Executive Director - Technical Services, Dalmia Cement

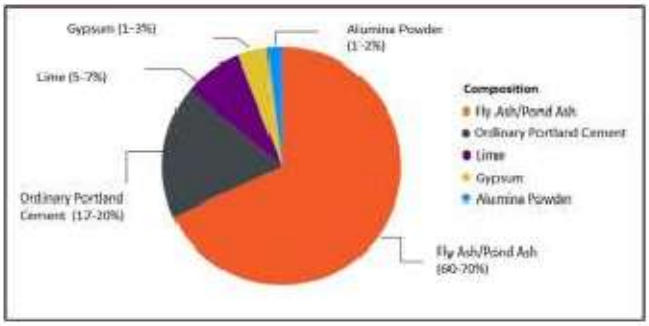


The global construction industry is standing at a critical crossroads. For decades, traditional clay bricks and standard concrete blocks have served as the literal building blocks of our cities. However, their environmental toll-ranging from topsoil erosion to heavy carbon emissions-is no longer sustainable. As engineers, our responsibility extends beyond mere structural integrity; we are tasked with building a smarter, greener, and more resilient future.

On this Engineers' Day, as we celebrate innovation and problem-solving, one material stands out as a triumph of modern structural engineering: Autoclaved Aerated Concrete (AAC) blocks. Originally invented in the 1920s by Swedish architect Johan Axel Eriksson, AAC has evolved into a premier sustainable alternative for modern high-rise and commercial infrastructure. By blending lightweight properties with remarkable thermal and structural performance, AAC blocks are fundamentally changing how we design and execute contemporary masonry.

The Science and Engineering Behind AAC

To truly appreciate AAC, one must look at the cellular level. Standard concrete relies on a dense matrix of aggregates, sand, and cement. In contrast, AAC is a non-reinforced, precast concrete material made from Fly ash (or silica sand), cement, lime, water, and an aluminum powder as an expansive agent. Typical composition is as below:

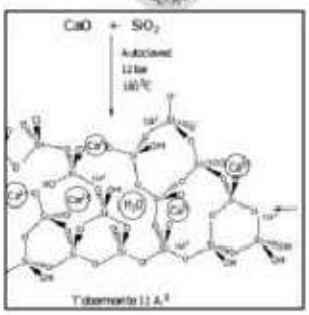


The engineering magic happens during the mixing and curing phases:

✦ The Expansion Phase: When aluminum powder reacts with the calcium hydroxide in the lime and cement, it generates hydrogen gas. This causes the mixture to expand to roughly twice its original volume, creating millions of microscopic, evenly distributed air voids.

This hydrothermal process triggers a chemical reaction that forms Tobermorite, a crystalline calcium silicate hydrate. This specific crystalline structure gives AAC its unique balance of low density and high compressive strength, making it fundamentally different from standard concrete.

✦ The Autoclaving Phase: After the mixture sets, it is cut into precise dimensions as per the



requirement and placed into an autoclave-a large pressurized steam chamber. For 10 to 12 hours, the blocks are steam cured under high pressure (around 12 bars) and high temperatures of around 190°C.

Advantages over traditional concrete blocks & Clay Bricks:

1. Dead Load Reduction and Structural Savings

Property	Units	AAC Block	Clay Brick	Concrete Blocks
Size	mm	600 x 200 x (75 to 300)L	230 x 75 x 115	300 x 200 x 150
Size Tolerance	mm	± 3 to 5 mm	± 05 to 15	± 05 to 10
Compressive Strength	N/mm²	3 - 4.5 (IS 2185 part 3)	2.5 to 3.5	Up to 10
Normal Dry Density	Kg / m³	551 - 660	1800	2000 to 2200
Sound Reduction Index	dB	45 for 200 mm Thick Wall	50 for 230 mm Thick Wall	50 for 230 mm Thick Wall
Fire Resistance	Hrs	2 to 6 (Depending on thickness)	2	2 to 3
Thermal Conductivity °C	W / m²-k	0.16 - 0.18	0.81	1.2 to 1.5
Drying Shrinkage	%	0.04% (Size of block)	-	0.09 to 0.08

Because AAC blocks are roughly one-third the weight of traditional bricks, they significantly decrease the dead weight of a building. For structural design engineers, this reduction scales down the load-bearing requirements of the entire superstructure. Lower dead load translates directly into a reduced requirement for structural steel and concrete in columns, beams, and foundations, cutting overall structural material costs by up to 15%.

2. Thermal Efficiency and HVAC Optimization

The millions of microscopic air pockets within AAC blocks act as a highly effective thermal barrier. AAC boasts a thermal conductivity coefficient that is up to six times lower than traditional masonry. For mechanical and HVAC engineers, this means building envelopes built with AAC naturally regulate indoor temperatures. This reduces peak cooling and heating loads, yielding long-term energy savings of up to 25% for building occupants.

3. Acoustic Insulation

Modern urban environments demand effective acoustic zoning. The cellular structure of AAC provides an excellent Sound Transmission Class (STC) rating, typically reducing sound transmission by up to 45 decibels. This makes it an ideal choice for multi-family residential complexes, hospitals, and educational facilities where noise mitigation is crucial.

4. Fire and Seismic Resilience

Safety is the cornerstone of engineering. AAC is completely inorganic and non-combustible. A standard 8-inch AAC wall offers a fire rating of up to four hours, far exceeding traditional brick masonry. Furthermore, because seismic forces are directly proportional to the mass of a structure, the lightweight nature of AAC blocks dramatically improves a building's performance and survival rate during earthquakes.

Project Lifecycle and On-Site Efficiency

Beyond material science, AAC blocks provide substantial economic advantages during the construction phase. Engineering managers face constant pressure to reduce project timelines without sacrificing quality. AAC delivers on this front through superior workability.

- Dimensional Precision: AAC blocks are manufactured under strict factory tolerances. This uniformity allows for thin-bed mortar applications (using specialized polymer adhesives) instead of thick, traditional cement-sand mortar joints. This reduces mortar consumption by nearly 75% and virtually eliminates the need for thick internal plastering.
- Speed of Execution: Because AAC blocks are significantly larger than clay bricks (typically equivalent to roughly 8 to 9 standard bricks in volume), masonry teams can lay them up to three times faster. This accelerates the building envelope completion date, allowing interior fit-outs to begin ahead of schedule.

- Ease of Workability: AAC can be easily sawn, drilled, channeled, and routed on-site using standard woodworking tools. This simplifies the installation of electrical conduits, plumbing lines, and mechanical fixtures, minimizing material waste and labor hours.

The Environmental Imperative: Engineering a Greener Future

As engineers, we must champion the lifecycle sustainability of the materials we select. Traditional clay bricks require the consumption of fertile agricultural topsoil and burning vast amounts of coal during kiln firing.

AAC blocks offer a vastly superior environmental profile:

- Waste Utilization: The primary raw material in most AAC production is fly ash-an industrial byproduct sourced directly from thermal power plants. By encasing fly ash within the concrete matrix, AAC prevents this waste from occupying landfills or polluting water bodies.
- Lower Carbon Footprint: The manufacturing of AAC consumes less energy overall compared to traditional brick baking, and the autoclaving process is highly energy-efficient. Additionally, because the blocks are lightweight, transport-related fuel consumption and emissions drop significantly.
- Green Building Certification: Using AAC blocks directly contributes points toward global green building certifications such as LEED and BREEAM, helping projects meet stringent modern environmental mandates.

Overcoming Implementation Challenges

While the benefits are clear, field engineers must manage specific properties of AAC to ensure flawless execution:

- Moisture Management: AAC has a high initial water absorption rate due to its porous nature, though its capillary action is lower than that of clay bricks. It is vital to use proper water-resistant primers, external renders, and high-quality thin-bed adhesives to prevent moisture ingress.
- Training: Adequate training of Masons in handling and usage of AAC is required
- Initial resistance as Masons are not used to this kind of new building material
- Tensile and Shear Considerations: Because AAC has lower tensile strength relative to its compressive strength, structural engineers must design proper bond beams and lintels at critical intervals to prevent micro-cracking caused by structural settling or thermal movement.

Conclusion

Engineering is not merely about calculating loads or managing schedules; it is the art of directing the great sources of power in nature for the use and convenience of humanity. On this Engineers' Day, we are reminded that our designs outlive us, shaping the landscapes of tomorrow.

Autoclaved Aerated Concrete represents a matured, engineered solution to the complex demands of modern construction. By choosing AAC blocks over legacy materials, we optimize structural efficiency, lower project lifecycles, and significantly reduce our carbon footprint. It is time for the engineering community to fully embrace this technology, updating our building codes, procurement standards, and design philosophies. Let us build higher, faster, and smarter-engineering a sustainable foundation for the generations to come.

Agro-Processing Centers Enable Income & Employment Generation in Rural India

Dr. Jaswant Singh, ARS (Rtd); FIE
Ex PC(PE), HOD(AED),ICAR-ISRI,

Abstract

In India the state of Uttar Pradesh is one of the great agricultural production systems of the world. This State leads India in wheat production, ranks second in rice, possesses exceptionally large sugarcane, potato, dairy and horticultural economy, and accounts for roughly one-fifth of India's foodgrain output. The Uttar Pradesh Economic Survey 2025-26 reported foodgrain production of about 737.4 lakh tonnes in 2024-25 and placed agriculture and allied activities at roughly one-quarter of the State economy. Yet the same agricultural scale reveals an important structural paradox: rural Uttar Pradesh is exceptionally efficient at producing biological raw material, but a substantial part of the subsequent value creation-grading, preservation, milling, extraction, formulation, packaging, branding, certification and distribution-often occurs outside the immediate production catchment.

Introduction

This article describes that Agro-Processing Centers (APCs) can address the missing middle if they are treated not as subsidised collections of machines but as professionally engineered rural production systems. ICAR described an APC as a farm- or village-level complex combining two or more processing technologies; its national post-harvest engineering programme has established hundreds of such centres for value addition, entrepreneurship and employment. The next generation required in Uttar Pradesh should extend this concept to include raw-material aggregation, objective quality assessment, cleaning and grading, processing, scientific storage, cold-chain elements where justified, food-safety control, packaging, digital traceability, renewable energy and productive use of by-products.

The central scientific proposition is the next increase in rural prosperity which need not arise only from producing another tonne per hectare; it can also arise from retaining more economic value from every tonne already produced. This requires APCs to be commodity-specific, market-led and designed around material balance, annual capacity utilisation, food safety, energy and water efficiency, working-capital availability and professional management. Uttar Pradesh's Food Processing Industry Policy 2023, the World Bank-supported $325.10 million UP-AGREES project, the Agriculture Infrastructure Fund experience, current MoFPI food-processing programmes and an expanding FPO/SHG ecosystem provide an unusually favourable institutional setting.

Properly designed, APCs can become nodes of distributed rural manufacturing: raising farmers' share of value addition, creating skilled non-farm work for rural youth and women, reducing avoidable post-harvest loss, improving resource circularity and strengthening India's capacity to design, operate, maintain and improve its own rural processing technology. In this sense, agro-processing is not peripheral to the Engineers' Day theme. Rather, it is a practical expression of engineering excellence for sustainability and technological sovereignty.

Agricultural Output to Rural Value Retention

A farmer in Uttar Pradesh may spend four months growing a crop, yet a large fraction of the commodity's commercial transformation can take place in a matter of hours after it leaves the village.

Wheat acquires additional value after cleaning, grading, milling, blending and packaging. Mustard becomes a different economic product after

extraction, filtration, testing and bottling. Milk increases its market reach after chilling, standardisation, pasteurisation and conversion into value-added products. A mango or aonla acquires an entirely different economic life after grading, pulping, drying or preservation. Even what appears to be "waste"-bran, husk, oilcake, fruit pomace or livestock dung-can become a secondary raw material when appropriate technology and markets exist.

The farmer is therefore often highly involved in biological production but much less involved in industrial value creation. That distinction should define the next phase of agricultural engineering in Uttar Pradesh.

The World Bank, in approving UP-AGREES, described UP as India's leading wheat-producing State and second-largest rice producer, while specifically identifying inadequate post-harvest infrastructure, limited access to investment and modern technology among small landholders, and weak value addition as constraints on rural incomes. The project consequently places value-chain strengthening, finance, digital agriculture, farm-gate infrastructure and commodity clusters at the centre of its intervention.

The physical scale is enormous. Uttar Pradesh's 2024-25 foodgrain production was reported at about 73.74 million tonnes, representing approximately 20.6% of India's foodgrain production. The State Economic Survey also reported a rise in crop gross value added per hectare over recent years and approximately 65,000 food-processing units employing around 2.55 lakh workers. These numbers illustrate both the size of the agricultural feedstock and the already significant-but still expandable-processing economy.

Dairying reinforces the point. NDDB data show Uttar Pradesh producing about 38.78 million tonnes of milk in 2023-24, making it the country's largest milk-producing State.

The difficulty is not that every unprocessed kilogram represents a "loss"; raw agricultural commodities themselves have functioning markets. The more precise problem is that a production region captures less economic value when economically viable post-harvest functions are located far from the source.

There is also genuine physical loss. The NABCONS post-harvest assessment commissioned by the Ministry of Food Processing Industries estimated national harvest and post-harvest losses of roughly 3.89-5.92% for cereals, 5.65-6.74% for pulses, 2.87-7.51% for oilseeds, 6.02-15.05% for fruits and 4.87-11.61% for vegetables. These are national commodity estimates and should not be misrepresented as Uttar Pradesh-specific percentages, but they demonstrate why perishability, handling and preservation require engineering attention. The same assessment was still being referenced in a 2026 parliamentary response while the Ministry had initiated a further national post-harvest-loss assessment.

This matters environmentally as well as economically. A tonne of food lost after harvest carries with it the land, irrigation, fertiliser, diesel, electricity and labour used to produce and transport it. Avoiding an economically preventable post-harvest loss is therefore equivalent to producing useful food without cultivating an additional hectare for that recovered quantity. This leads to what may be called the second-harvest principle: The first harvest is biological-the crop obtained from the field. The second harvest is economical value recovered from that crop through engineering, preservation, quality assurance, processing and intelligent marketing.

For much of the Green Revolution era, agricultural engineering understandably concentrated on the first harvest: irrigation, mechanisation, productivity, harvesting and input efficiency. The next transformation must give equal seriousness to the second. This is particularly relevant because Uttar Pradesh is not a homogeneous production environment. ICAR program themselves organize

interventions across distinct regions such as the Bhabhar-Tarai, western and mid-western plains, Bundelkhand, north-eastern plains and Vindhyan zone, reflecting major differences in water availability, crop systems, climate risks and market geography. A processing plant copied mechanically from western UP into Bundelkhand simply because a subsidy is available would therefore violate the first principle of good engineering: design for the operating environment.The objective should not be an APC in every village. Nor should it necessarily be one identical APC in every district. The objective should be the right processing capability, on the right scale, in the right production catchment, connected to the right market. That is a much harder objective-but it is also the difference between infrastructure and stranded capital.

The Agro-Processing Centre as a Rural Engineering System

ICAR's established APC concept provides a useful foundation. Its farm/village-level models combine two or more processing technologies such as mini rice mills, oil expellers, flour mills, cleaners, grinders and feed mills. In one documented AICRP demonstration, the processing line included a 60 kg/h oil expeller, 150 kg/h dalia machine, 700 kg/h flour mill and 50 kg/h grinder. The historical unit served approximately 15 villages and directly employed six people. These figures are useful evidence that decentralised multi-commodity processing can operate in production catchment, but its old investment cost should not be used as a 2026 project-cost benchmark.

ICAR now reports 392 APCs established nationally through its post-harvest engineering system for employment generation, value addition and capacity development. ICAR-CIAE has also developed and commercialised cleaners-cum-graders, mini dal mills, millet mills, fruit graders, storage systems, solar dryers, modified-atmosphere technologies and numerous other processing systems.

The Uttar Pradesh APC of the coming decade should build on that experience but should be conceived more comprehensively.

Practical process architecture is:

Production catchment / FPO members Collection, digital weighing and farmer identification ? Incoming quality control: moisture, size, maturity, foreign matter, defects

Cleaning →sorting → grading → conditioning Scientific storage / pre-cooling / chilling where commodity requires it Primary processing Secondary value addition only where market and economics justify it Food-safety verification ? packaging → batch coding → inventory Institutional buyer / processor / wholesale / retail / digital commerce / export

Alongside this mainstream should run a second engineering stream:

bran / husk / peel / pomace / seed / oilcake / reject grade / wastewater / biomass

↓

safe food use → feed use → ingredient extraction → energy → compost/soil use → final disposal

This creates an APC that is not merely a machine shed, but a small industrial ecosystem. Several design principles follow: The APC must begin with feedstock, not machinery. Before purchasing equipment, a detailed resource survey should establish how many tonnes of each commodity are commercially available within the practical collection radius, in which weeks of the year they arrive, what proportion farmers are actually willing to route through the APC, what varieties are involved and what quality range is expected.

The distinction between production in the district and processable throughput available to one enterprise is critical. A district may produce hundreds of thousands of tonnes, but a new FPO processing unit may reliably aggregate only a few tonnes per day. Designing from district production statistics rather than captive throughput is a

common route to overcapacity. Market design must precede process design. "We shall produce flour and then find customers" is not a robust business model. The engineering sequence should instead be: customer requirement ? product specification ? required process ? equipment capacity ? raw-material specification.

For example, an institutional buyer may value consistent moisture, mesh size, microbiological quality and delivery reliability more than an attractive consumer brand. Another customer may require small retail packs and traceability. These are fundamentally different processing businesses.

Multi-commodity should mean complementary, not indiscriminate. A cereal-pulse-oilseed APC can spread machine utilisation across seasons where cleaning, milling and packaging infrastructure can be safely shared or segregated. But combining wet fruit processing, spice grinding and cereal milling simply to keep a building busy may introduce hygiene, allergen, odour, pest-management and workflow problems. Every multi-product layout therefore requires a proper hygienic zoning study.

Cold storage must be a solution to a defined biological problem, not a status symbol. Refrigeration makes sense where product physiology, throughput, holding time and price behaviour justify the energy and capital cost. For many grains, dry scientific storage is more rational; for selected fruits, vegetables and milk, rapid removal of field heat or chilling may be essential. "Put a 20-tonne cold room in every APC" is therefore not an engineering prescription.

Quality assurance must be designed into the plant: FSSAI's current FoSCoS system links licensing requirements to the type and scale of food business, and manufacturing operations can require appropriately qualified production supervision. Current licensing categories distinguish, for example, general food processing, cereal/pulse milling, vegetable-oil processing and dairy operations. An APC intended to sell packaged food should consequently budget from the beginning for hygienic surfaces, potable-process water where required, pest control, product testing, record keeping, calibration, traceability, compliant labels and trained personnel. Compliance cannot be "added" after construction without potentially expensive redesign.

This changes the engineering definition of a successful APC. It is not a building in which all sanctioned machines have been installed. It is a system in which raw material enters repeatedly, compliant product leaves repeatedly, customers buy repeatedly, farmers are paid reliably and the enterprise produces positive operating cash flow.

Designing APCs for Uttar Pradesh's Production Geography

The most practical strategy is to develop modular APC archetypes and configure them according to local production and demand, rather than constructing one universal plant.

Production situation	Core APC modules	Higher-value options, only after market validation	Useful co-product route
Wheat–rice–pulse clusters	intake, moisture testing, cleaner, grader, destoner, milling, packing, dry storage	speciality flours, graded/branded grains, pulse products, institutional packs	bran, broken grain, husk and screenings into authorised feed/energy streams

Bundelkhand pulse–oilseed systems	cleaner, grader, mini dal mill, oil expeller, filtration, packaging	premium pulses, filtered/cold-pressed oils where market exists, millet products	oilcake as feed input where compliant; husk/biomass utilisation
Potato/vegetable clusters	washing where required, grading, sorting, packing, ventilated/cold storage based on product	dehydration, flakes or other secondary processing only at adequate scale	peels/off-grade material evaluated for feed, starch, digestion or compost
Mango/aonla/fruit clusters	washing, inspection, grading, cutting/pulping, hygienic thermal processing or drying	pulp/puree, dried products, preserves and institutional ingredients	pomace/seed recovery, animal-feed or bioresource pathways as technically safe
Sugarcane clusters	controlled crushing/heating, improved furnace, hygienic contact surfaces, moisture control and packing	granular/liquid/speciality jaggery after product-market validation	bagasse for process heat or other biomass applications
Dairy-intensive catchments	village collection, testing, chilling and digital milk accounting	pasteurised/value-added dairy at hub scale rather than duplicating small plants	dung-to-biogas systems and nutrient recovery where collection economics work

The table deliberately avoids assigning universal profit percentages or machine sizes. Such values should emerge from a Detailed Project Report based on local mass balance and actual quotations, not from generic assumptions.

Consider the potato value chain. The engineering objective is not necessarily to convert every potato into chips or flakes. In many situations the economically strongest intervention may be much simpler: curing, defect removal, size grading and market segregation. One incoming stream can become several commercial grades. That is an important engineering principle: value addition begins with information and segregation, not necessarily with transformation.

Fruit creates a different problem. Once a highly perishable commodity is harvested, deterioration gives the seller a limited time window. Pulping, controlled thermal treatment or dehydration can extend marketability, but these operations also impose food-safety, packaging, working-capital and buyer requirements. The meaningful achievement is not "longer shelf life" in isolation; it is creating a product whose extended shelf life can actually be monetised.

Grain is different again. Because wheat, rice and pulses are less perishable under proper dry storage, the major APC opportunity may be quality differentiation, cleaning, grading, milling, packaging and co-product recovery rather than

emergency preservation.

Bundelkhand deserves special emphasis. A drought-prone production system should not simply imitate infrastructure designed for water-abundant western districts. ICAR treats Bundelkhand as a distinct agro-climatic region, and the World Bank has made climate resilience a central element of UP-AGREES in Eastern UP and Bundelkhand. Pulses, oilseeds, millets and compatible livestock-linked processing can be particularly suitable where resource mapping confirms sufficient volumes, because dry processing generally creates a different water-and-energy profile from highly water-intensive wet processing.

Dairy offers perhaps the most instructive Uttar Pradesh example of how collection, processing, institutions and engineering can be integrated. In June 2025 NDDB reported that the Varanasi Milk Union was procuring more than one lakh litres per day from about 30,000 milk producers, with a processing capacity of two lakh litres per day. It also reported a cow-dung-based biogas model supplying energy to the dairy plant. NDDB highlighted eight Milk Producer Organisations in UP, including the women-led Balinee organisation in Bundelkhand.

This case contains several lessons directly transferable to APC design:

Production is aggregated before industrial processing; producer institutions provide the raw-material network; capacity utilisation matters; quality must be measured at procurement; and

a biological residue can become an energy resource.

The engineering rule is: Decentralise the functions that benefit from proximity to the farmer; centralise the functions that benefit strongly from scale. A ?5-lakh or ?20-lakh modular cleaner, grading or milling system may economically belong close to the production catchment. An aseptic plant, sophisticated analytical laboratory, large blast-freezing system or specialised packaging line may be far more efficient as a shared regional asset. That distinction is fundamental to preventing public capital from being fragmented into technically impressive but economically underutilized facilities.

Income, Employment and Enterprise Behind Machinery

The economic mechanism through which an APC can increase farmer income is often misunderstood. It does not automatically raise the price of a crop. Nor does processing magically turn a low-value raw material into a high-profit retail product. Value addition creates additional revenue and additional cost.

For one tonne of raw material:

"Net value created"="Revenue from main product"+"Revenue from co-products"-"Raw material"-"Processing"-"Packaging"-"Energy"-"Labour"-"Logistics"-"Finance"-"Quality/compliance"-"Losses"

Only when the right-hand side is sustainably positive has processing created economic value. The farmer receives additional benefit only if part of that surplus is returned through a higher procurement price, patronage bonus, FPO dividend, ownership return, reduced marketing cost or paid local employment.

Annual operating days

A machine operating for 220 days has very different economics from the same machine working for 45 days. Capacity utilisation: A 5-tonne/day unit processing only 1 tonne/day bears almost the same depreciation, interest and managerial overhead as a much fuller plant. Working-capital cycle. A processor may appear profitable on paper and still fail because farmers need immediate payment during a concentrated harvest while customers pay after 30-60 days. These considerations explain why a viable APC is often best designed around multi-season utilisation. A compatible grain-pulse-oilseed facility, for example, may handle different raw materials in different months, provided process segregation, cleaning and food-safety requirements are met.

Employment should likewise be estimated from the actual plant configuration : Direct roles may include machine operators, electricians, maintenance personnel, food technologists or quality supervisors, pack-line workers, warehouse personnel, procurement coordinators, accountants, drivers, sales staff and digital inventory operators. Indirect demand may arise for transport, fabrication, repair, packaging, input supply and distribution.

ICAR's older farm-gate APC case documented six direct jobs in one multi-machine enterprise, while the organisation's broader post-harvest engineering programme reports hundreds of APC installations explicitly intended for value addition, employment generation and entrepreneurial capacity development. The most interesting employment outcome may be qualitative rather than numerical: the creation of a rural technical workforce.

A rural plant that wastes electricity, groundwater and biomass is not sustainable. A plant that cannot be repaired because a minor proprietary controller has failed is not technologically sovereign. A plant that relies upon complex imported automation even though a locally serviceable electromechanical solution would achieve the required quality may be technologically impressive but economically fragile.

For APCs, technological sovereignty should mean the ability to: design → manufacture → select → operate → maintain → repair→ measure → improve → replicate the technology under Indian rural operating conditions.

A cold room operating throughout the night cannot simply be labelled "solar-powered" because panels have been installed on the roof. Engineers must model the hourly load, grid availability, compressor duty cycle, power quality, battery or thermal-storage economics and backup requirement. Similarly, solar-hybrid drying may be much more sensible than photovoltaic electricity converted back into resistive heat for certain dehydration applications.

This is an important interpretation of technological sovereignty: India should not merely consume advanced technology; it should possess the engineering judgement to know where technology is useful and where it is not. Uttar Pradesh does not need to begin from an institutional vacuum. Several existing programmes already address different components of the APC system.

An APC is therefore an unusually powerful convergence point for engineering disciplines. The scientific and engineering community can contribute by developing standardised modular plant layouts, lifecycle-costing tools, food-grade machine standards, energy benchmarks, solar-hybrid dryers, low-cost sensors, small-scale controlled-atmosphere solutions, efficient jaggery furnaces, modular dal mills, improved storage, waste-to-value systems and predictive-maintenance tools suitable for rural Indian conditions. ICAR's continuing work on farmer-centric processing technologies and machinery testing provides an institutional foundation for precisely this kind of effort.

An APC should never be conceived as a subsidy-delivery mechanism. It should be conceived as an enterprise whose initial risk is intelligently reduced by public policy.

Sir M. Visvesvaraya's legacy is particularly appropriate to this subject because his conception of engineering extended beyond structures and machines to the economic development of society. The twenty-first-century engineer faces a similarly broad responsibility. When one thinks of technological sovereignty, the imagination naturally turns to semiconductors, artificial intelligence, space systems, defence technology and advanced manufacturing. These are undoubtedly important. But technological sovereignty has another, quieter dimension.

A nation in which a farmer can produce an agricultural commodity but a rural community cannot economically clean it, preserve it, test it, process it, package it, repair the machine that processes it, utilise its residues or connect the

finished product to a market is sovereign in production but not yet fully sovereign in its value chain.

Conclusions

Agro-Processing Centres offer an opportunity to close the gaps. They can transform the village from a place from which raw material departs into a place where knowledge, manufacturing and enterprise accumulate. They can transform agricultural residues from a disposal problem into industrial feedstock. They can transform an FPO from an aggregation institution into an owner of productive assets. They can transform a rural young person from an intermittent agricultural worker into a technician, quality controller, machine operator or entrepreneur. They can transform women's participation from labour contribution into technical and enterprise ownership. Also, they can transform sustainability from a slogan into measurable quantities of energy, water, material recovery and avoided loss. None of these outcomes is automatic. The APC of the future must be market-led rather than subsidy-led; modular rather than monolithic; professionally managed rather than informally administered; food-safe rather than merely functional; measured rather than assumed; resource-efficient rather than equipment-heavy; and digitally enabled without becoming technologically extravagant. The second harvest is created when engineering gives that produce quality, shelf life, utility, identity and market value. For Uttar Pradesh, that second harvest can become a new frontier of rural industrialisation. And this is perhaps one of the most tangible meanings of the Engineers' Day aspiration for "Engineering Excellence for a Sustainable and Technologically Sovereign India": to create engineering systems sophisticated enough to compete with the world, yet practical enough to improve prosperity in the village where India's agricultural wealth begins.

Agro-processing centres in production catchments minimise post-harvest losses, generate employment opportunities, enhance income of farmers and landless workers and facilitate health of rural communities. This indeed , is one of the solutions for improving the economic scenario through value addition activities of the major commodities in rural sector.

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Effect of Extraction Angle in Horizontal Sugarcane Crushers on Juice Extraction - A Simulation Study

Dr S.I. Anwar*
* Former Principal Scientist
Division of Agricultural Engineering, ICAR-Indian Sugarcane Research Institute,
Lucknow - 226002 (INDIA)

Abstract

In a typical 3-roller power driven horizontal sugarcane crusher, normally two angles are formed; between first and second roller on cane feeding side and between first and third roller on bagasse exit side. While juice extraction all the juice, which is squeezed out, is not recovered due to reabsorption of extracted juice by the expanding bagasse acting as sponge. Juice re-absorption by bagasse is very difficult to check. However, it can be reduced by changing the angle of extraction. This paper deals with a simulated study to see the effect of extraction angle on the recovery. Results show that by changing the angle of crushing angle recovery can be improved.

Key words: Sugarcane, Juice extraction, Crushers, Reabsorption

Introduction

Sugarcane bagasse produced in the process of juice extraction from sugarcane behaves like a sponge when comes out of rollers at bagasse side. Reabsorption of juice by the expanding bagasse, when the pressure is released, is an inevitable phenomenon. It is more in vertical crushers where the part of juice of top most cane is absorbed by the bagasse of second cane and juice from second cane is absorbed by the third cane and so on. However, problem of reabsorption can not be ignored even in horizontal crushers, where juice goes to the bagasse side adhering with rollers and trapped between layers of crushed canes and is absorbed by the expanding bagasse. So part of the objective of cane crushing is not achieved as the juice is extracted but not actually gained or recovered.

Many studies on performance of sugarcane crushers have been reported (Gangadkar et. al., 2016; Gangadhar, et. al., 2017; Danyal et. al. 2021 and many more) but very less studies on the cause of low extraction have been done.

Srivastava and Agarwal (1992) conducted studies on reabsorption of juice where they reported that reabsorption decreases with speed of compression and relaxation. So the extraction after reabsorption increases with increase with speed. This was however; done on Instron machine where the bagasse while releasing of load was in contact with juice so got sufficient time for absorption of juice. In actual conditions while the bagasse is moving, juice trickles down due to gravity. Thus bagasse gets comparatively lesser time for reabsorption of juice. However, a check on reabsorption will be helpful in recovering more juice from sugarcane.

In a typical 3-roller horizontal crusher, two important angles are formed; (a) angle between roller A and B) referred to as crushing angle and (b) angle (between roller A and C) referred to as extraction angle (Fig.1).

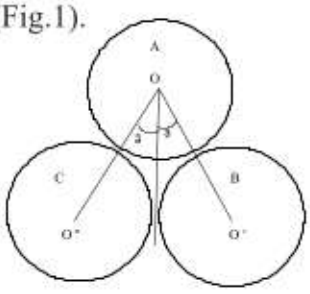


Fig.1. Formation of crushing and extraction angle in a typical 3-roller horizontal sugarcane crusher

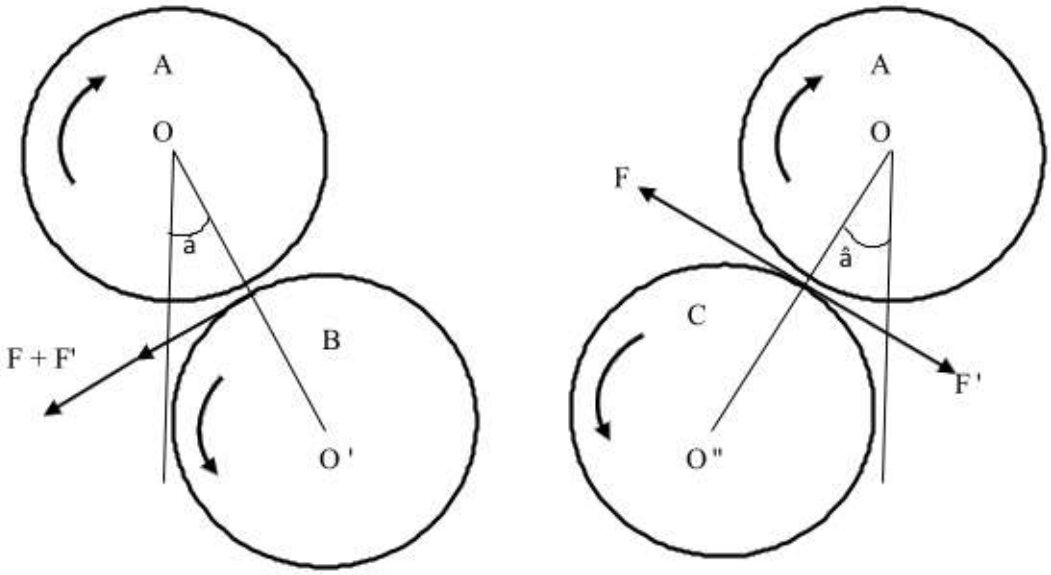
The cane first passes between roller A and B and the maximum extraction takes place at a point where the gap between rollers is minimum. The juice which comes out at that point is subjected to two forces;

i) Inertia force, $F = mv2/r$ .....(1) and

ii) Gravity force, $F' = mg\ Sin$

Where, m, v, r and g are mass of juice, velocity of roller, radius of roller and acceleration due to gravity respectively.

These forces and their direction have been shown in Fig.2(a).



(a) Between A and B (b) Between A and C

Fig.2. Forces acting on extracted juice

Here adhering force between roller surface and juice is neglected. Since both of these forces are in the same direction, it helps in movement of juice in the direction of roller movement. As the pressure is released beyond the contact point and the bagasse expands like sponge, major part (almost all) of extracted juice is reabsorbed by the expanding bagasse.

Again, the bagasse (crushed cane) obtained from extraction between roller A and B passes between roller A and C, again extracted juice experiences two forces;

i) $F = mv2/r$ .....(1) and

ii) $F' = mg\ Sin$

But this time these forces act opposite to each other as shown in Fig.2(b). Therefore, for juice to tickle down in opposite direction of roller movement F' should be greater than F, i.e.

mg Sin mv2/r or Sin v2/rg or Sin -1 v2/rg

However, in most of the cases values of is more than the desired value but still there is scope for improvement. Due to movement of rollers, some of the extracted juice goes towards bagasse side and is totally absorbed by the bagasse. To reduce such effect and to partially avoid juice going towards bagasse side checking reabsorption, the extraction angle could be increased. By this way more juice will tickle down and extraction would improve.

In the present study an attempt has been made to see the effect of extraction angle on juice extraction.

Materials and methods

Sugarcane crushing is basically done between two rollers. Even in a typical 3-roller setup it passes first between roller A and B and then between roller A and C. At a time cane is subjected to force applied by two rollers. Larger gap is kept between A and B to facilitate feeding or accommodating more canes. Lesser gap is kept between A and C for actual extraction. Considerable quantity of juice is extracted while working between A and C.

The test for effect of crushing angle was carried out under simulated condition. A 2-roller laboratory model of sugarcane crusher was used for the simulated conditions. Details of crusher used are given below:

Details of crusher used in the simulation study

A. Crusher used for simulated conditions	
Features	**Values**
Model	Laboratory model
Size of rollers (L x D), mm	362 x 150
Grooves on rollers	8 nos circumferential 'V' grooves (Depth-3 mm , pitch-4 mm)up to 75 mm length and 12 nos horizontal grooves on rest of the length
Power source	1 h.p. electric motor
Transmission of power	Through 'V' belt and pulley
Installation	On a wooden table

Test under simulated condition

Sugarcane bagasse acts like sponge when pressure is released when it comes out of rollers at bagasse side. Expanding bagasse reabsorbs the juice, which comes in contact with it. To simulate the condition, foam of 25 g/cm3 density and 30 mm thickness was used in place of canes. A piece of 81 x 13.5 cm size (weight 99 g) was used for the experiment. The gap between rollers was maintained as 4 mm throughout the experiment. The larger gap was set in order to avoid rupturing of foam. The foam piece was first soaked with some quantity of water and passed between the rollers. The piece therefore, becomes a material similar to sugarcane and was used as basic material for remaining part of the experiment. Measured quantity of water was sprinkled on the foam and was allowed to be completely soaked by the foam. It was then passed between the rollers. Water thus extracted was collected and measured and the weight of foam was again recorded. Based on values of extracted/recovered water and the quantity of water added, extraction percent was calculated. The extraction angle was changed/increased by lifting the two legs of table by placing bricks at bagasse side and the process was repeated. This was continued till five bricks were placed one over another. The angle was therefore changed from 0o to 15o with an increment of almost 3o. Bricks were then removed one by one thereby decreasing angle. Similarly bricks were placed at cane feeding side also. The experiment was carried out till five readings were obtained for each setting. The change in angle for every part was to avoid effect of permanent distortion (2% only, when measured in the last) in the foam piece. The experimental layout and experimental data are shown in table 1 and 2 respectively:

Table: 1. Experimental layout in simulation condition

1X	1B1	1B2	1B3	1B4	1B5	2B4	2B3	2B2	2B1	2X
1C1	1C2	1C3	1C4	1C5	2C4	2C3	2C2	2C1	3X	3B1
3B2	3B3	3B4	3B5	4B4	4B3	4B2	4B1	4X	3C1	3C2
3C3	3C4	2C5	4C4	4C3	4C2	4C1	5X	5B1	5B2	5B3
5B4	3B5	3C5	5C4	5C3	5C2	5C1	4B5	5B5	4C5	5C5

Where, X is the horizontal position, C - Cane side, B - Bagasse side and prefix and suffix show replication number and no. of bricks placed respectively.

Table: 2. Experimental data under simulated conditions

X1	1B1	1B2	1B3	1B4
1. 291.78	1. 296.14	1. 295.78	1. 295.73	1. 298.11
2. 195.74	2. 197.10	2. 196.74	2. 196.69	2. 199.07
3. 85.37	3. 100.14	3. 98.34	3. 108.61	3. 104.21
4. 29.26	4. 33.82	4. 33.25	4. 36.73	4. 34.96
5. 43.78	5. 50.81	5. 49.98	5. 55.22	5. 52.35
1B5	2B4	2B3	2B2	2B1
1. 299.01	1. 293.79	1. 297.14	1. 295.01	1. 296.12
2. 199.97	2. 194.75	2. 198.10	2. 195.97	2. 197.08
3. 112.42	3. 106.93	3. 101.91	3. 99.41	3. 94.88
4. 37.60	4. 36.40	4. 34.30	4. 33.70	4. 32.04
5. 56.22	5. 54.91	5. 51.44	5. 50.73	5. 48.14
X2	1C1	1C2	1C3	1C4
1. 291.92	1. 295.56	1. 293.63	1. 292.53	1. 296.25
2. 192.88	2. 196.52	2. 194.59	2. 193.49	2. 197.21
3. 92.46	3. 96.01	3. 86.33	3. 81.65	3. 82.74
4. 31.67	4. 32.48	4. 29.40	4. 27.91	4. 27.93
5. 47.94	5. 48.48	5. 44.37	5. 42.20	5. 41.96
1C5	2C4	2C3	2C2	2C1
1. 298.32	1. 299.04	1. 296.73	1. 294.53	1. 294.73
2. 199.28	2. 199.99	2. 197.69	2. 195.49	2. 195.69
3. 80.90	3. 86.99	3. 90.14	3. 93.28	3. 94.29
4. 27.12	4. 29.09	4. 30.38	4. 31.67	4. 31.99
5. 40.60	5. 43.50	5. 45.60	5. 47.72	5. 48.18
X3	3B1	3B2	3B3	3B4
1. 296.31	1. 296.13	1. 297.35	1. 294.39	1. 295.21
2. 197.27	2. 197.09	2. 198.31	2. 195.35	2. 196.17
3. 99.60	3. 99.78	3. 100.03	3. 106.00	3. 108.53
4. 33.61	4. 33.69	4. 33.64	4. 36.01	4. 36.76
5. 50.63	5. 50.63	5. 50.44	5. 54.26	5. 55.32

2B5	4B4	4B3	4B2	4B1
1. 293.52	1. 291.86	1. 292.85	1. 298.23	1. 292.01
2. 194.48	2. 192.82	2. 193.81	2. 199.19	2. 192.97
3. 108.44	3. 104.78	3. 102.93	3. 99.20	3. 94.29
4. 36.94	4. 35.90	4. 35.15	4. 33.26	4. 32.29
5. 55.76	5. 54.34	5. 53.11	5. 49.62	5. 48.86
X4	3C1	3C2	3C3	3C4
1. 293.02	1. 290.13	1. 294.45	1. 297.56	1. 296.21
2. 193.98	2. 191.09	2. 195.41	2. 198.52	2. 197.17
3. 94.29	3. 91.87	3. 88.72	3. 91.25	3. 84.68
4. 32.18	4. 31.67	4. 30.13	4. 30.66	4. 28.59
5. 48.61	5. 48.04	5. 45.40	5. 45.97	5. 42.95
2C5	4C4	4C3	4C2	4C1
1. 298.43	1. 291.65	1. 296.73	1. 294.38	1. 296.18
2. 199.39	2. 192.61	2. 197.69	2. 195.34	2. 197.14
3. 78.29	3. 81.90	3. 85.62	3. 86.77	3. 88.86
4. 26.23	4. 28.08	4. 28.85	4. 29.48	4. 30.00
5. 39.26	5. 42.52	5. 43.31	5. 44.42	5. 45.07
X5	5B1	5B2	5B3	5B4
1. 297.58	1. 293.43	1. 297.56	1. 294.19	1. 297.88

Note: 1. Total weight (Wt of foam + water) 2. Weight of water in foam 3. Weight of water extracted 4. Extraction (Total weight basis) 5. Extraction (Water basis)

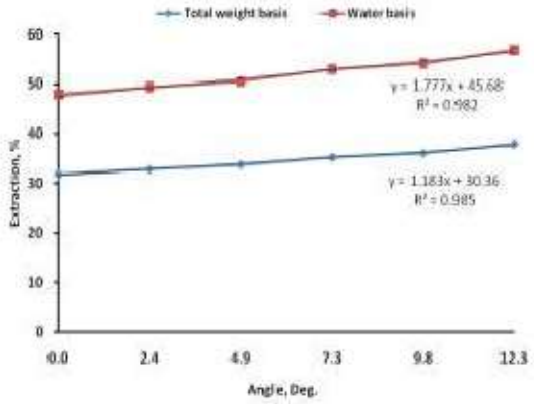


Fig. 3. Extraction (bagasse side lifted)

Results and discussion

Figure 3 shows the effect of extraction angle on extraction on water as well as total weight basis. Higher values in case of water basis are due to lesser values in denominator, which is quantity of water only. Whereas in total weight basis denominator contains weight of water as well as foam and the total values in denominator is more.

Figure clearly shows that when bagasse side is lifted extraction increases. This is due to the reason that while lifting bagasse side, extraction angle ? increases and less water goes towards bagasse side so the reabsorption is comparatively less. In this case resultant force on water forcing it to move towards bagasse side is less and is equal to difference between F and F'.

When cane/feed side is lifted, extraction decreases (Fig. 4). It is due to increase in crushing angle ?. In this situation more water goes towards bagasse side

and is reabsorbed by the expanding foam affecting extraction negatively. Here force acting on water is more i.e. it is the sum of F and F' forcing more water available for reabsorption. Reason for more extraction on water basis has already been explained earlier.

Conclusions

It may be seen from above simulated study that extraction increases when bagasse side is lifted i.e. with increase in extraction angle and it decreases when cane side is lifted i.e. with increase in crushing angle. Hence it is recommended that in horizontal sugarcane crushers, extraction angle should be more and crushing angle should be less. An installation device may also be developed for installation of sugarcane crusher modifying crushing and extraction angles.

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The Jurisprudence of Innovation Laws and Copyright Protection: Contemporary Indian Concept

Raj Vikram Singh, AIE-232728 (IEI)
B.Tech.(Electrl),MA(Pub.Admin), MBA(IIITL),LLB(LU)
Advocate (High Court of Judicature
Allahabad-Lucknow Bench)



The complex relationship between legal rights and human ingenuity is central to "The Jurisprudence of Innovation i.e., Patent Laws and Copyright protection

The Architecture of Ambition

At its core, the IPR (Intellectual Property Rights) laws present the jurisprudence of innovation as these are the legal alchemy that transforms abstract thought into tangible economic assets. Innovation naturally carries immense risk; developing a disruptive technology or crafting an original work requires staggering investments of time, capital, and intellectual labour. Without a codified legal framework to protect these investments, the incentive to share discoveries openly would evaporate, stalling societal progress. Patent and copyright laws establish the critical rules of engagement by offering a carefully calibrated societal contract. They grant creators a legally defensible, temporary monopoly over their work, providing the essential collateral required to secure early-stage investment, structure equity, and confidently enter competitive markets.

The Catalyst for Collective Advancement

This legal architecture does more than just protect the individual creator; it acts as an engine for collective public growth. In exchange for exclusive commercial rights, patent law mandates the total public disclosure of an invention's underlying mechanics. This requirement ensures that once the protection period expires, the technology fully enters the public domain, serving as a stepping stone for the next generation of innovators rather than being locked away forever as a private trade secret.

Similarly, copyright law draws a strict boundary by protecting the specific expression of a concept rather than the underlying idea itself, leaving room for competitors to iterate and build parallel solutions. By rigorously defining what constitutes a genuine, novel breakthrough-and actively preventing the endless monopolization of minor, non-functional tweaks-these intellectual property laws actively design an economic ecosystem. It is an environment where the immense risks of ingenuity are sufficiently rewarded, while ensuring that the public ultimately inherits the compounding benefits of protected innovation.

Tracing the Patent and Copyright laws history

To truly grasp the contemporary frameworks of intellectual property, we must first trace the global genesis of these rights by looking at four historical milestones which formed the legal bedrock of innovation, setting the stage for the highly complex, globally interconnected frameworks we navigate today. These watershed moments show that protecting human ingenuity and original creation is not a modern construct; it is a foundational concept that has been centuries in the making.

Our journey begins in 1474 with the Venetian Statute. This was a pivotal moment in legal history- the very first codified patent system. For the first time, a state formally awarded exclusivity to inventors, recognizing that protecting an individual's commercial rights over there intellectual property was essential to incentivizing public progress.

From the city-state of Venice, the paradigm shifted to the United Kingdom. In 1624, the Statute of Monopolies was enacted to fundamentally curb the abuse of royal privileges. It explicitly restricted monopolies to the "true and first inventors," establishing a crucial precedent: legal protection must be a hard-earned reward for genuine, original innovation, not an arbitrary political favour.

Less than a century later, the focus expanded from mechanical inventions to the protection of creative expression. The 1710 Statute of Anne emerged as



the world's first formal copyright law, extending vital legal safeguards to authors and literary works, and laying the groundwork for the idea-expression dichotomy we use today.

Finally, as commerce globalized, localized laws were no longer sufficient. The 1883 Paris Convention laid the foundational architecture for international industrial property protection. It created a cross-border consensus, ensuring that an innovator's rights did not simply evaporate the moment their creation crossed a geographical boundary.

As innovation accelerated and global trade expanded, the localized laws of the past were no longer sufficient. The legal framework had to evolve from a fragmented patchwork into a cohesive global standard-an era defined by international harmonization.

Our first major leap in this global alignment occurred with the 1886 Berne Convention. While previous treaties addressed industrial property, the Berne Convention revolutionized copyright law on a global scale. It established two incredibly powerful concepts: automatic protection and national treatment. Practically, this meant that authors and artists no longer had to navigate a bureaucratic labyrinth to register their work in every individual country. Their creative expression was instantly recognized and protected across international borders, fundamentally changing how literature, art, and eventually software, were shared with the world.

A century later, the rapidly integrating global economy required a strictly enforced baseline for all intellectual property rights. This culminated in the 1995 TRIPS Agreement (Trade-Related Aspects of Intellectual Property Rights). Brokered by the World Trade Organization, TRIPS was a true watershed moment. It compelled member nations to harmonize their domestic IP standards, creating a predictable and standardized legal environment for global commerce. Most notably, it mandated the universal 20-year patent term, ensuring that innovators and investors had a guaranteed, uniform runway to commercialize their breakthroughs and recoup high-risk research investments across all member markets.

Together, these two treaties established the modern rulebook, ensuring that the jurisprudence of innovation speaks a universally understood legal language, regardless of where the invention or creation originates.

While the international community was busy forging sweeping treaties like the aforementioned Berne Convention, India's domestic intellectual property landscape was being constructed under the

complex, overarching shadow of British colonial administration. To fully grasp the nuances of our contemporary legal framework, we must first critically examine its colonial roots-a system that was heavily, and unapologetically, modelled on the United Kingdom's own legal structures.

This legal evolution formally commenced with Act VI of 1856. This was not merely a new law; it was a profound paradigm shift. It served as the first formal patent legislation on the Indian subcontinent, introducing the Western legal construct of granting exclusive, monopolistic privileges to individual inventors. For a region whose historical and philosophical foundation was largely built upon open, community-based knowledge sharing and generational artisanship, the codified privatization of ideas marked a radical economic and cultural departure.

As the machinery of the Industrial Revolution accelerated and the commercial landscape of the subcontinent transformed, the scope of legal protection had to adapt. The subsequent legislative updates-specifically the Acts of 1872 and 1888-broadened this legal umbrella. They successfully consolidated protections for industrial patterns and designs, legally acknowledging that the aesthetic geometry and structural design of a manufactured product carried intrinsic commercial value just as vital as its mechanical function.

This entire era of colonial IP legislation ultimately culminated in the passage of the 1911 Indian Patents and Designs Act. More than just a consolidation of rules, this Act represented a pivotal moment of administrative maturation. It unified a previously fragmented patchwork of protections under a single, cohesive legal framework. Most importantly, it established the centralized office of the Controller of Patents. By institutionalizing the rigorous administration of intellectual property, the 1911 Act built the exact bureaucratic foundation that a newly independent India would later inherit-a foundation the nation would eventually deconstruct and meticulously rebuild to align with its own sovereign, socio-economic ambitions.

Post-Colonial Transformation in India- From Compliance to National Interest

When India awoke to independence in 1947, the nation inherited an intellectual property framework inherently misaligned with its sovereign reality. The colonial legal structures, culminating in the 1911 Act, were fundamentally engineered to protect the import monopolies of foreign corporations rather than to stimulate domestic manufacturing or research. For a nascent republic facing profound developmental and public health challenges, this inherited jurisprudence was not merely inadequate; it served as an active economic barrier. A radical recalibration was required to shift the legal paradigm from colonial compliance to rigorous national interest.

The philosophical blueprint for this transformation emerged with the landmark Justice N. Rajagopala Ayyangar Committee Report of 1959. This comprehensive review did not just recommend superficial legislative tweaks; it dismantled the prevailing colonial philosophy of intellectual property. Justice Ayyangar articulated a bold, localized vision: patent rights must not operate in a vacuum of absolute monopolistic privilege. Instead, they must be strictly subordinated to the broader socio-economic needs of the state. The legal objective decisively shifted from purely rewarding the foreign inventor to fiercely protecting the Indian public, ensuring that critical technologies remained accessible to a vast, developing populace.

This ideological pivot materialized into the watershed Patents Act of 1970, arguably one of the most brilliant examples of economic statecraft in modern legal history. Its most revolutionary legislative stroke was the complete abolition of product patents for pharmaceuticals, food, and agrochemicals. In their place, the Act permitted only process patents, and explicitly restricted their duration to a significantly truncated term of just seven years. By legally protecting only how a vital drug was manufactured rather than monopolizing

the drug itself, this framework aggressively incentivized and legalized scientific reverse-engineering.

This was not merely a defensive legal manoeuvre; it was the spark that ignited a domestic industrial revolution. By weaponizing patent law for the public good, the 1970 Act empowered local scientists to engineer highly efficient, alternative manufacturing methods. It laid the unshakeable foundation for the Indian generic pharmaceutical industry, fundamentally transforming a legally constrained, import-dependent nation into the undisputed pharmacy of the world.

The Patents Act, 1970

The crowning legislative achievement of post-independence India was undeniably the Patents Act of 1970. Born directly from the visionary framework of the Ayyangar Committee Report, this legislation was a masterclass in balancing the rigid monopolistic rights of the inventor with the urgent welfare needs of a developing republic. It was not merely a legal document; it was a sovereign declaration that intellectual property must, first and foremost, serve the public good.

At the heart of this delicate balancing act was the strategic implementation of Process Patents. By explicitly restricting patent protection in essential sectors-specifically food and pharmaceuticals-to the process of manufacturing rather than the product itself, the law engineered an era of extreme domestic affordability. It gave domestic chemists and scientists the legal runway to safely reverse-engineer life-saving drugs, provided they innovated a different, often more efficient, manufacturing pathway. This single, calculated legislative choice birthed the nation's globally dominant generic pharmaceutical industry.

However, the Act went further by embedding a critical, state-level failsafe: Compulsory Licensing. This powerful legal mechanism ensured that the government retained the sovereign right to override an absolute monopoly in times of acute national crisis. If a life-saving medication was aggressively priced out of the reach of the common citizen, the state could legally compel the foreign patent holder to license the formula to local manufacturers. It was a bold, unapologetic mechanism that prioritized human life and public health emergencies over unchecked corporate exclusivity.

Yet, no domestic law exists in a permanent vacuum. As the global economic landscape shifted radically with the advent of the World Trade Organization, India entered the complex era of TRIPS Compliance. To fully integrate into the modern global trading system and secure its position in international commerce, the nation was compelled to harmonize its fiercely independent framework with international baseline standards. In 2005, this culminated in a monumental amendment: the formal reintroduction of product patents. India was forced to pivot from an ecosystem of defensive, process-driven imitation to playing the high-stakes global game of absolute, product-based innovation-a profound transition that continues to shape our entrepreneurial and scientific landscape today.

The Patent Act 1970- Philosophical Shift

The 2005 amendment to the Patents Act of 1970 represents a tectonic shift in the nation's economic and legal philosophy, aggressively pivoting the ecosystem from a defensive posture to the forefront of global innovation.

The Transition to Product Patents For decades, the strategic reliance on process patents successfully insulated and nurtured domestic manufacturing, prioritizing accessibility over absolute invention. However, full integration into the modern global economy demanded a fundamental rewrite of those rules. To comply with the TRIPS mandate, India systematically dismantled its protective barriers and formally transitioned to a rigorous product patent regime. The legal mandate was no longer simply to find a novel way to manufacture an existing item; the mandate was to pioneer the item itself.

Global Harmonization This paradigm shift ushered

in the global harmonization of patent terms, locking in a standardized 20-year period of protection. For foreign and domestic capital alike, this harmonization was the ultimate signal of market maturity. It provided the precise legal predictability and standardized runway required to underwrite the staggering financial risks associated with early-stage, cutting-edge research.

The Ultimate Quid Pro Quo Yet, this extended monopoly is not a government handout; it is the ultimate societal quid pro quo. In exchange for two decades of fiercely enforced, exclusive commercial rights, the inventor must completely surrender the veil of secrecy. They are legally compelled to execute a comprehensive, transparent public disclosure of their technology. This ensures that the moment the patent expires, the exact mechanics of the invention enrich the public domain, fuelling the next generation of scientific iteration.

The Unyielding Threshold To ensure the system rewards only genuine brilliance rather than mere opportunism, the law enforces a stringent, unyielding three-pronged test. An invention must demonstrate absolute novelty, meaning it has never been anticipated anywhere in the world. It must exhibit non-obviousness, requiring a definitive inventive step that would genuinely surprise a skilled expert in that specific field. Finally, it must prove undeniable utility, demonstrating concrete industrial applicability. This high bar guarantees that society trades a monopoly only for a true technological leap.

Contemporary Frameworks

The 2016 National IPR Policy marked a critical maturation in India's legal landscape, shifting the national narrative from passive legal compliance to proactive economic strategy. It rests on a comprehensive framework designed to embed intellectual property into the very DNA of domestic enterprise.

" Awareness: The foundational step is demystifying intellectual property. It is about propagating the immense value of IP to all strata of society, transforming it from abstract legal jargon into a practical, everyday tool for grassroots innovators and seasoned researchers alike.

" Generation: Awareness must translate into action. This pillar focuses on actively stimulating the creation of diverse, high-quality IP assets across all sectors. For modern enterprises-whether a hyper-growth tech startup or a specialized Section 8 company-this means cultivating an internal culture where every novel process or creative expression is immediately identified for potential protection.

" Legal Framework: A robust ecosystem requires strong yet meticulously balanced legislative boundaries. This ensures the laws fiercely protect the innovator's exclusive rights while simultaneously safeguarding the broader socio-economic interests of the public.

" Administration: The most brilliant laws are entirely useless if bogged down by bureaucratic friction. This initiative mandates the aggressive modernization of service-oriented IPR administration, streamlining digital filings, and drastically reducing pendency times to ensure the patent office moves at the speed of modern business.

" Commercialization: Protection is ultimately meaningless without a pathway to profit. This is where abstract rights transform into tangible financial collateral. A strong IP portfolio provides the undeniable legal certainty founders require to confidently step into a high-stakes pitch room, justify their valuation models, and secure the capital necessary to scale.

" Enforcement: Rights require teeth. Strengthening adjudicatory mechanisms ensures that when IP conflicts inevitably arise, they are resolved swiftly and decisively, deterring infringement and protecting the integrity of the marketplace.

" Human Capital Development: Finally, to complete the policy's seven-pillar vision, the state must continuously build institutional capacity. This

ensures we are actively training the next generation of specialized IP experts, attorneys, and administrators required to sustain and expand this complex ecosystem over the long term.

2024 Amendments

The 2024 amendments to the Patents Rules mark a decisive shift towards operational efficiency, drastically reducing the bureaucratic friction that has historically slowed down the patent lifecycle.

Accelerating the Examination Process Historically, applicants had a relaxed 48-month window from the priority date to file a Request for Examination. The new rule radically compresses this timeline to just 31 months. This acceleration forces filers to commit to the patent process much earlier, aligning the examination request directly with the national phase entry deadline and significantly speeding up the overall time-to-grant.

Streamlining Post-Grant Compliance Once a patent is granted, the ongoing compliance burden has been substantially eased. Previously, patentees were required to submit statements regarding the commercial working of their patents every single year. Under the updated framework, this tedious administrative requirement has been reduced to just once every three years.

Recognizing the True Innovators For the individual creators behind the science, the amendments introduce a formal Certificate of Inventorship. In the past, inventorship recognition was merely implicit in the initial filing paperwork. Now, inventors can obtain a dedicated, standalone certificate, providing undeniable proof of their contribution even if the patent rights are assigned to a corporate entity.

Financial and Administrative Flexibility The new rules also incentivize long-term planning by offering a 10% discount on renewal fees if patentees pay electronically for at least four years in advance. Finally, the amendments empower the Controller of Patents to officially excuse procedural delays for up to six months. This provides a critical safety net, ensuring that minor administrative oversights no longer risk destroying incredibly valuable intellectual property rights.

As the laws in the field of IPR is maturing in the country the brilliance of Indian patent jurisprudence lies in its refusal to eternal monopolies which are often aimed by large corporation. In this regard the health sector can be taken for an instance where the provisions of the patent laws prevent not extent legal cover that may compromise public health for corporate monopolies, a stance perfectly encapsulated by Section 3(d).

The Anti-Evergreening Provision

India enforces an exceptionally high threshold for what constitutes an "Inventive Step" within the pharmaceutical sector. Section 3(d) acts as an uncompromising anti-evergreening shield. It strictly dictates that the mere discovery of a new form of a known substance is inherently unpatentable. To secure a legal monopoly, a pharmaceutical entity must prove a significant, measurable enhancement in actual therapeutic efficacy. This doctrine explicitly prevents corporations from artificially extending their 20-year patents through minor, non-functional chemical tweaks.

The Novartis Precedent This rigorous threshold was battle-tested and permanently cemented during the landmark Novartis case. The judiciary's ruling sent an undeniable global message: the Indian legal framework will generously reward genuine, life-saving breakthroughs, but it will absolutely not tolerate the monopolization of incremental, superficial modifications at the expense of patient access.

The Ultimate Sovereign Failsafe When market pricing completely fails the patient, Section 84 provides the ultimate legal failsafe: Compulsory Licensing. As famously demonstrated in the Natco v. Bayer case, if a critical, life-saving drug is priced beyond the reach of the general public during a health emergency, the state retains the power to intervene. The government can legally compel the

foreign patent holder to license the formula to domestic generic manufacturers, ensuring that affordable access always supersedes absolute exclusivity in matters of life and death.

To grasp the full weight of India's anti-evergreening laws, we must examine the defining legal battle of modern pharmaceutical jurisprudence: the 2013 Novartis case.

The Subject of Dispute Novartis approached the Indian patent office seeking protection for 'Glivec,' a profoundly effective, life-saving leukemia medication. Crucially, they were not attempting to patent a newly invented molecule. Instead, they sought a fresh patent for the beta-crystalline form of Imatinib Mesylate-a chemical compound that was already known to the scientific community. This set the stage for a massive test of the newly amended system: would the Indian state grant a fresh 20-year monopoly for a structural modification?

The Supreme Court Ruling The Indian Supreme Court delivered a resounding, historic "no." In a landmark, unyielding interpretation of Section 3(d), the highest judiciary ruled that the mere discovery of a new physical form of a known compound does not inherently qualify as a patentable invention. To earn that monopoly, the applicant must unequivocally prove "enhanced therapeutic efficacy." The court meticulously determined that while this beta-crystalline form may have exhibited better storage stability or handling properties, it did not actually treat the patient's cancer any more effectively than the original, known molecule.

The Global Impact The ripple effects of this verdict were monumental. It permanently affirmed India's sovereign right to aggressively curb the practice of evergreening, drawing a hard line against corporations attempting to infinitely artificially extend their intellectual property monopolies. By denying this specific patent, the court decisively secured the survival of the domestic generic drug ecosystem. It ensured that local manufacturers could continue producing and globally exporting affordable, life-saving generic equivalents of the drug. Ultimately, it proved to the world that a nation's legal framework can fiercely protect human life and public health without completely dismantling the foundational incentives required for true scientific innovation.

AI & Patentability

The intersection of Artificial Intelligence and patent law represents the most dynamic frontier in contemporary Indian jurisprudence. For years, innovators in the software space faced a formidable statutory wall: Section 3(k) of the Patents Act.

The Traditional Barrier Historically, Section 3(k) explicitly excluded mathematical methods, business models, and computer programs "per se" from being granted patent protection. This strict statutory language created a profound chilling effect on tech-driven enterprise. Patent examiners routinely dismissed complex algorithms and foundational code as mere abstract mathematics or pure logic, regardless of their real-world commercial application. For software and AI developers, this meant relying on the thinner protections of copyright rather than securing the robust, 20-year monopoly of a patent.

The 2024 Paradigm Shift The legal landscape experienced a seismic evolution with the 2024 Madras High Court ruling in Idemia v. Controller. The judiciary recognized that applying a blanket, unnuanced ban on software patents in an AI-driven global economy was fundamentally stifling progress. The court decisively clarified that Section 3(k) is a "targeted exclusion," not an absolute embargo. The ruling established a critical precedent: if an AI model or software-based invention delivers a tangible, meaningful technical advancement, it legally transcends the "computer program per se" barrier.

The Modern Strategy This ruling completely rewrites the intellectual property playbook for modern technology ventures. The crux of any successful AI-related patent strategy in India now hinges entirely on articulation. You can no longer

merely submit raw algorithms or theoretical data models to the patent office. You must unequivocally demonstrate a clear "technical effect" and "technical contribution." To secure a patent today, the filing must explicitly prove how the artificial intelligence physically improves a hardware system, optimizes a tangible manufacturing process, or solves a definitive, real-world technical problem.

Copyright laws

While patent laws rigorously safeguards the functional, technical application of modern breakthroughs the spectrum of IPR laws are expansive and holds multiple chains of legal thoughts that facilitates the protection of original creativity this brings us to the second foundational pillar of our legal framework: Copyright laws. If patent law is designed to govern the industrial mechanics and absolute utility of an idea, copyright law steps in to govern the tangible expression of human creativity. As we pivot from the realm of strict functional monopolies, we shift our legal lens toward the idea-expression dichotomy. We will now explore how copyright frameworks structure the ownership of software, literature, and artistic works, ensuring that while fundamental concepts remain free for society to build upon, the unique, original expression of the creator is fiercely and unapologetically protected.

Copyright Act of 1957

Unlike the rigorous, multi-year examination process required to secure a patent, the Copyright Act of 1957 operates on the principle of spontaneity. The very moment a developer compiles a piece of original code or an author commits a thought to paper, legal protection vests automatically. While formal registration provides powerful prima facie evidence in a courtroom, it is not a mandatory prerequisite to defend a creative work.

The Generational Monopoly

The duration of this protection is vast, reflecting the enduring commercial and cultural value of creative expression. A copyright extends for the entire lifetime of the author, plus an additional 60 years post-mortem auctoris. This sweeping timeline ensures that the economic benefits of a creative asset can sustain multiple generations.

The Oxygen of Fair Dealing

However, absolute, unchecked control over cultural, literary, and technical works would paralyze societal progress. This is where Section 52 introduces the indispensable doctrine of Fair Dealing. This provision carves out critical legal exceptions, permitting the unauthorized use of protected works for private study, rigorous criticism, and educational instruction. It is the legal oxygen that allows academic discourse to breathe, ensuring that the public can still engage with, analyze, and critique a work without the constant threat of infringement litigation.

The Indelible Moral Right

Perhaps the most profound element of the Indian copyright framework is its recognition that a creation is intrinsically tied to the creator's identity. Under Section 57, an author retains indelible Moral Rights. Even if a founder completely assigns all economic and commercial rights of their software or manuscript to a corporate entity, an employer, or an investor, the core rights of paternity and integrity remain. The creator retains the absolute right to claim authorship and the right to prevent the work's mutilation or distortion. The commercial asset can be sold, but the creator's legacy cannot simply be erased.

Case Study: EBC v. D.B. Modak

To define the exact standard of "originality" required to claim copyright over derivative works, Indian jurisprudence relies on the landmark Supreme Court ruling in Eastern Book Company v. D.B. Modak. The dispute centred around a highly practical legal question: can a commercial publisher claim copyright over copy-edited Supreme Court judgments-documents whose raw text inherently

belongs in the public domain?

Rejecting Mere Labour

Prior to this ruling, the threshold for protection occasionally leaned on the outdated "Sweat of the Brow" doctrine, suggesting that mere physical labour, time, and financial investment were enough to earn copyright protection. The Supreme Court decisively rejected this standard. The judiciary ruled that simply transcribing, mechanically proofreading, or aggregating public information-regardless of the exhaustive effort involved-does not warrant a legal monopoly.

The Modicum of Creativity

In its place, the Court formally adopted the "Modicum of Creativity" standard. To secure copyright protection, a derivative work must demonstrate a minimum degree of genuine intellectual effort. The Court meticulously drew a dividing line for the publishers. The raw text of the judicial pronouncements remains completely free and accessible, squarely in the public domain. No one can monopolize the law itself.

Rewarding Skill and Judgment

However, the publisher's specific editorial inputs-such as the drafting of precise headnotes, logical paragraph sequencing, and complex legal cross-referencing-require distinct, specialized "skill and judgment." Consequently, those specific editorial enhancements are granted full copyright protection. This ruling elegantly balances public access with commercial incentive, ensuring that raw government data remains free while strictly rewarding the intellectual labor required to make that data organized and commercially valuable.

The New Frontier: Personality Rights

The rapid advancement of artificial intelligence brings us to a completely new frontier in intellectual property: the domain of personality rights. The legal framework is no longer just protecting what a creator makes; it is now actively protecting the very essence of who the creator is.

The Reality of Voice Cloning

As AI models become increasingly sophisticated, the ability to replicate a human voice has transformed from a technological novelty into a tangible threat to performers. This reality was confronted head-on when the courts intervened to protect the vocal style of renowned singer Arijit Singh from unauthorized AI exploitation. The judiciary established a critical, modern precedent: an artist's voice and distinct vocal techniques are legally recognized as protectable attributes of their persona. It definitively signalled that you cannot simply train an algorithm to steal a performer's livelihood.

The Evolution of Publicity Rights

This legal shield extends beyond just voice, reaching into the broader realm of an individual's public persona and distinct catchphrases. This was clearly enforced when the Delhi High Court upheld the rights of actor Jackie Shroff. The court intervened to prevent the unauthorized, commercial use of his signature "Bhidu" persona by unlicensed AI chatbots and content creators. This ruling firmly established that public figures hold inherent publicity rights, ensuring they retain absolute control over how their unique identity and associated mannerisms are monetized in the digital space.

The Future of AI Regulation

These high-profile cases are actively laying the groundwork for an emerging, highly complex legal doctrine regarding AI regulation. The core intellectual property battleground has now shifted directly to the training data itself. The legal consensus is increasingly treating the ingestion of copyrighted works and protected personas for AI training as inherently infringing behaviour. Moving forward, AI developers will bear the heavy burden of unequivocally proving that their use of protected data is either fundamentally transformative or falls

strictly within the very narrow confines of "fair use."

Personality Rights and Generative AI

The explosive rise of generative artificial intelligence has forced intellectual property law to confront an entirely new frontier: the commercial exploitation of human identity. We are no longer merely debating the unauthorized use of software or literature; we are navigating the unprecedented unauthorized replication of a person's digital soul.

The Jackie Shroff Precedent This urgency was brought to the forefront in the Delhi High Court's ruling regarding Jackie Shroff's battle against rogue entities. The actor was forced to take legal action against creators utilizing generative AI to commercially exploit his distinct persona. The court did not just protect his name and static image; it extended a powerful legal shield over his signature "Bhidu" persona and unique vocal delivery. This ruling firmly established that a celebrity's meticulously cultivated public identity cannot be hijacked and monetized by unlicensed algorithms.

The Arijit Singh Voice Cloning Injunction

The legal boundaries of this new frontier were further cemented by the Bombay High Court in Arijit Singh v. Codible Ventures. In a landmark interim order, the court confronted the specific, insidious threat of AI voice cloning. By intervening to legally protect Singh's distinct vocal style and specific singing mannerisms, the judiciary recognized that a performer's voice is an intrinsically protectable personality attribute. It sent an undeniable message to the tech industry: training an AI to replicate a human voice without explicit consent is a direct violation of their fundamental rights.

Bridging Trademarks and Copyright What we are witnessing through these pivotal cases is the real-time, aggressive evolution of a distinct "Right to Publicity" within Indian jurisprudence. As generative AI technology rapidly outpaces traditional statutes, the courts are proactively constructing a new legal architecture. This emerging trend seamlessly bridges the gap between the commercial brand protection traditionally offered by Trademark law and the creative expression protections inherent in Copyright law. It ensures that in a digital age where any likeness can be perfectly synthesized, an individual's fundamental identity remains unequivocally and exclusively their own.

Exponential Growth in Indian IP (Intellectual Property)

The landscape of Indian intellectual property is undergoing a period of unprecedented, exponential growth that directly alters how founders structure their ventures and approach the market. During the 2023-24 financial year, India shattered previous administrative records by formally granting over 100,000 patents-an extraordinary historical milestone that signals a profound maturation of the national research ecosystem. We are simultaneously seeing a sustained creative boom, with an annual average of over 35,000 copyright filings, proving that developers, artists, and authors are actively and aggressively locking down the legal rights to their specific expressions.

Fueling the Startup Engine

This massive surge in intellectual property generation is not entirely organic; it is being heavily accelerated by strategic state intervention. The government has drastically lowered the initial barrier to entry by offering a massive 80% rebate in government fees for formally recognized startups. This aggressive financial support ensures that securing robust legal protection is no longer a luxury strictly reserved for multinational conglomerates. For founders who are actively refining a financial model to justify early-stage team salaries, or those meticulously assembling the mathematical formulas required for a high-stakes investor pitch, these subsidized IP assets serve as undeniable financial collateral. Even the administrators guiding the distinct operations of a Section 8 company can leverage these highly accessible protections to safeguard their proprietary methodologies or

educational content, ensuring their core mission is protected without draining limited operational capital.

The Catalyst of Fearless Innovation

The single most transformative legislative catalyst driving this modern growth is the Jan Vishwas Act of 2023, which formally took effect in August 2024. Prior to this landmark legislation, the looming threat of disproportionate criminal penalties for minor, often accidental IP administrative violations cast a massive chilling effect on aggressive business operations. The Jan Vishwas Act fundamentally dismantled this psychological and legal barrier by decisively shifting numerous intellectual property violations from severe criminal offenses to strictly administrative financial penalties. This calculated legislative pivot has successfully fostered a thriving national ecosystem defined by "Fearless Innovation." It completely removed the paralyzing fear of accidental criminality, finally empowering domestic creators, engineers, and corporate leaders to operate, experiment, and rapidly scale with absolute confidence within the boundaries of a thoroughly modernized, pro-business legal framework.

Conclusion

The IPR laws primarily Patent and Copyright laws, at their core, are the architectural foundation of a modern economy. From the rigorous anti-



evergreening thresholds to the emerging legal shields surrounding digital personality rights, the law must constantly evolve to match the relentless pace of human ingenuity. Intellectual property is a key aspect for economic development and for the progress of a nation; balancing these rights with public interest remains our greatest judicial challenge. It is precisely this friction-between rewarding the staggering financial and intellectual risks of the individual creator and ensuring the vital, life-saving advancement of the broader society-that defines a sovereign republic's maturity. By rigorously navigating this delicate equilibrium, the legal framework empowers visionary founders, scientists, and artists to confidently scale their breakthroughs, ensuring that the temporary monopolies protecting their genius ultimately serve as the permanent engine propelling the entire public forward.

The Middle-Class Workshop: India's Quiet Engine of Technological Sovereignty

Based on: "Engineering Excellence for a Sustainable and Technologically Sovereign India".

by, Er. Vikas Rai,

EC Member (2025-27), IEI- UP State Centre; Joint Honorary Secretary & EC Member (2024-26), IEI- Prayagraj Local Centre, Electrical Engineering Division.

India's technological strength is often measured by semiconductor plants, defence systems, space missions and large industries. Yet behind every large enterprise stands another India- thousands of small workshops, tool rooms, fabricators, repair units and family-run manufacturing businesses.

A workshop in Aligarh making locks, Moradabad producing metalware, Firozabad sustaining glass skills, Bhadohi creating world-class carpets, or Kanpur supplying industrial components may have limited capital, but it possesses something equally valuable: practical knowledge, skilled hands and the ability to solve problems. Uttar Pradesh's ODOP programme demonstrates how such local capabilities can become organised economic ecosystems.



The opportunity now is to convert local skill into technological capability.

India already has a strong policy foundation—MSMED Act, PMEGP, MUDRA, Udyam, CGTMSE, GeM, RAMP, PM Vishwakarma and public-procurement support. Uttar Pradesh adds ODOP, MSME Promotion Policy 2022 and cluster-based incentives.

But the weakness is fragmentation. A small entrepreneur may have finance, training, technology and market schemes available, yet must often navigate different institutions and procedures to access them. Delayed payments remain another serious constraint: by December 2025, MSMEs had filed more than 2.56 lakh delayed-payment applications involving Rs. 55,244 crores, while over 52,000 applications were awaiting review.

The answer is not another scheme. It is better convergence.

WHAT INDIA CAN DO NEXT IS -

FIRST, create a "One District–One Technology Network": Each industrial district should connect MSMEs with engineering colleges, polytechnics, testing laboratories, tool rooms, banks and large industries. Aligarh,

Moradabad, Firozabad, Kanpur and other clusters can become living laboratories for this approach.

SECOND, make advanced technology shareable: CNC machines, metrology, CAD/CAM, automation and testing facilities should increasingly be available through Common Facility Centres rather than requiring every small unit to purchase them individually. UP's existing policy already supports technology, quality, patents and common infrastructure.



THIRD, make universities partners of MSMEs: Germany offers a useful lesson, where applied research connects research institutions directly with SMEs to turn ideas into marketable products.

FOURTH, make learning practical: Germany's dual education system combines classroom learning with company-based experience. India can strengthen apprenticeships and engineering education around real production problems.

FIFTH, give small businesses predictable cash flow and simple digital markets: India's TEAM (Trade Enablement And Marketing) initiative is already using ONDC to widen market access for micro and small enterprises. The next step should be seamless integration of procurement, finance, logistics and dispute resolution.

In thousands of small workshops across India, engineering excellence is being built every day through skilled hands, practical innovation and the courage to achieve more with less. No policy fix explains why these units survive downturns that break larger firms- the reason lies partly outside engineering, in the spiritual thought process governing how the entity is run.

The deeper Indian lesson is equally important. *Karma Yoga* teaches excellence in action - *"Yogah Karmasu Kaushalam"*. For the entrepreneur, this can mean honest work, quality, responsibility towards employees and continuous improvement. It is not merely a spiritual principle; it is a practical foundation for sustainable enterprise.

India does not need every workshop to become a large factory.

It needs every workshop to become more capable.

From local skill to modern technology, from workshop to cluster, from cluster to supply chain, and from local market to global market -that is the pathway to Technological Sovereignty.

India's future may therefore be built not only in its largest laboratories, but also *machine by machine, workshop by workshop and district by district.*

AI क्या नहीं कर सकता: आर्टिफिशियल इंटेलिजेंस की सीमाएं

महेश कुमार गुप्ता
(Ex. Principal, Govt. Polytechnic Lucknow, U.P. | Fellow, IEI)

आज के तकनीकी युग में आर्टिफिशियल इंटेलिजेंस (AI) ने शिक्षा, उद्योग और हमारे दैनिक जीवन में क्रांतिकारी बदलाव लाए हैं। मशीनें अब इंसानों की तरह लिख सकती हैं, डेटा का विश्लेषण कर सकती हैं और जटिल समस्याओं को सुलझा सकती हैं। लेकिन, इतने उन्नत होने के बावजूद, AI की कुछ स्पष्ट सीमाएं हैं जिन्हें समझना बेहद जरूरी है। आइए विस्तार से जानते हैं कि AI क्या-क्या नहीं कर सकता और इसके व्यावहारिक उदाहरण क्या हैं:

1. चेतना और भावनाओं का अभाव

AI कितनी भी अच्छी बातें क्यों न कर ले, उसके पास खुद का जीवन, चेतना या भावनाएं नहीं होती हैं। वह खुशी, दुख या सहानुभूति को महसूस नहीं कर सकता; यह केवल अपनी प्रोग्रामिंग के आधार पर इंसानी समझ का अनुकरण (Simulate) करता है। उदाहरण: यदि आप AI को बताते हैं कि आप उदास हैं, तो वह आपको सांत्वना देने वाले बहुत अच्छे शब्द लिख सकता है, लेकिन वह वास्तव में आपके दर्द को महसूस नहीं कर सकता या आपके कंधे पर हाथ रखकर आपको भावनात्मक सहारा नहीं दे सकता।

2. भौतिक दुनिया के कार्यों में असमर्थता

AI डिजिटल दुनिया में बहुत शक्तिशाली है, लेकिन बिना रोबोटिक्स या हार्डवेयर के यह वास्तविक दुनिया में कोई भौतिक काम नहीं कर सकता। उदाहरण: AI आपको एक बेहतरीन और स्वादिष्ट रेसिपी बनाकर दे सकता है, लेकिन वह खुद रसोई में जाकर सब्जियां नहीं काट सकता या आपके लिए खाना नहीं बना सकता। इसी तरह, वह आपके भौतिक दस्तावेज़ किसी कार्यालय में जमा नहीं कर सकता।

3. 100% सटीकता की कमी (Hallucination)

AI पर आंख मूंदकर भरोसा करना खतरनाक हो सकता है। कई बार यह पुरानी, अप्रासंगिक या पूरी तरह से गलत जानकारी बहुत ही आत्मविश्वास के साथ दे देता है। तकनीकी भाषा में इसे 'Hallucination' कहा जाता है। उदाहरण: यदि आप AI से किसी दुर्लभ ऐतिहासिक घटना या किसी विशेष कानूनी धारा के बारे में पूछते हैं, तो कई बार वह पूरी तरह से काल्पनिक जानकारी गढ़ सकता है और उसे सच की तरह पेश कर सकता है। इसलिए, तथ्यों की जांच (Fact-checking) हमेशा आवश्यक है।

1. संवेदनशील निर्णय और पेशेवर सलाह

AI कभी भी एक पेशेवर इंसान (जैसे डॉक्टर या वकील) की जगह नहीं ले सकता। इसके अलावा, यह आपके जीवन से जुड़ेव्यक्तिगत, नैतिक और संवेदनशील फैसले लेने के योग्य नहीं है। उदाहरण: AI आपको बुखार या सिरदर्द के सामान्य कारण और घरेलू उपाय बता सकता है, लेकिन वह एक डॉक्टर की तरह आपकी नब्ज़ देखकर, आपकी मेडिकल हिस्ट्री समझकर कोई गंभीर बीमारी डायग्नोस नहीं कर सकता या सर्जरी का फैसला नहीं ले सकता।

2. मौलिक रचनात्मकता का अभाव

यद्यपि AI बेहतरीन लेख लिख सकता है और सुंदर चित्र बना सकता है, लेकिन इसकी यह 'रचनात्मकता' मौलिक नहीं होती। यह केवल पहले से मौजूद इंसानी डेटा और पैटर्न्स को जोड़कर या बदलकर नई चीजें प्रस्तुत करता है। इसके पास खुद का कोई वास्तविक अनुभव या मूल प्रेरणा नहीं होती। उदाहरण: AI किसी प्रसिद्ध कवि की शैली की नकल करके एक कविता लिख सकता है, लेकिन वह किसी इंसान की तरह जीवन के किसी गहरे निजी अनुभव (जैसे बचपन की यादों या संघर्ष) से प्रेरित होकर कोई बिल्कुल नई और मौलिक रचना नहीं कर सकता।

3. जवाबदेही (Accountability) की कमी

इंसानों के विपरीत, AI में जवाबदेही की कोई भावना नहीं होती। यदि AI के किसी फैसले या जानकारी से कोई बड़ा नुकसान हो जाता है, तो वह कोई नैतिक या कानूनी जिम्मेदारी नहीं ले सकता। उदाहरण: यदि कोई व्यक्ति AI से वित्तीय सलाह लेकर शेयर बाजार में पैसा लगाता है और उसे भारी नुकसान होता है, तो वह इसके लिए AI पर मुकदमा नहीं कर सकता। फैसले और उसके परिणामों की पूरी जिम्मेदारी इंसान की ही होती है।

निष्कर्ष

AI एक अत्यंत शक्तिशाली उपकरण है, जो हमारे काम को आसान और तेज बनाता है। लेकिन यह समझना बहुत जरूरी है कि मानवीय चेतना, नैतिकता, मौलिक सोच और सहानुभूति हमेशा अद्वितीय रहेगी। एक मशीन कभी भी मानवीय विवेक और अनुभव का पूर्ण विकल्प नहीं बन सकती।



A.Lalitha - Pioneering the Way for Women in Engineering

Ms Amita Saxena



As India celebrates Engineers' Day on 15 September-commemorating the birth anniversary of Sir M. Visvesvaraya-it is an ideal occasion to reflect upon and celebrate the remarkable women who broke socio-cultural barriers to shape the landscape of Indian engineering. Leading this pantheon of pioneers is Ayyalasomayajula Lalitha, a visionary who etched her name in history as India's very first woman engineer.

Early Life and Triumphant Perseverance

Born in April 1919 in Madras (now Chennai) into a middle-class family, Lalitha grew up in an era when social norms dictated strict traditional roles for women. Her father, Pappu Subba Rao, was an electrical engineering professor, which exposed her early on to technical concepts, though societal expectations still limited higher education for young women.

Lalitha's life took a tragic turn when, in keeping with the times, she was married at the age of 15. By 1937, at just 18 years old, she lost her husband and was left to navigate a conservative society as a young widow with a four-month-old daughter, Syamala.

In a period when widowed women were routinely expected to withdraw from public life, Lalitha chose a path of resilience, self-reliance, and courage. Supported by her forward-thinking father, she resolved to complete her education to build an independent future for herself and her daughter.

Path-Breaking Education at Guindy

After completing her secondary education, Lalitha sought admission to the prestigious College of Engineering, Guindy (CEG)-an institution that had never before admitted female students.

Recognizing her talent and determination, the principal of the institution, along with government authorities, made special provisions to allow her admission. In 1940, Lalitha enrolled in the Electrical Engineering program. To accommodate her, the college had to construct dedicated amenities and adapt its campus environment.

During her studies, Lalitha balanced the demanding rigorous academic coursework of an engineering program with the full-time responsibilities of motherhood. Her perseverance paid off when, in 1943, she graduated with first-class honors, officially becoming India's first female engineer. Her accomplishment inspired other women; soon after, PK Thresia and Leelamma George joined and graduated from the same institution.

A Stellar Professional Career

Upon graduation, Lalitha began her practical training at the Central Standards Office in Simla (Shimla). She later joined the Associated Electrical Industries (AEI), a major British firm, where she worked for over two decades.

As a practicing electrical engineer, Lalitha worked on significant public infrastructure and power projects. Among her notable professional contributions were her technical design work on the electrical setups for the iconic Bhakra Nangal Dam-one of independent India's most ambitious hydroelectric power projects-as well as specialized work on power grid design, transmission equipment, and substation transformers.

Representing India on the Global Stage

Lalitha's professional expertise gained international recognition. In 1964, she was invited to represent India at the First International Conference of Women Engineers and Scientists (ICWES) held in

New York.

At this global summit, she stood as an ambassador for Indian women in STEM, sharing her experiences and proving that women from developing nations could attain technical mastery and lead engineering efforts on equal footing with their international peers.

Legacy and Modern Impact

A. Lalitha passed away in October 1979, but her impact continues to ripple through generations. Today, thousands of Indian women are actively shaping cutting-edge fields-from aerospace engineering at ISRO and renewable energy development to software architecture, artificial intelligence, and civil infrastructure.

Her journey demonstrated that technical aptitude knows no gender. By breaking through institutional resistance, personal grief, and systemic bias, A. Lalitha did not simply earn a degree; she fundamentally expanded the horizon of possibilities for Indian women.

On this Engineers' Day, we remember A. Lalitha not just as a historical first, but as an enduring emblem of determination, professional excellence, and structural change.

"She did not simply enter a profession; she shattered a ceiling, lit the pathway, and ensured that the doors of engineering remained open for generations to come."

जीवन की रेल

संकलित - प्रो० जमाल नुसरत

छुक छुक छुक छुक रेल चली है जीवन की,

छुक छुक छुक छुक रेल चली है जीवन की,

हँसना-रोना, जागना-सोना, खोना-पाना, सुख दुख।

छुक छुक छुक छुक रेल चली है जीवन की।। 1

छोटी छोटी बातों से मोटी मोटी खबरों तक।

ये गाड़ी ले जाएगी हमको माँ की गोद से कब्रों तक।।

सब चिल्लाते रह जाएंगे रुक रुक रुक रुक ।

छुक छुक छुक छुक रेल चली है जीवन की।। 2

सामां बांध के रखो लेकिन चोरों से होशियार रहो।

जाने कब चलना पड़ जाए चलने को तैयार रहो।।

जाने कब सीटी बज जाए सिगनल जाए झुक।

छुक छुक छुक रेल चली है जीवन की।। 3

पाप और पुन्य की गठरी बाँधे सत्य नगर को जाना है।

जीवन नगरी छोड़ के हमको दूर सफर पर जाना है।।

यह भी सोच लें हमने क्या क्या माल किया है बुक।

छुक छुक छुक छुक रेल चली है जीवन की।। 4

रात और दिन इस रेल के डिब्बे और साँसों का इन्जन है।

उमर है इस गाड़ी के पहिए और चिता स्टेशन है।।

जैसे दो पटरी हो वैसे साथ चले सुख-दुख।

छुक छुक छुक रेल चली है जीवन की ।। 5

वास्तविक विकास

प्रो० जमाल नुसरत

वर्ष 2047 तक अपने देश को पूर्ण रुप से विकसित करने का लक्ष्य हमने रखा है। इस दिशा में वांछित कदम भी उठाए गए हैं और अधिक उठाये जाने की योजनाएं तैयार हो चुकी हैं। बहुत से क्षेत्रों में यह दिखाई भी पड़ रही हैं। विभिन्न देशो ने पैमाने भी विकास के सम्बंध में बना रखे हैं। कोई कहता है कि (यहाँ क्रमांक से बिन्दु की महत्ता से तात्पर्य नहीं है) अमुक महत्वपूर्ण है जबकि कोई दूसरा किसी दूसरे को। क्रमशः विकास के निम्न बिन्दु हैं।

1. जी.डी.पी.
2. निर्यात की राशि
3. स्वास्थ्य एवं आयु
4. विधुत उत्पादन
5. विधुत उपभोग
6. साक्षरता
7. परमाणु शक्ति
8. सेना की शक्ति
9. मनोरंजन
10. खाद्यान्न की पैदावार
11. जल की उपलब्धता
12. कृषि योग्य भूमि का क्षेत्रफल
13. प्रदूषण पर नियंत्रण
14. तकनीकी योग्यता
15. स्मार्ट शहर
16. नियमों का पालन

17. इमानदारी
18. पर्यावरण जागरुकता
19. प्रतिव्यक्ति आय
20. मुकदमों का दायर होना
21. मुकदमों में निर्णय
22. मानव अधिकार
23. स्वच्छता
24. डिजिटलाईजेशन
25. कृत्रिम बुद्धिमत्ता
26. अंतरिक्ष विकास
27. शिक्षा व कौशल विकास
28. महिला सुरक्षा
29. धार्मिक सुरक्षा
30. उत्पीड़न का स्तर
31. पड़ोसी देशों से संबंध
32. वैश्विक आपदाओं में सहयोग
33. संयुक्त राष्ट्र में मित्र देश।
34. देशाटन का प्रतिशत
35. विदेशो में सैर / पर्यटन
36. नोबेल पुरस्कार
37. नए अविष्कार तथा पेटेन्ट
38. अमीर-गरीब का अनुपात

यह सूची कोई अंतिम नहीं है एवं इनके महत्ता के अनुरुप बिन्दु भी निश्चित नहीं हैं। यदि प्रत्येक के विषय में विचार किया जाए तथा प्राथमिकताओं को उल्लिखित किया जाए तो पूरी पुस्तक हो जाएगी। यहाँ यह कदापि

उद्देश्य भी नहीं है तथा इस योग्य भी अपने को नहीं पाता हूँ। मात्र कुछ बिन्दुओं की ओर ध्यान आकर्षित कराना है।

तकनीक में, कृत्रिम बुद्धिमत्ता में, अन्तरिक्ष के सम्बन्ध में, खाद्यान्न के उत्पादन के सम्बन्ध में, युद्ध तथा परमाणु में योग्यता के संबंध में, पर्यावरण में जागरुकता, प्रदुषण के नियंत्रण में, हमारी स्थिति अन्य विकसित देशों से यदि अच्छी नही है तो खराब भी नहीं है।

विकसित भारत की ओर ले जाने में सबसे महत्वपूर्ण योगदान इन्जीनियरों का ही है। प्राकृतिक संसाधनों में पेट्रोल-डीजल को छोड़कर अन्य सभी संसाधनों से हम परिपूर्ण हैं। हम आज भी तथा आने वाले कल में अपनी समस्त जनता को रोटी-कपड़ा मकान तथा काम देने में सक्षम हैं बढ़ती जनसंख्या तथा भविष्य में यदि और अधिक तत्परता से नियोजन किया जाए तो समस्याओं का युक्ति संगत समाधान संभव है। रोटी, कपड़ा, मकान तथा काम के साथ-साथ शिक्षा, स्वास्थ्य तथा पारस्परिक आदर तथा सद्भाव भी आवश्यक होगा। प्रसन्नता भी विकास का अंग है।

इसके निमित्त यह आवश्यक होगा कि तकनीक का सदुपयोग इस प्रकार हो कि उसका प्रभाव प्रत्येक भारतवासी को पहुँचे।

1- जल :- प्रत्येक को मिले। स्वच्छ जल पीने को तथा कृषि के लिए, उचित समय पर, उचित गुणवत्ता का उचित मात्रा में उचित मूल्य पर मिले। बाढ़ से सूखे से राहत। पड़ोसी देशों से लेने तथा देने में। भूजल बाढग्रस्त तथा जलमग्न क्षेत्रों के विषय में उचित निर्णय एवं कार्यान्वयन सुनिश्चित हो। पिघलते ग्लेशियर, गरम हो रही दुनिया के प्रति आवश्यक कार्यान्वयन। हिमालय की पर्वत मालाएं कम कठोर हैं तथा जलवायु से अत्यधिक प्रभावित हो रही हैं इसके प्रति भी यथोचित नियोजन।

2- ऊर्जा :- सौर ऊर्जा, पवन ऊर्जा, हरित हाईड्रोजन का उपयोग अधिक करें एंव जीवाश्म ईंधनों पर निर्भरता को यथा शीघ्र घटाएं। इस संबन्ध में

भी देश एवं प्रदेशों में उपलब्ध संसाधनों पर निर्भर रहना ही यथोचित परिणाम सुनिश्चित हो। ऊर्जा से काम मिलता है, काम ही विकास की नींव है।

3- कृषि :- जल की उचित मात्रा, उपलब्ध जल के अनुरुप ही बोआई, मौसम की जानकारी, मिट्टी की जाँच। ड्रोन का उपयोग। मुकदमे घटाना, राजस्व कर्मियों को भी मुकदमे होने पर निजी रुप से जिम्मेदार बनाया जाना। कम लागत में अधिक उत्पादन। उचित बाजार उपलब्ध कराना। कृषि से भाग रहे युवाओं को पुनः गांवों की ओर ले जाना । गांव खाद्यान्न उत्पादन तथा धन उत्पादन का केन्द्र रहें।

4- कृत्रिम बुद्धिमत्ता AI का संतुलित उपयोग जिससे नौकरियाँ बढ़ें न कि कम हों। विज्ञान की प्रगति से, अन्तरिक्ष में, तकनीक में, चिकित्सा में उपयोग तो किया जाए परन्तु यह भी सुनिश्चित हो कि कही हमारे संस्कार, तथा संसार में कमाई हुई मान्यताएं तथा मान पर कोई अप्रत्याशित प्रभाव न पड़े। एआई से भय नहीं जनमानस को प्रेम हो।

5- शिक्षा एवं कौशल विकास :- यह भ्रांति है कि शिक्षा से मात्र नौकरी मिलती है, वरन बौद्धिक विकास भी होता है। शिक्षा अनिवार्य हो तथा सबको इसे सुगमता से कम मूल्य में समय से मिले यह सुनिश्चित हो। मात्र धन न होने पर शिक्षा से कोई वंचित न रहे। यदि शिक्षा तथा कौशल विकास होगा तो उसका रोजगार स्वतः सुनिश्चित है। शिक्षा विदेशों की भाँति धनोपार्जन का साधन न बनने पाए। शिक्षक तो माता-पिता जैसा होता है।

6- हुनर की महत्ता को स्वीकार करना - पश्चिम की पद्धति है कि प्रयोग करो और फेंकों को बदल कर बार बार प्रयोग / उपयोग को सुनिश्चित किया जाए। प्रत्येक वस्तु संसाधनों के सतत प्रयत्नों के बाद प्राप्त हुई है इसे जब तक किसी भी रूप में उपयोग कर सकते हैं करें। व्यर्थ में सामान

बढ़ाना ठीक नहीं है वरन हुनर से उसी का उपयोग बराबर कराते रह ।लुहार, कुम्हार, धातु लकड़ी, कांच उद्योग, कपड़ा तथा बर्तन उद्योग आदि सरल उदहारण है ।

7- स्वास्थ्य :- स्वास्थ्य तथा चिकित्सा एक दूसरे के पूरक हैं। इलाज समय पर कम मूल्य पर उपलब्ध होना आवश्यक है। विकसित देशों में इलाज बहुत अधिक मूल्य है अब यह बीमारी अपने देश में भी आकर घर कर रही है। बीमारी है तो इलाज हो। इलाज सस्ते में तथा शीघ्रता से हो।

8- सुशासन तथा न्यायालयों में समय सीमा।

सुशासन प्रत्येक नागरिक का अधिकार है। अधिकारी को इस बात के लिए मजूरी दी जाती है (वेतन)। वह मालिक नहीं है, नियमों के अनुरुप बिना किसी द्वेष के इमानदारी से निर्वहन अपने कर्तव्यों को करें। त्रुटि करने पर अधिकारी को सामान्यतया कोई दण्ड नहीं दिया जाता। अधिक से अधिक निलम्बन या स्थानान्तरण, वह तो कुछ नहीं है। उसे मजूरी तो फिर भी मिल जाती है। अदालतें निर्णय लेने में, चार्जशीट दाखिल करने में , प्रतिवाद के जमा करने में बहुत अधिक समय स्वीकार कर एक सरल न्याय को से अन्याय में बदल देते हैं। फलतः दादागीरी जन्म लेती है। इस पर भी यथोचित नियंत्रण की आवश्यकता है। सुशासन तथा सामयिक न्याय ही विकास के स्तंभ हैं।

9- संविधान की अनुपालना :- किसी भी स्तर पर संविधान की धारणा एवं अपेक्षाओं के से विपरित कार्य को रोका जाए। इसे सदा सर्वोच्च प्राथमिकता दिए जाने की आवश्यकता है। इसमें इसकी मूल भावना को परिवर्तित नहीं किया जा सकता है। हाँ सामयिक बिन्दुओं का संसोधन तो होगा ही यह विकास की आवश्यक प्रक्रिया ही है। समस्त विकसित देश हमारे संविधान की सराहना करते हैं तथा इसे सार्वभौमिक स्वीकार करते हैं।

10- जी.डी.पी :- यह अवश्य ही बढ़नी भी चाहिए परन्तु इसका विभाजन अमीरों और गरीबों के मध्य कैसा है यह भी अधिक महत्वपूर्ण है। यह आवश्यक नहीं है कि हम संसार के प्रथम तीन देशों में अपना नाम अंकित करा लें वरन प्रत्येक भारत वासी की भी जब औसत आय बढ़ेगी तो देश स्वतः ही विकसित रुप में परिणित हो जाएगा।

यहाँ मात्र अत्यावश्यक बिन्दुओं का वर्णन किया गया है। यदि हम जल, कृषि, ऊर्जा, शिक्षा, स्वास्थ्य, तकनीक, सुशासन तथा संविधान के प्रति अधिक जागरुक रहे तो निश्चित रुप से ही हम संसार के शिखर पर होगें। हमारी सोच, हमारा ज्ञान, हमारे संस्कार, हमे पुनः हमारा स्थान दिलाएगें।

हमारे योग्य राष्ट्रपति एंव महान इंजीनियर, राष्ट्रपति ए.पी.जे. कलाम साहेब ने कहा है-"हमारे पास ज्ञान, संस्कार, बुद्धिमता तथा तकनीक का अपार भण्डार है इसको समस्त संसार मे बाँटकर अपार आदर तथा धन का भण्डार प्राप्त किया जा सकता है।" जय हिन्द।

B.Sc, B.E, FIE(I), FIWRS, MISCA, MIWWA, Prof. WALMI.

Jamalnusrat@gmail.com. (M) 7355962950.

गीता ज्ञान

संकलन कर्ता श्रीमती संगीता गुप्ता
पत्नी इ. राधे श्याम
अधीक्षण अभियन्ता (से. नि.) उ. नि. लि.

कर्म सम्बन्धी विशेष बात

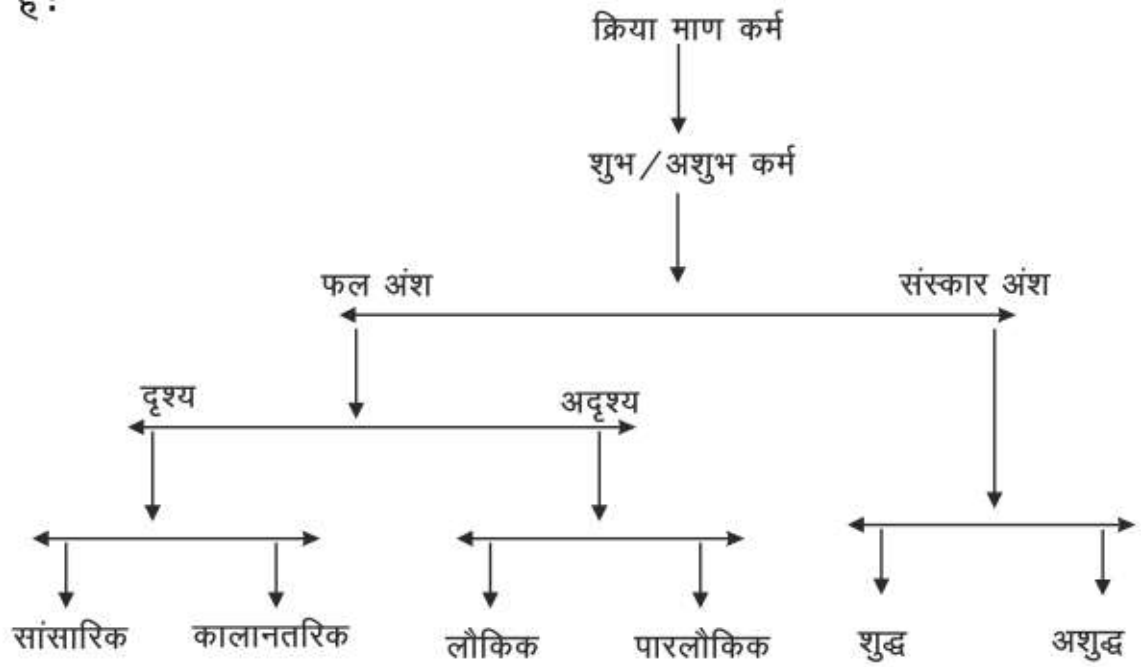
कर्म 3 प्रकार के होते है :
1.क्रियामाण कर्म
2.संचित कर्म
3.प्रारब्ध कर्म

1.क्रियामाण कर्म : अभी वर्तमान मे जो भी कर्म किये जाते है वे क्रियामाण कर्म कहलाते है ।

2.संचित कर्म : वर्तमान से पहले इस जन्म मे किए हुए अथवा पहले के अनेक मनुष्य जन्मो मे किये हुए कर्म संगृहीत है , वे संचित कर्म कहलाते है।

3.प्रारब्ध कर्म : संचित मे से जो कर्म फल देने के लिए प्रस्तुत (उन्मुख) हो गए है , अर्थात जन्म , आयु और अनुकूल- प्रतिकूल परिस्थिति के रूप मे परिणित होने के लिए सामने आ गए हो , वे प्रारब्ध कर्म कहलाते है ।

- **क्रियामाण कर्म 2 प्रकार के होते है "शुभ और अशुभ" जिसे रेखा-चित्र द्वारा दर्शाया गया है :**



शुभ कर्म: जो कर्म शास्त्रानुसार किये जाते है वे शुभ कर्म कहलाते है।

अशुभ कर्म: जो शास्त्र निषिद्ध कर्म किये जाते है , वे अशुभ कर्म कहलाते है ।

क्रियामाण शुभ कर्म अथवा क्रियामाण अशुभ कर्म प्रत्येक के 2 भेद है: फल अंश और संस्कार अंश ।

- **फल अंश के 2 भेद है। दृष्ट और अदृष्ट ।**
- **दृष्ट के भी दो भेद है । तात्कालिक एवं कालांतरिक**

जैसे भोजन करते हुए जो रस आता है , सुख होता है , प्रसन्नता होती है , और तृप्ति होती है यह **"दृष्ट का तत्कालिक फल"** है और भोजन परिणाम मे आयु , बल , आरोग्य आदि का बढ़ना - यह **"दृष्ट का कालांतरिक फल"** है ।

- **इसी प्रकार अदृष्ट के भी 2 भेद है : लौकिक और पारलौकिक ।**

- जीते जी फल मिल जाये इस भाव से यज्ञ , दान , तप , तीर्थ , व्रत , मंत्र-जप आदि शुभ कर्मो को विधि -विधान से किया जाये और उसका कोई प्रबल प्रतिबन्ध ना हो तो यहां ही पुत्र , धन,यश , प्रतिष्ठा आदि अनुकूल को प्राप्त होना - यह **"अदृष्ट का लौकिक फल"** है।

- मरने के बाद स्वर्ग आदि प्राप्ति हो जाये - इस भाव से यथार्थ विधि -विधान और श्रद्धा - विश्वास पूर्वक जो यज्ञ ,दान , तप आदि शुभ कर्म किये जाते है मरने के बाद स्वर्ग आदि लोको की प्राप्ति होना - यह **"अदृष्ट का पारलौकिक फल"** है।

- ऐसे ही डाका डालने , चोरी करने , मनुष्य की हत्या करने आदि अशुभ कर्मों का फल यहां ही कैद , जुर्माना , फांसी आदि होना - यह **"अदृष्ट का लौकिक फल"** है।

- और पापों के कारण मरने के बाद नरकों में जाना और पशु, पक्षी , कीट -पतंग आदि बनना यह **अदृष्ट का पारलौकिक फल** है।

- **क्रियामाण कर्म के संस्कार अंश के भी 2 भेद है : शुद्ध एवं पवित्र संस्कार एवं अशुद्ध एवं अपवित्र संस्कार ।**

- इन दोनों शुद्ध एवं अशुद्ध संस्कारो से स्वाभाव (आदत) बनता है अशुद्ध संस्कारो का सर्वथा नाश करने पर स्वाभाव शुद्ध (निर्मल, पवित्र) हो जाता है।

संचित एवं प्रारब्ध कर्म के सम्बन्ध में विस्तृत विवरण अगले अंक में -------

Emerging Engineering Technologies for Sustainable Sugarcane Production

Mrityunjai K. Singh, Rajesh U. Modi, Himanshu S. Pandey, Shyam Nath
ICAR-Indian Sugarcane Research Institute, Lucknow

Abstract

Sugarcane occupies fields for almost twelve months and demands intensive labour and machinery inputs at every stage, from seedbed preparation to harvest and transport, so engineering intervention is central to the crop's economic viability. This chapter brings together decades of implement development at the ICAR–Indian Sugarcane Research Institute (ISRI), Lucknow spanning tillage, planting, inter-culturing, plant protection, ratoon management, harvesting, and trash management with recent engineering studies that mark a shift from mechanical tools toward sensing and AI-enabled systems. These include a deep-learning ensemble framework for field diagnosis of sugarcane pest damage an unmanned aerial vehicle (UAV) based herbicide spraying system optimized for weed control, a tractor-operated cane node planter that mechanizes precision planting of primed single-bud nodes a convolutional neural network (CNN) that classifies human physiological stress from facial imagery during manual harvesting, an automated deep-learning framework for real-time weed identification in standing sugarcane, and a computer-vision system that classifies crop lodging from field photographs to guide harvest decisions. Across these studies, CNN backbones such as DarkNet53, ResNet50, and EfficientNet-B0 repeatedly emerge as high-accuracy, field-deployable options, while UAV and sensor-based platforms consistently cut water, labour, and input use without sacrificing efficacy. Read together, the six studies show sugarcane engineering research converging on integrated systems that combine mechanical precision, sensing, and automation to raise timeliness, precision, worker safety, and resource-use efficiency across the crop cycle.

1. Introduction

India remains a predominantly agrarian economy, with 60–65% of the population dependent on agriculture and allied activities. The rural population has declined steadily from about 91% in 1901 to nearly 55% by 2025 as rural and urban migration draws workers toward employment and better amenities, and several welfare schemes have further reduced the rural workforce, shortage of labour supply and increasing wages. Indian agriculture is characterized by small, fragmented holdings, and sugarcane cultivation reflects these structural constraints. As a long-duration crop that occupies land for nearly twelve months, sugarcane demands intensive labour and machinery inputs across land preparation, planting, intercultural operations, harvesting, and timely transport to mills. Since cultivation accounts for 60–70% of total sugar production costs, efficient field operations are central to the economic viability of the sugar industry.

Mechanization is therefore a critical engineering input for sugarcane, not only in substituting shortage of labour but in optimizing the use of inputs such as seed, fertilizer, water, and agrochemicals. Farm power availability in India varies widely, from about 1.0 kW/ha in some states to 6.0 kW/ha in Punjab, with a national average of 3.14 kW/ha, of which roughly 88% is derived from mechanical and electrical sources. The strong correlation observed between farm power availability and agricultural output underscores the case for expanding mechanization further. Demographic pressures, an ageing farming population, declining numbers of draft animals, and falling labour force participation in agriculture which add further urgency. Precision mechanization has been shown to reduce seed and fertilizer use by 15–20%, cut operational time by 20–30%, lower labour requirements by 20–40%, and raise yields by 13–23%. With India's overall farm mechanization level at around 45%, still lower than China (59.5%) and Brazil (75%), reaching 75% mechanization is considered an important milestone toward the Viksit Bharat 2047 vision, positioning engineering intervention as a comprehensive enabler across every stage of sugarcane production (Modi et al., 2020; Singh & Modi, 2022).

The key engineering objectives that motivate this mechanization agenda are:

- Ensuring timeliness of field operations across the crop calendar
- Reducing the direct and indirect cost of operations
- Minimizing human drudgery associated with manual field tasks
- Enhancing the productive efficiency of critical inputs such as fertilizers, pesticides, water, and labour

Sugarcane is cultivated over roughly 5.2 million hectares in India, yielding close to 350 million tonnes annually, and around 4.5 million people depend on its cultivation and processing for their livelihood (FAOSTAT, 2026). The crop is energy, labour, and cost intensive, requiring nearly 400 man-days per hectare across its cycle when traditional tools are used, which raises the cost of cultivation and adds substantially to human drudgery. Well-designed machinery not only ensures the timely completion of operations but also improves precision and productivity while lowering input cost and labour dependence. Since its establishment in 1952, the ICAR–Indian Sugarcane Research Institute (ISRI), Lucknow has been involved in development and refinement of machinery for mechanized sugarcane cultivation, start from seedbed preparation to ratoon and trash management, and the adoption of these machines has demonstrated significant savings in labour, cost, time, and drudgery. Recently, these mechanical systems have been extended with application of computer vision, deep learning, and UAVs, forming the emerging engineering technologies (Pandey et al., 2025).

2. Engineering Interventions in different farm operations

2.1 Seedbed Preparation

Primary tillage tools such as mouldboard and disc ploughs, combined with secondary tillage implements such as disc harrows and cultivators, are commonly used to prepare sugarcane seedbeds.

A single primary tillage pass followed by two secondary tillage passes is typically sufficient for good tilth. ISRI developed the culti-harrow specifically to reduce the cost, time, and energy associated with this stage. Sub-soiling at a depth of 35–40 cm every four years is also recommended to break the hardpan layer and improve root penetration, supporting healthier crop establishment in subsequent seasons.

2.2 Sugarcane Planting

Traditional sugarcane planting is highly labour-intensive, requiring 40–45 man-days per hectare across furrow opening, sett cutting, sett placement, fertilization, and soil covering. Mechanization efforts at ISRI have produced multiple models of semi-automatic and tractor-operated sugarcane cutter planters that substantially reduce labour requirements, complete planting in 4–5 hours per hectare, and cut planting costs by more than 50% relative to traditional methods. To support water-saving approaches such as furrow planting, ISRI has developed deep-furrow openers, deep-furrow planters, and deep-furrow sugarcane cutter planters capable of completing all planting operations in a single pass. Trench planters have also been developed to mechanize planting under wide-spaced paired-row geometry (30:120 cm), which helps conserve water, reduce lodging, and improve ratoon performance. For ring-pit planting, valued for its high productivity but traditionally constrained by labour availability, tractor-operated pit diggers have reduced pit-digging cost by about 70% while enabling nearly 150 pits per hour. Machinery for intercropping systems, including raised bed seeders and raised bed seeder-cum-cane planters, allows simultaneous sowing of wheat or pulses alongside sugarcane, and recent advances include machines for planting potato and multi-crop bed seeders combined with cane planters, all validated in field trials. A notable recent advance in this area is the Ikshu tractor-operated cane node planter, fully mechanizes the planting of pre-cut, primed single-bud cane nodes through an integrated system of deep furrow openers, a ground-wheel-driven node metering mechanism, a fertilizer applicator, and soil-covering devices working in a single pass.



2.3 Inter -culturing Operations

Sugarcane typically requires 4–5 inter-culturing operations, each demanding 25–30 man-days per hectare if performed manually. Mechanization using cultivators, rotary weeders, and sweep shovels substantially improves weeding efficiency. ISRI has developed interculture equipment fitted with sweep shovels, as well as a sugarcane manager machine that combines inter-culturing with band placement of fertilizer, reducing the number of separate field passes required.

2.4 Plant Protection

Weed, pest, and disease management are essential for maintaining optimal sugarcane productivity, yet traditional manual spraying and scouting methods remain labour-intensive and consume excessive water and time. Unmanned aerial vehicles (UAVs, or agricultural drones) present a promising alternative, offering efficient chemical application, up to 90% reduction in water usage, lower labour requirements, and more timely plant protection interventions. Through optimized spray parameters and wider adoption among small and marginal farmers, drone-based operations can meaningfully improve farm profitability. ISRI has developed standard operating procedures (SOPs) for drone-based spraying across sugarcane operations, achieving field capacities of approximately 2.5 ha/h and delivering rapid, precise, resource-efficient crop protection. Recent quantitative field evaluation of UAV-based herbicide spraying, summarized in Section 3.2, has further refined the operational parameters including flight speed, flight height, and droplet characteristics, needed to optimize this technology for sugarcane weed management. Complementing chemical-application engineering, image-based deep learning systems are emerging as a diagnostic layer that can identify pest damage and weeds automatically from field photographs, helping target interventions more precisely and paving the way toward autonomous, site-specific spraying.



2.5 Ratoon Management

Ratoon crops account for more than 50% of India's sugarcane area. Although ratooning is generally profitable, yields often remain lower than those of plant crops owing to inadequate post-harvest care. Essential ratoon operations – stubble shaving, root pruning, inter-culturing, and fertilizer application – are labour-intensive when performed with traditional tools. ISRI developed the Ratoon Management Device (RMD), a multi-operation unit that performs all these tasks in a single pass with a field capacity of 0.25 ha/h, and a disc-type RMD variant for ratoon fields with surface trash, which achieves 0.28 ha/h (Singh et al., 2017).



2.6 Sugarcane Harvesting

Efforts to mechanize sugarcane harvesting in India have been actively pursued at institutions including ISRI, VSI Pune, and TNAU Coimbatore. Tractor-operated whole-stalk harvesters and detrashers were developed in earlier phases but were not widely commercialized. More recently, self-propelled billet harvesters have been introduced in several sugar mill zones, enabling efficient cut-and-load harvesting. Although highly effective, these machines are capital-intensive and require careful management to remain economically viable. A typical billet harvester can process 100–150 tonnes of cane per day, with an hourly capacity of 12–15 tonnes and diesel consumption of 18–20 litres per hour, harvesting roughly 1.0 ha/h on average. These harvesters are best suited to fields with single-row or wider planting at a row spacing of 1.0 m or more, provided the soil is properly earthed up, and they are also capable of harvesting fallen or lodged cane, adding operational flexibility. Government subsidies of 40–50% are available for sugarcane harvesters in states such as Madhya Pradesh, Maharashtra, Haryana, Punjab, Bihar, and Gujarat, though no equivalent subsidy is currently available in Uttar Pradesh. Where cane remains manually harvested, human drudgery and physiological strain are themselves engineering concerns.



2.7 Trash Management

Handling sugarcane trash remains a persistent challenge in manually harvested systems (Srivastava, 2003). Composting aided by vinasse and filter cake can return substantial nutrients to the soil, yet the adoption of trash mulching in sugarcane farming has been constrained by the lack of a single machine that can perform mulching and stubble shaving together, limiting soil-health benefits and slowing trash decomposition ahead of ratoon crop initiation. To address this gap, ISRI has developed a tractor-operated trash mulcher-cum-stubble shaver device for sugarcane ratoon crops that combines trash mulching, chemical spraying, and stubble shaving into a single field pass. The device operates at a tractor speed of 2.5 km/h, consumes 4.5 L/h of diesel, and achieves an effective field capacity of 0.3 ha/h at 80% field efficiency (Singh et al., 2024).



3. Emerging Technologies

3.1 Artificial Intelligence, Computer Vision and Precision Crop Management

Recent advances in sugarcane engineering increasingly integrate deep learning, computer vision and UAV technology to improve crop protection, diagnosis and field decision-making. Singh et al. (2026) developed a field- and laboratory-image based deep-learning pipeline for classifying eleven categories of sugarcane pest damage using 4,155 expert-annotated images and seven pretrained CNN backbones.

EfficientNet-B0, YOLO11n-cls and ResNet-50 achieved validation accuracies of about 96–97%, while an attention-weighted ensemble provided the best balance of accuracy (96.4%), macro-F1 (96.2%) and ROC–AUC (0.9985). The models were also exported to TorchScript and ONNX and demonstrated through a deployment GUI, supporting practical field use. For weed management, Modi et al. (2023a) developed a CNN-based identification system using 5,660 augmented images representing sugarcane and nine weed species. DarkNet53 achieved 99.1% validation accuracy and an F1 score above 99%, with independent field verification accuracies of 96.6–96.7%. This provides a basis for site-specific herbicide application. Modi et al. (2026b) further demonstrated UAV-based precision spraying, where 3.0 m/s flight speed and 1.0 m height produced the best spray deposition. The optimized UAV used 55 L/ha compared with 500 L/ha for knapsack spraying, while achieving about 80% weed-control efficiency, 2.6 ha/h field capacity, 89% water saving and approximately 82% lower input cost. Together, these studies demonstrate a transition from image classification toward integrated, resource-efficient precision crop management.

3.2 Integrated Mechanization, Ergonomics and Harvest -Oriented Automation

The convergence of these approaches also suggests a practical architecture for future sugarcane systems: camera or UAV sensing can identify crop and field conditions, analytical models can support timely decisions, and mechanized implements can execute targeted operations with improved timeliness, precision, labour efficiency and resource conservation. Mechanization research is simultaneously addressing planting, worker ergonomics and harvest operations through purpose-built machines and intelligent sensing. Modi et al. (2026a) developed the tractor-operated 'Ikshu' cane node planter for single-bud planting. The round-cup metering mechanism with active push, operated at 0.7 m/s, achieved a 5.3% miss index, 81.0% quality feed index, 91.7% precision index and 85.0% germination. The planter operated at 0.18 ha/h and reduced seed requirement by 74.3%, labour by 84.9% and operating cost by 64.9% compared with conventional sett planting, with a benefit-to-cost ratio of 1.85. Worker-centred automation was demonstrated by Modi et al. (2024), who used CNNs to classify stress during manual sugarcane harvesting from facial images. Using data from 20 subjects and 4,300 augmented images, DarkNet53 achieved 95.9% validation accuracy and 88% net accuracy on field testing, indicating potential for low-cost, non-invasive ergonomic monitoring. In harvest engineering, Modi et al. (2023b) developed a lodging-classification system from field images collected across two cultivars and two seasons. ResNet50 achieved 98.5% validation accuracy and 94% net accuracy during independent field testing, providing a potential sensing layer for automated lifting and separating mechanisms. Collectively, these technologies indicate a shift toward integrated agricultural systems in which mechanical operations, sensing and artificial intelligence complement one another. The common emphasis on field validation, measurable resource savings, automated decision support and integration of previously separate tasks strengthens their potential for practical adoption in sugarcane production.

5. Conclusion

Substantial progress has been made in India toward mechanizing sugarcane cultivation, with region-specific machinery developed, field-tested, and commercialized through manufacturers. Recent advances such as deep-learning-based pest and weed diagnosis, precision UAV spraying, the Ikshu cane node planter, camera-based human stress classification, and computer-vision lodging detection are extending this progress from conventional mechanical implements toward integrated, sensor and automation enabled systems. Achieving higher system-wide efficiency will require coordinated effort among researchers, manufacturers, extension agencies, and farmers. Continued adoption of cost-effective machinery, drone-based spraying, and AI-assisted diagnostic and monitoring tools can significantly reduce labour requirements and drudgery, improve input-use efficiency, lower operational costs, and boost overall productivity across sugarcane-based cropping systems.

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श्रीमद्भगवद्गीता हमारे जीवन में कैसे उपयोगी है ??

श्रीमती श्यामा सुंदरी श्रीवास्तव
w/o **इंजी ० डी के श्रीवास्तव**
SCC Member, IEI UP State Centre

निर्मानमोहा जितसङ्गदोषा अध्यात्मनित्या विनिवृत्तकामाः।
द्वन्द्वैर्विमुक्ताः सुखदुःखसंज्ञै-र्गच्छन्त्यमूढाः पदमव्ययं तत्॥

परिचय:

श्रीमद्भगवद्गीता (गीता) ग्रन्थ के रचयिता महर्षि वेद व्यास है। श्रीमद्भगवद्गीता लगभग 5000 वर्ष पूर्व महाभारत युद्ध आरंभ होने के ठीक पहले भगवान श्री कृष्ण ने अर्जुन को जो उपदेश दिया था वह श्रीमद्भगवत गीता के नाम से प्रसिद्ध है। यह महाभारत के भीष्म पर्व का अंग है गीता का दूसरा नाम गीतोपनिषद है।

भगवत गीता नाम क्यों पड़ा ? :

गीत का शाब्दिक अर्थ है "गीत" और भगवत का अर्थ है "भगवान" अर्थात भगवान् का गीत। चूँकि यह भगवान श्री कृष्ण द्वारा महाभारत युद्ध के समय अर्जुन को सुनाया गया दिव्य उपदेश है इसलिए इसे 'भगवद् गीता' कहते है। यह उपदेश किसी जाती विशेष के लिए नहीं, बल्कि पूरे मानव कल्याण के लिए था। भगवान कृष्ण ने यह उपदेश रविवार के दिन एकादशी तिथि पर कुरुक्षेत्र की रणभूमि में दिया था। गीता में कुल 18 अध्याय और 700 श्लोक है। अर्जुन से पहले गीता का पावन ज्ञान सूर्य देव को मिला था। गीता की गिनती उपनिषदों में होती है।

गीता क्यों सुनी जाए और कुछ कितने श्लोक है :

१. कर्तव्य से भटके हुए अर्जुन को कर्तव्य सिखाने के लिए और आने वाले पीढ़ियों को धर्मज्ञान सिखाने के लिए।
२. गीता में ज्ञान भक्ति कर्म योग मार्गों की विस्तृत व्याख्या की गई है इन मार्गों पर चलने से व्यक्त निश्चित ही परम पद का अधिकारी बन जाता है।
३. गीता अर्जुन के अलावा धृतराष्ट्र एवं संजय ने सुना , गीता में 700 श्लोक हैं जिसमें श्री कृष्ण जी ने 574 श्लोक, अर्जुन ने 85 श्लोक , धृष्टतास ने एक श्लोक और संजय ने 40 श्लोक बोले है।

गीता का सार :

१. प्रभु श्री कृष्ण की शरण में जाना
२. जीवन का एकमात्र सत्य है और वह है मित्र बनाना
३. अच्छे कर्म करें और फल की इच्छा ना करें
४. मानव शरीर अस्थाई है और आत्मा स्थाई है
५. लोक में जितने देवता हैं सब भगवान की ही विभूतियां हैं
६. निष्काम भाव सेवा करना तथा प्रभु की शरण में जाना है हमारा उपदेश होना चाहिए
७. गीता में श्रीकृष्ण ने कहा है कि दम्भ, घमण्ड, अभिमान, क्रोध, कठोरता और अज्ञान यह सब आसुरी लक्षण हैं, इन चीजों का त्याग करके ही व्यक्ति अच्छा मनुष्य बन सकता है।

श्रीमद्भागवत गीता में कहा गया है कि जीवन में तीन मंत्र हमेशा याद रखने चाहिए. आनंद में कभी किसी को वचन ना दें, क्रोध में उत्तर नहीं देना चाहिए और दुःख में कोई निर्णय नहीं लेना चाहिए। यह एक ऐसी ग्रन्थ है जो सिर्फ धर्म ही नहीं बल्कि अपने मन ,शरीर और बुद्धि इन सभी को नियंत्रित करने की शिक्षा प्राप्त होती है तथा अन्याय के विरुद्ध लड़ने की भी शिक्षा मिलती है । श्रीमद्भागवत गीता का ज्ञान मानव जीवन और जीवन के बाद के जीवन दोनों के लिए उपयोगी माना गया है. गीता संपूर्ण जीवन दर्शन है और इसका अनुसरण करने वाला व्यक्ति सर्वश्रेष्ठ होता है।

Advanced Technologies in Chemical Industries

Er. Dinesh Kumar Srivastava, FIE
B.Tech , M.Tech
State Council Comm. Member, IEI (I)
Vice Chairman, IIChE, Regional Centre, LKO

The chemical industry is passing through a remarkable phase of transformation. Rapid advances in digitalisation, artificial intelligence, automation, advanced materials, biotechnology, and sustainable process technologies are redefining the way chemical plants are designed, operated, and managed. The focus is no longer limited to higher production and profitability; modern chemical industries must simultaneously achieve energy efficiency, environmental sustainability, safety, quality, and resource conservation [1,2].

1. Digitalisation and Artificial Intelligence

One of the most significant developments is the integration of **Artificial Intelligence (AI), Machine Learning (ML), Industrial Internet of Things (IIoT), and advanced analytics** into chemical-process operations. Sensors installed throughout a plant can continuously monitor temperature, pressure, flow, vibration, composition, and equipment health.

AI-based systems can analyse large volumes of process data and identify deviations before they develop into serious operational problems. Predictive maintenance enables industries to anticipate equipment failures and schedule maintenance at the optimum time, thereby reducing unplanned shutdowns and maintenance costs. Digital twins are another emerging technology, providing virtual representations of operating plants and equipment that can be used to simulate operating conditions, optimise processes, and identify potential bottlenecks without disturbing actual plant operations [3,4].

2. Advanced Process Control and Automation

Modern chemical plants are increasingly moving from conventional process control to **Advanced Process Control (APC)** and model-based optimisation. These systems continuously adjust process parameters to maintain optimum operating conditions.

Automation, robotics, distributed control systems, and smart instrumentation are improving plant reliability and safety. Automated systems can perform repetitive or hazardous activities, reducing human exposure to dangerous chemicals and high-temperature or high-pressure environments. The integration of AI with process intensification and advanced control is expected to further improve plant efficiency and flexibility [4,6].

3. Green and Sustainable Chemical Technologies

Sustainability has become a central requirement for the chemical industry. Conventional processes often consume substantial quantities of fossil fuels, water, and raw materials while generating greenhouse-gas emissions and waste.

New technologies are addressing these challenges through **energy-efficient reactors, process intensification, waste-heat recovery, renewable energy, water recycling, carbon capture, utilisation and storage (CCUS), and conversion of industrial waste into useful products [1,5,9].**

Green chemistry focuses on preventing waste and reducing the use or generation of hazardous substances at the design stage rather than treating them after they have been produced. The principles of green chemistry therefore provide an important foundation for developing safer and more sustainable chemical processes [7,8].

4. Advanced Separation Technologies

Separation processes such as distillation, absorption,

extraction, and evaporation are among the largest energy consumers in many chemical plants. Advanced separation technologies therefore offer enormous opportunities for energy conservation.

Membrane technology, adsorption, advanced solvents, molecular sieves, and hybrid separation processes are increasingly being adopted to reduce energy consumption and improve product purity. Process intensification can further reduce equipment size, energy requirements, and environmental impact while improving process performance [1,5].

5. Biotechnology and Bioprocessing

The convergence of chemical engineering and biotechnology is opening new avenues for manufacturing. Biocatalysis, fermentation, synthetic biology, and engineered microorganisms can produce chemicals, fuels, pharmaceuticals, polymers, and speciality products under comparatively mild operating conditions.

Bio-based chemicals derived from renewable biological resources can reduce dependence on petroleum-based raw materials. The development of bio-refineries is particularly promising, where biomass is converted into multiple value-added products.

6. Advanced Materials and Nanotechnology

The development of nanomaterials, advanced catalysts, high-performance polymers, composites, and functional materials is creating new opportunities across the chemical sector. Advanced catalysts can increase reaction rates and selectivity while reducing energy requirements and unwanted by-products [2].

Nanotechnology can enhance catalyst performance, membrane properties, filtration, energy storage, and surface characteristics. These advanced materials are finding applications in corrosion protection, batteries, hydrogen technologies, electronics, renewable energy, and speciality chemicals.

7. Hydrogen and Carbon Management

The transition towards a low-carbon economy has placed hydrogen at the centre of future energy and chemical strategies. Green hydrogen produced using renewable electricity has significant potential in ammonia, methanol, refining, and other energyintensive industries [1].

At the same time, carbon-management technologies are becoming increasingly important. Captured carbon dioxide can potentially be utilised as a feedstock for fuels, chemicals, carbonates, and other value-added products. The integration of carbon capture with utilisation and storage can help reduce emissions from difficult-todecarbonise industrial processes [1,9,10].

8. Additive Manufacturing and 3D Printing

Additive manufacturing (3D printing) is emerging as a valuable technology for chemical-engineering applications. It can produce customised reactor components, heat exchangers, catalyst supports, mixing devices, and complex geometries that may be difficult to manufacture using conventional methods.

This technology can reduce material usage, shorten development cycles, and enable rapid prototyping of innovative process equipment.

9. Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) is an advanced technology increasingly used for process improvement and equipment optimisation in chemical industries. It enables engineers to simulate fluid flow, heat and mass transfer, turbulence, mixing, combustion, and chemical reactions. CFD helps identify flow maldistribution, pressure losses, hot spots, and inefficient heat transfer. It supports improved design of reactors, heat exchangers, furnaces, pipelines, and process equipment, while reducing energy consumption, development time, and experimental costs. Integration with AI and Digital Twins further enhances predictive process optimisation. [11,12]

The Road Ahead

The chemical industry of the future will not be

defined by a single technology. Its transformation will come from the integration of digital technologies, advanced process engineering, artificial intelligence, clean energy, biotechnology, advanced materials, and circular-economy principles [1,4,7].

However, technology alone cannot guarantee success. Skilled engineers, strong safety culture, effective leadership, continuous learning, and responsible decisionmaking will remain fundamental. Chemical engineers must increasingly combine traditional process knowledge with digital, environmental, and multidisciplinary capabilities.

The ultimate objective should be to create chemical industries that are safer, smarter, cleaner, more efficient, and economically competitive. The transition from conventional chemical plants to intelligent and sustainable manufacturing systems is already underway. Organisations that embrace innovation while maintaining the highest standards of safety and environmental responsibility will be best positioned to lead the chemical industry of tomorrow.

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IEUP SCC (2025-27) MEMBERS



CHAIRMAN
ER VIJAYA PRATAP SINGH,
F-1156426 (MR)
Address : 18 / 904, Indira Nagar Lucknow-226016
+91 9415402815
: atvps@yahoo.com



HONORARY SECRETARY
ER NIRENDRA KUMAR NISHAD,
F-123592-5 (ET)
Address : Ayush Sadan Vijay Khand Kh-5396 Badri Nagar Nandergunj, Near Ekvellari Post-Sanjini Nagar Lucknow, (UP)-226008
+91 9452101029
: nkn1456@rediffmail.com



IP CHAIRMAN
ER SATYA PRAKASH,
FIE-1286095 (CV)
Address : C/O Chain Sukh Agrwal 2-407 Proteek Laurel, Sector – 120, Noida, Gautam Buddha Nagar Uttar Pradesh-201301
+91 9415061434
: singhalsp21@gmail.com



AEROSPACE ENGG. DIVISION
ER. VINOD SAXENA,
F-1048548 (AS)
Address : Feb-44, Vishwas Khand-2 Gomti Nagar, Lucknow-226010
+91 9696260470
: vin123saxena@yahoo.com



AGRICULTURAL ENGG. DIVISION
DR SAIYED IRFAN ANWAR,F- 1143575 (AG)
Address : DIVISION OF AGRICULTURAL ENGR INDIAN INST OF SUGARCANE RESEARCH RAEBARELI ROAD PO DILKUSHA LUCKNOW (UP)- 226002
+91 9450396061
: sianwar@yahoo.co.in



ARCHITECH ENGG. DIVISION
ER SHARAD CHANDRA ASTHANA, M-130527-6 (AR)
Address : Shop No 9, Heera Guest House, OP Kumar Guest House, Pahadia Varanasi-221002
+91 9415501776
: sharad.c.asthana@gmail.com



CHEMICAL ENGG. DIVISION
ER DINESH KUMAR SRIVASTAVA, F-1285595 (CH)
Address : A-95 SOUTH CITY, RAIBAREILLY ROAD LUCKNOW (UP)-226025
+91 8052996855
: dks_tech@yahoo.co.in



CIVIL ENGG. DIVISION
ER ASHOKA KUMAR SINGH,
F-1304625 (CV)
Address : K-1047, SECTOR K ASHIYANA COLONY LUCKNOW (UP)- 226012
+91 9936415588
: aksingh.idup@yahoo.com



CIVIL ENGG. DIVISION
DR. AWADHESH KUMAR GUPTA,
F-1186975 (CV)
Address : HOUSE NO 347, SECTOR-B VIKAS NAGAR LUCKNOW (UP)-226010
+91 7839470399
: cetkanpur@gmail.com



CIVIL ENGG. DIVISION
ER ASHISH YADAV, M- 1769485(CV)
Address : B/926 VIKAS NAGAR LUCKNOW (UP)- 226022
+91 8004360920
: ashish.iet08@gmail.com,



COMPUTER ENGG. DIVISION
DR. PRAVEEN KUMAR SHUKLA,
M-164296-5 (CP)
Address : PROFESSOR AND DEAN SCHOOL OF ENGINEERING BABU BANARASI DAS UNIVERSITY
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M-1730665 (EL)
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: jaswant_singh_us@yahoo.com



ER PRABHAT KIRAN CHAURASIA,
F-108923-0 (MC)

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: erjsmishra@gmail.com



ER. JITENDRA BAHADUR SINGH,
F-114856-3(CV)

Address : B-2/55 Sector -F Jankipuram Near Engg College Chauraha Lucknow (UP)-226021
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