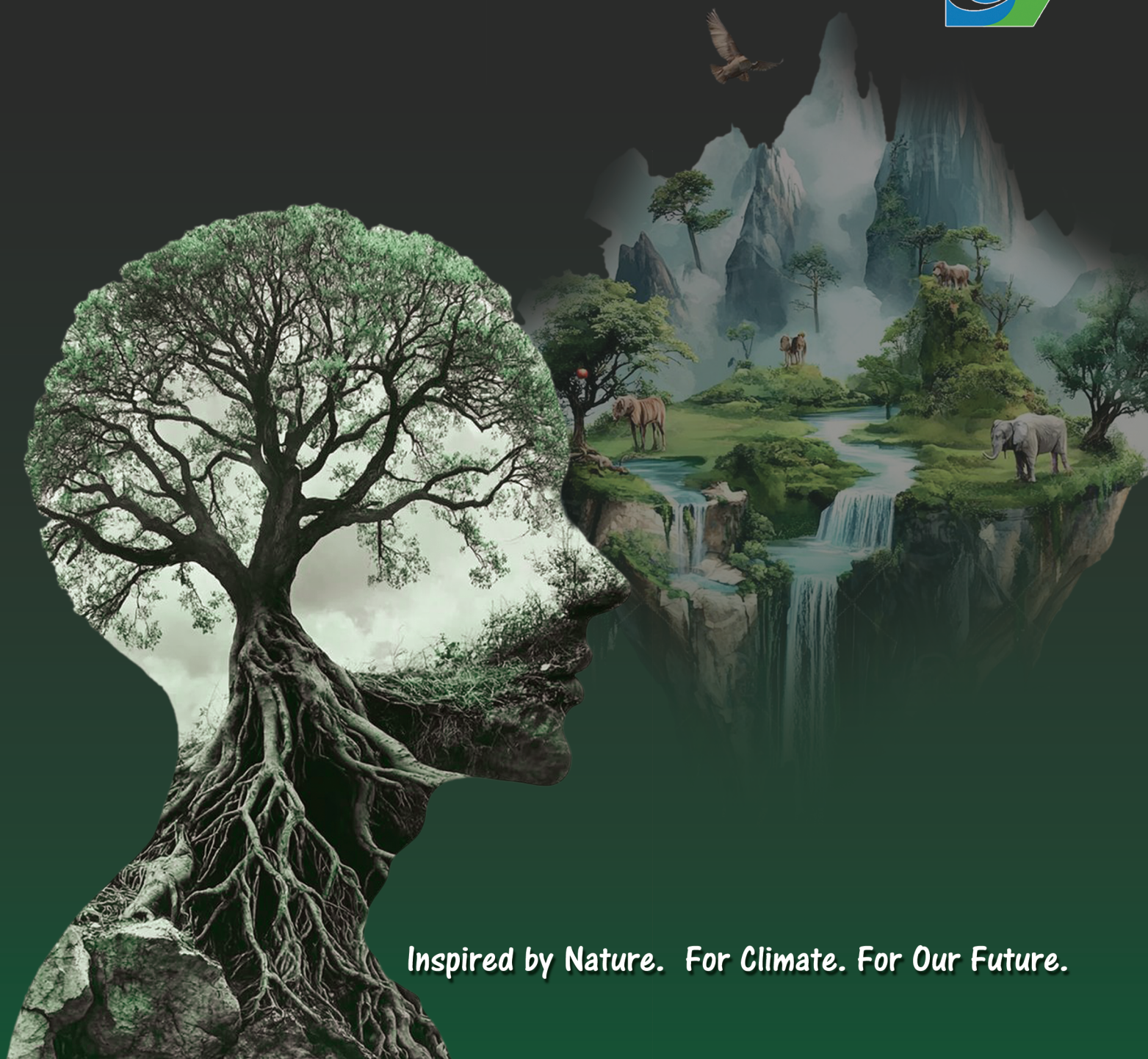


World Environment Day 2026

Souvenir

Vol. -VII

Envicare



Inspired by Nature. For Climate. For Our Future.

Brahmaputra Cracker & Polymer Limited

(A Government of India Enterprise)





Envicare

World Environment Day 2026

Brahmaputra Cracker & Polymer Limited
(A Government of India Enterprise)

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Editorial Desk



Jutika Mahatta



R.B. Shashank

Dear Reader,

“We have not inherited the Earth from our parents; we have borrowed it from our children.”
— Wendell Berry

Although these words were spoken in 1970 by a renowned environmentalist Wendell Berry, they remain profoundly relevant today. The quote serves as a powerful reminder of our responsibility towards the planet and our obligation to protect it for future generations. This year's World Environment Day theme, “Inspired by Nature. For Climate. For Our Future,” echoes the same urgent message.

Economic growth and technological progress are vital for human advancement, but they must not harm the environment or compromise the future of the next generations. Rapid population growth, unsustainable consumption and over exploitation of natural resources have intensified climate change, biodiversity loss, and environmental imbalance. The effects of these practices are now evident through heat-waves, floods, droughts, diseases, and species extinction of many species of the flora & fauna. Protection of the environment has therefore become a shared global responsibility.

Nature demonstrates sustainable and balanced systems that humanity can learn from. By adopting long-term thinking and eco-friendly innovations, such as renewable energy, sustainable agriculture, green architecture, and circular economies, development can progress in harmony with the planet.

Sustainability demands action—reducing emissions, conserving natural resources, restoring ecosystems, and adopting responsible practices across industries, communities, and everyday life. Industries play a crucial role in shaping a sustainable future. BCPL intends to stand in alignment with INDIA's net zero goals by creating roadmap for emission reduction. BCPL is in process of implementing sustainable practices by installing renewable energy sources, improving operational efficiencies, implementing effective waste management systems and water conservation strategies.

Awareness is the foundation of meaningful action. Since its inception, BCPL has been conducting various environmental awareness programs for its stakeholders. The souvenir “**Envicare**,” published by the BCPL Environment Department, is one such initiative. Since 2019, **Envicare** has been spreading environmental awareness among students, communities, organizations, and stakeholders. We hope this edition of **Envicare** will leave a lasting impression on readers, inspire thoughtful reflection, and motivate individuals to actively participate in nurturing the Earth for ourselves and for generations yet to come.

We the human beings, are not the owners but are temporary custodians who should work for the preservation of planet, setting an example before passing on to the upcoming generations rather than fulfilling our immediate needs. Our mission is to secure a sustainable future—a future where clean air, safe water, fertile land, and rich biodiversity remain accessible to all; where innovation and sustainability progress hand in hand; and where true development is measured not only by economic growth, but also by environmental well-being and human resilience.

HAPPY READING !

Deepak Gupta
Chairman
BCPL



दीपक गुप्ता
अध्यक्ष
बी.सी.पी.एल.



M E S S A G E

Warm Greetings on the occasion of World Environment Day 2026. Every year on this day of 5th June, millions of people across the globe unite to pause, reflect and act for the planet we call home. This year's global theme, "Inspired by Nature. For Climate. For Our Future," reminds us that nature is not merely a resource, it is the very foundation of life and development. As a responsible Corporate, our responsibility is even greater to ensure that growth and sustainability go hand in hand.

On World Environment Day, I invite each one of you to pause and reflect on something fundamental to our existence, the environment that sustains us and enables all progress.

The challenges before us, climate change, biodiversity loss, and environmental degradation are imminent, real and urgent. As a leading organization, BCPL has a pivotal role to play in India's transition towards a cleaner, greener energy future. Our continuous efforts in expanding business, improving energy efficiency, and reducing carbon footprint reflect our commitment to sustainable development.

However, sustainability is not achieved through policies alone, it is driven by people. Each of us has a role to play. I urge you to adopt environmentally responsible practices both at work and in your daily lives—be it minimizing waste, conserving energy, supporting green initiatives, or contributing innovative ideas that can make our operations more sustainable. Even small actions, when multiplied across our workforce, can create a significant positive impact.

Let us also remember that the decisions we make today will shape the future for generations to come. We have both an opportunity and a responsibility to ensure that we leave behind a cleaner & healthier planet.

Climate action is no longer simply about reducing carbon emissions on paper, it requires rethinking the systems that power our economy and repair our economies and repairing our relationship with the climate and nature. Nature shows us that systems do not work in isolation. A healthy forest, balanced river basin, or a sustainable local ecosystem thrives on interconnectivity and efficiency.

At this crucial turning point we must shift our focus from problem identification to active implementation, we must redesign our economies by accelerating our energy transition, prioritizing infrastructure and smart urban planning and finally by valuing and protecting natural ecosystems.

I extend my heartfelt gratitude to team BCPL for making efforts to raise environmental awareness through the publication of **Envicare Vol. VII**. May this publication serve as a valuable source of inspiration and encouragement for sustainable practices.

On this World Environment Day, let us reaffirm our collective commitment to environmental stewardship and work together to make BCPL a benchmark in sustainable and responsible energy practices.

Let us be inspired by nature, act decisively for our climate, and build a safe, equitable and sustainable future for all.

Deepak Gupta



M E S S A G E

Pranjal Changmai
Managing Director
BCPL



प्रांजल चांगमाय
प्रबंध निदेशक
बी.सी.पी.एल.

On the occasion of World Environment Day, I extend my warm greetings to all members of the BCPL family.

This year's theme, "Inspired by Nature, For Climate, For Our Future" serves not merely as a celebration of nature, but as a powerful call for collective and immediate action. It reminds us that the Earth is sending clear signals through rising temperatures, extreme weather events, and changing ecosystems. At the same time, positive change is visible across the world through renewable energy, sustainable practices, greener cities, and environmental restoration initiatives.

Our government has launched several significant initiatives to reduce carbon emissions and accelerate the adoption of clean energy solutions. In alignment with India's vision, BCPL has also undertaken initiatives, though on a modest scale, toward adopting environmentally responsible practices and develop a roadmap toward achieving net-zero emissions.

The seventh edition of BCPL's annual magazine, "Envicare," reflects the organization's commitment to raising awareness about the conservation and protection of the environment and inspiring sustainable living practices among individuals and communities.

I congratulate the BCPL Environment Team for their initiative and urge everyone to contribute through awareness, innovation, and responsible practices to build a greener and more sustainable future.

With best wishes,

(Pranjal Changmai)



M E S S A G E

Pruthiviraj Dash
Director (Finance)
BCPL



पृथ्वीराज दाश
निदेशक (वित्त)
बी.सी.पी.एल.

This year, World Environment Day is being observed under the theme "Inspired by Nature, For Climate, For Our Future," which highlights the urgent need for collective action towards environmental sustainability and climate resilience. The theme emphasizes Climate Action, Nature-Based Solutions, Renewable Energy, Sustainable Living, and Ecosystem Restoration, all of which are essential for securing a sustainable future.

Our planet provides invaluable natural resources and ecosystem services that form the foundation of economic growth and human well-being. However, increasing industrialization and unsustainable consumption patterns have significantly impacted the environment, making climate change and ecological conservation critical global concerns. In this context, sustainable development and responsible utilization of resources are no longer optional, but integral to long-term economic and financial stability.

As businesses across the world increasingly adopt the principles of sustainable finance and ESG (Environmental, Social & Governance) practices, it becomes imperative for organizations to align growth strategies with environmental responsibility. Investments in energy efficiency, waste minimization, resource optimization, and green initiatives are not merely environmental obligations, but prudent measures for ensuring operational sustainability and long-term value creation.

BCPL remains firmly committed towards environmental protection and sustainable business practices. The Company continues to integrate environmental consciousness into its operational framework while maintaining the highest standards of efficiency and compliance. I appreciate the dedicated efforts of Team BCPL in contributing towards this shared responsibility.

I am confident that "**Envicare Vol. VII**" will further strengthen environmental awareness and inspire collective action towards building a greener, cleaner, and more sustainable future.

(Pruthiviraj Dash)



Assam Pollution Control Board
(Department of Environment Forests & Climate Change ::
Government of Assam)

অসম প্রদূষণ নিয়ন্ত্ৰণ পৰিষদ
(অসম চৰকাৰৰ বন, পৰিৱেশ আৰু জলবায়ু পৰিবৰ্তন বিভাগ)

Dr. Arup Kumar Misra
Chairman



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It gives me immense pleasure to convey my warmest greetings to Brahmaputra Cracker and Polymer Limited (BCPL) and its dedicated Environment Department on the occasion of **World Environment Day 2026**.

This year's global focus on **climate change and accelerating action to combat its impacts** is a clarion call that industry, institutions, and individuals must heed together. Climate change is no longer a future concern; it is an unfolding reality that demands immediate, bold, and sustained action at every level.

BCPL, as a Government of India Enterprise and the largest petrochemical complex in North- East India, occupies a position of unique responsibility. Operating amidst the ecologically rich and climate-sensitive landscape of Assam and the Brahmaputra valley, a region increasingly vulnerable to floods, erosion, and shifting rainfall patterns BCPL's environmental stewardship carries significance far beyond its industrial boundaries.

The Assam Pollution Control Board has always believed that awareness is the first step towards action. In that spirit, the **Envicare Vol. VII**, stands as a commendable and consistent effort by BCPL's Environment Department to nurture environmental consciousness within the organisation and beyond.

I congratulate the entire team behind **Envicare** and urge readers to carry forward its message not merely as observers, but as active participants in the fight against climate change.

Together, let us build an Assam and a world that is greener, cleaner, and resilient for generations to come.

(Dr Arup Kumar Misra)
Chairman



केन्द्रीय प्रदूषण नियंत्रण बोर्ड

CENTRAL POLLUTION CONTROL BOARD

(MINISTRY OF ENVIRONMENT, FORESTS & CLIMATE CHANGE, GOVT. OF INDIA)

REGIONAL DIRECTORATE (NORTH - EAST)

CTO BUILDING, GROUND FLOOR - II, SHILLONG - 793001



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Inspired by Nature. For Climate. For Our Future.

I am pleased to extend my warm greetings and best wishes on the occasion of World Environment Day 2026 and for the publication of Seventh edition of 'Envicare', the yearly environmental souvenir brought out by Brahmaputra Cracker and Polymer Limited.

"Inspired by Nature. For Climate. For Our Future.", the theme for the WED 2026, conveys a thoughtful message on the importance of harmonizing development with environmental sustainability. Nature continues to inspire solutions that are resilient, sustainable and essential for combating climate change and preserving ecological balance for future generations.

As the apex environmental regulatory body of the country, Central Pollution Control Board emphasizes the need for industries to adopt environmentally responsible practices, cleaner technologies, efficient resource utilization and sustainable operational strategies with the best available techniques (BAT) for production and pollution control. In this context, the efforts of Brahmaputra Cracker and Polymer Limited towards environmental protection, pollution prevention, and promotion of environmental awareness are commendable.

Publications such as Envicare play an important role in disseminating knowledge, sharing best practices and fostering environmental consciousness among industries, institutions and society. I appreciate the initiative taken by BCPL in bringing out **Envicare Vol. VII** as a meaningful contribution towards environmental awareness and sustainable development.

I congratulate the editorial team, contributors and all associated with this publication for their dedicated efforts. I am confident that this souvenir will inspire other industries to strengthen their commitment towards environmental conservation and climate action.

On this occasion of World Environment Day, let us collectively work towards protecting nature, reducing environmental impacts and securing a cleaner, greener and sustainable future for generations to come.

With best wishes,

Dr. Shantanu Dutta

Regional Director, Central Pollution Control Board
Regional Directorate, Shillong



M E S S A G E



सुनील कान्ति

कार्यकारी निदेशक व रिफाइनरी प्रमुख

Sunil Kanti

Executive Director & Refinery Head, GR.

रिफाइनरी प्रभाग

Refineries Division

इंडियन ऑयल कॉर्पोरेशन लिमिटेड

रिफाइनरी प्रभाग : गुवाहाटी रिफाइनरी

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IndianOil



Guwahati Refinery

It gives me immense pleasure to convey my warm greetings and best wishes to the entire fraternity of Brahmaputra Cracker and Polymer Limited (BCPL) on the occasion of World Environment Day 2026. I also compliment BCPL for bringing out the seventh edition of "Envicare", reflecting the organization's continued commitment towards environmental awareness and sustainability.

The World Environment Day theme for this year, "Inspired by Nature. For Climate. For Our Future#NowForClimate" is a timely reminder that environmental protection and sustainable development must remain at the heart of industrial growth. Today, industries across the world are expected not only to achieve operational excellence, but also to actively contribute towards reduction of emissions, conservation of natural resources, energy efficiency, waste minimization, and preservation of biodiversity.

The energy and petrochemical sector have a significant role to play in building a low- carbon and sustainable future. Continuous efforts towards cleaner technologies, responsible resource utilization, circular economy practices, and enhanced environmental stewardship are essential for ensuring long-term sustainability.

I am confident that World Environment Day celebrations and this edition of Envicare will inspire all stakeholders to further strengthen their commitment towards a greener, cleaner, and more sustainable future for generations to come.

Sunil Kanti

(Executive Director & Refinery Head)

Guwahati Refinery

Indian Oil Corporation Limited

Joyonto Panging
Chief Operating Officer
BCPL



जयन्त पांगिंग
मुख्य संचालन अधिकारी
बी.सी.पी.एल.



M E S S A G E

World Environment Day, observed annually on 5 June, serves as a global platform to raise awareness and inspire collective action for the protection and preservation of our environment. As the world continues to confront escalating environmental challenges, this occasion stands as a powerful reminder of our shared responsibility to safeguard the planet for present and future generations.

This year, the **United Nations Environment Programme** emphasizes the urgent need to accelerate climate action, promote clean energy transitions, and restore ecosystems sustainably through the theme *"Inspired by Nature. For Climate. For Our Future."* The theme underscores the inseparable connection between nature, climate resilience, and sustainable development.

Action, indeed, speaks louder than words. Meaningful climate action is essential to reduce pollution, conserve natural resources, and address the growing threat of global warming. Even small, consistent efforts—such as planting trees, reducing waste, and conserving energy—can collectively create a significant and lasting impact.

As a responsible corporate citizen, BCPL continues to undertake multiple initiatives aimed at building a sustainable and environmentally responsible future. BCPL remains steadfast in its commitment to environmental stewardship, and I commend the entire BCPL team for their unwavering dedication to achieving the highest standards of sustainability.

I take this opportunity to congratulate the BCPL Environment team and am confident that the souvenir, **"Envicare Vol. VII,"** will serve as an important medium for disseminating environmental awareness and inspiring positive action, thereby contributing meaningfully to the larger goal of environmental protection and climate resilience.

Joyonto Panging

Sitangshu Paul
Chief General Manager
BCPL



सितांशु पाल
मुख्य महाप्रबंधक
बी.सी.पी.एल.



M E S S A G E

Recognizing the profound interconnection between the environment, human well-being, and global economic development, the United Nations designated 5th June as World Environment Day in 1974, establishing it as the world's largest global platform for environmental public outreach and awareness. Since then, this observance has served as a powerful reminder of our shared responsibility to protect and preserve the natural systems that sustain life on Earth.

Today, the far-reaching consequences of environmental degradation are evident across the globe. Floods, droughts, land degradation, and desertification pose serious threats to ecosystems, livelihoods, and economic stability. As the World Environment Day campaign gathers momentum, it presents a valuable opportunity to reflect, realign our priorities, and take meaningful, collective action for environmental protection.

World Environment Day is not merely a celebration of nature; it is an appeal that reminds us of our responsibility to protect and preserve the planet we call home. Industries, and organizations must collaborate to strengthen conservation frameworks and promote environmentally responsible practices. Equally important is the role of citizens in supporting initiatives that protect ecosystems and maintain ecological balance. **BCPL** is contributing to this noble cause through the adoption of circular economy practices, support for renewable energy projects, improvements in operational efficiency, plantation drives, community cleaning initiatives, and a range of awareness programmes for stakeholders under its Corporate Social Responsibility and Corporate Environment Responsibility commitments.

BCPL has been commendable towards the journey of sustainable environment. I would like to appreciate Environment Department for their initiative to come up with this souvenir to spread awareness towards environmental concerns through this media among all stakeholders.

Sitangshu Paul

HOD's Desk



Abhijit Nath

General Manager (Chemical)
Environment Department, BCPL

"The future depends on what we do in the present."

— Mahatma Gandhi

It gives me immense pleasure to extend my greetings to all readers of **Envicare** on World Environment Day 2026.

This year's theme **"Inspired by Nature. For Climate. For Our Future"** reminds us that nature creates nothing that goes to waste. As industries across the world embrace circularity and resource efficiency, there is much we can learn from this profound principle.

Over the years, environmental stewardship has evolved from being a responsibility of a few to a shared commitment of all. Today, every decision we make—whether in design, operations, maintenance, or resource utilization—has an impact on the world around us. As professionals and as citizens, we have the opportunity and the responsibility to ensure that this impact is a positive one.

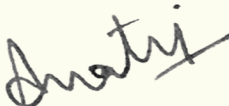
At BCPL, sustainability is not merely a goal; it is a way of thinking that guides our actions. Our continued efforts towards energy efficiency, resource conservation, waste reduction, circular economy initiatives, and our journey towards Net Zero reflect this commitment. While technology and innovation remain important enablers, meaningful progress is ultimately driven by the collective efforts of people who believe in making a difference.

Envicare reflects these efforts. It captures our experiences, achievements, and ideas, while also reminding us that environmental protection is a continuous journey.

I congratulate the editorial team for bringing out this edition and thank all employees and stakeholders whose dedication contributes to a safer, cleaner, and more sustainable future.

Let us continue to work together so that future generations inherit not only a stronger organization, but also a healthier planet.

Regards.


Abhijit Nath

Introducing Miyawaki Plantation in North East India: A Nature-Based Solution for Ecological Restoration and Climate Resilience



Dr. Shantanu Dutta

Regional Director
CPCB, Shillong

Introduction

Rapid urbanization, industrialization, deforestation and climate change have significantly affected ecological balance across many parts of India, including the ecologically sensitive North Eastern Region. Declining green cover, soil degradation, biodiversity loss and increasing environmental pressures necessitate innovative and sustainable approaches to ecological restoration. Among various afforestation techniques adopted globally, the Miyawaki method of dense native forest plantation has emerged as an effective nature-based solution for rapid ecological regeneration and climate resilience. The Miyawaki plantation technique, pioneered by the renowned Japanese botanist and plant ecologist Akira Miyawaki (1928-2021), focuses on creating dense native forests that grow rapidly and become self-sustaining within a relatively short period.

The introduction of the Miyawaki plantation technique in North East India was significantly influenced by the author's participation in a specialized environmental training programme in Japan sponsored by Japan International Cooperation Agency

(JICA) during October 26 to December 16, 2011. The training program entitled 'Rehabilitation of degraded land in Asia and Africa', provided extensive exposure to advanced environmental management practices, ecological restoration models, urban greening initiatives, and biodiversity conservation approaches implemented across Japan.

A major component of the training programme included interaction with renowned Japanese botanist and ecologist Prof Emeritus Akira Miyawaki, whose pioneering work on native forest restoration through dense plantation methods has already gained worldwide recognition. Field visits to several successful Miyawaki forests in Japan demonstrated the remarkable effectiveness of this method in restoring degraded landscapes, industrial zones, coastal belts, and urban ecosystems. During the course of the training the author also had the golden opportunity to take part in planting an 'Environmental Protection Forest' in Japan together with the pioneer of the method Akira Miyawaki himself.



Introducing the Miyawaki Plantation in North East India

North East India possesses rich biodiversity and fragile ecosystems that require sustainable conservation approaches. The Miyawaki method can play an important role in:

- Urban greening
- Restoration of degraded mining and industrial areas
- Riverbank stabilization
- Roadside plantation
- Institutional and community forestry
- Climate change mitigation

The approach is particularly relevant for environmentally sensitive regions where rapid ecological restoration is required.

The remarkable success of Miyawaki plantations in restoring degraded landscapes, industrial zones, urban spaces, and coastal protection belts in Japan strongly encouraged the author to explore the feasibility of introducing similar ecological restoration initiatives in North East India. With an understanding of the ecological and environmental benefits from an environmental protection forest being planted in Japan and various other countries in the world, the author undertook extensive plantation initiatives in collaboration with industries, institutions and environmental stakeholders to introduce the Miyawaki method in North East India, particularly in the states of Assam and Meghalaya. The objective was to utilize native species-based dense plantation techniques for ecological restoration, industrial greenbelt development, biodiver-

sity enhancement and climate resilience. Efforts have been made to introduce this innovative ecological restoration model in North East India. So far more than 850,000 native saplings were successfully introduced across over 50 plantation pockets, primarily within industrial premises and environmentally degraded areas in Assam and Meghalaya.

The plantations focused on:

- Restoration of degraded industrial landscapes
- Development of dense native greenbelts
- Improvement of local biodiversity
- Dust and pollution mitigation
- Carbon sequestration and climate adaptation
- Enhancement of ecological aesthetics

The Miyawaki plantations utilized indigenous tree and shrub species adapted to local climatic and ecological conditions of the North Eastern Region. Scientific soil preparation, dense multi-layer plantation, organic mulching and periodic maintenance were carried out in accordance with Miyawaki principles, suitably modified.

Several industrial organizations actively participated in the initiative by allocating land within their premises for ecological restoration and greenbelt development. These plantations demonstrated rapid growth, dense canopy formation, improved survival rates, and enhanced ecological conditions within a relatively short period.

One of the significant outcomes of the initiative has been the successful transformation of underutilized and environmentally stressed industrial spaces into self-sustaining green ecosystems supporting local flora and fauna. The plantations have

also contributed towards improving environmental awareness among industries and local communities regarding the importance of native biodiversity conservation and climate-resilient ecological restoration.

The successful introduction of Miyawaki plantations in Assam and Meghalaya demonstrates the adaptability and effectiveness of this Japanese ecological restoration model under Indian conditions, particularly in ecologically sensitive and high-rainfall regions of North East India. The initiative highlights the potential of nature-based solutions in addressing environmental degradation, industrial pollution, and climate-related challenges while simultaneously promoting sustainable development and biodiversity conservation.

Concept of Miyawaki Plantation

The Miyawaki method is based on the principle of restoring native forest ecosystems by planting diverse indigenous species in dense formations. The method replicates natural forest conditions and accelerates ecological succession. The Key Characteristics of Miyawaki Plantation are:

- Use of native and indigenous plant species
- Multi-layer plantation system
- Dense planting pattern
- Rapid growth and canopy development
- Minimal maintenance after initial establishment
- Enhanced biodiversity and carbon sequestration

Unlike conventional plantation methods, Miyawaki forests grow nearly ten times faster and become self-sustaining within 10-15 years, as observed in North East India, compared to natural forests that may take over a century to mature.

Ecological and Environmental Benefits of Miyawaki technique of dense plantation

The Miyawaki technique of dense native plantation offers significant ecological and environmental benefits by rapidly restoring natural forest ecosystems using indigenous plant species. The Miyawaki method promotes dense multi-layer vegetation that accelerates forest growth and biodiversity recovery. Miyawaki forests exhibit high rates of carbon sequestration, thereby contributing effectively to climate change mitigation and reduction of atmospheric greenhouse gases. The dense vegetation improves air quality by trapping dust and pollutants, reduces ambient temperature, and enhances local microclimatic conditions. The extensive root systems of native species help prevent soil erosion, improve soil fertility, and increase groundwater recharge through better water retention. These plantations also provide habitat and food sources for birds, insects, butterflies, and other wildlife, thereby strengthening ecological balance and biodiversity conservation. In industrial and urban areas, Miyawaki forests serve as effective green buffers against noise, dust, and pollution while transforming degraded landscapes into self-sustaining green ecosystems. As a nature-based solution, the Miyawaki technique demonstrates immense potential for ecological restoration, environmental sustainability, and climate resilience. Besides, rapid biomass growth contributes significantly to carbon absorption and climate mitigation.

A successful Implementation of Miyawaki Technique in North East India

A remarkable ecological restoration initiative was undertaken by the author inside the industrial premises of Meghalaya Cement Limited, East Jaintia Hills district,

Meghalaya following the Miyawaki method of dense native plantation. In a degraded parcel of land with an area of approximately 0.42 hectares., nearly 10,500 saplings representing 52 native species were scientifically planted in a single day on 12.07.2016 to create a dense, self-sustaining native forest ecosystem. The plantation was designed using multilayer vegetation principles with indigenous species suited to the climatic and ecological conditions of Meghalaya. Over the last decade, from 2016 to 2026, the plantation has demonstrated remarkable growth and ecological transformation. The sequential photographs documenting the site vividly capture the gradual evolution of the plantation from a barren patch of land into a thriving dense forest ecosystem rich in greenery and biodiversity. The initiative stands as a powerful example of how a forest can indeed be born within ten years through scientific ecological restoration inspired by nature.

Outcomes and Benefits

The project demonstrated encouraging results within a relatively short period:

- Rapid growth of vegetation
- Dense canopy formation
- Increased bird and insect activity
- Improved green landscape
- Enhanced environmental awareness among employees and local communities

The success of the initiative highlighted the suitability of the Miyawaki method for industrial ecological restoration and climate adaptation in North East India.

Conclusion

The Miyawaki plantation method represents a scientifically proven and environmentally sustainable approach for ecological restoration and climate resilience.

Plantation of an Environmental Protection Forest in the premises of Meghalaya Cements Limited

		
Area before plantation	12.07.2016	12.07.2016
		
June 2020	June 2020	
		
May 2026	May 2026	
A 10 year old Environmental Protection Forest (2016-2026) is born		

Exposure to successful Miyawaki projects in Japan under the guidance of Prof. Emeritus Akira Miyawaki during the Japan International Cooperation Agency sponsored training programme provided valuable inspiration for introducing this innovative afforestation model in North East India.

The Miyawaki native dense plantation technique is closely aligned with the theme of World Environment Day 2026 — “Inspired by Nature. For Climate. For Our Future.” — as it represents a powerful nature-based solution for ecological restoration and climate action. The plantation technique or model emphasizes the restoration of native biodiversity through dense plantation of indigenous species, enabling rapid growth of self-sustaining forests. These mini forests significantly enhance carbon sequestration, improve air quality, conserve soil moisture, restore ecological balance, and support local biodiversity, thereby contrib-

uting directly to climate change mitigation and environmental sustainability. By recreating natural forest ecosystems even within degraded and industrial landscapes, the Miyawaki method demonstrates how solutions inspired by nature can strengthen climate resilience and promote a greener, healthier future for coming generations.

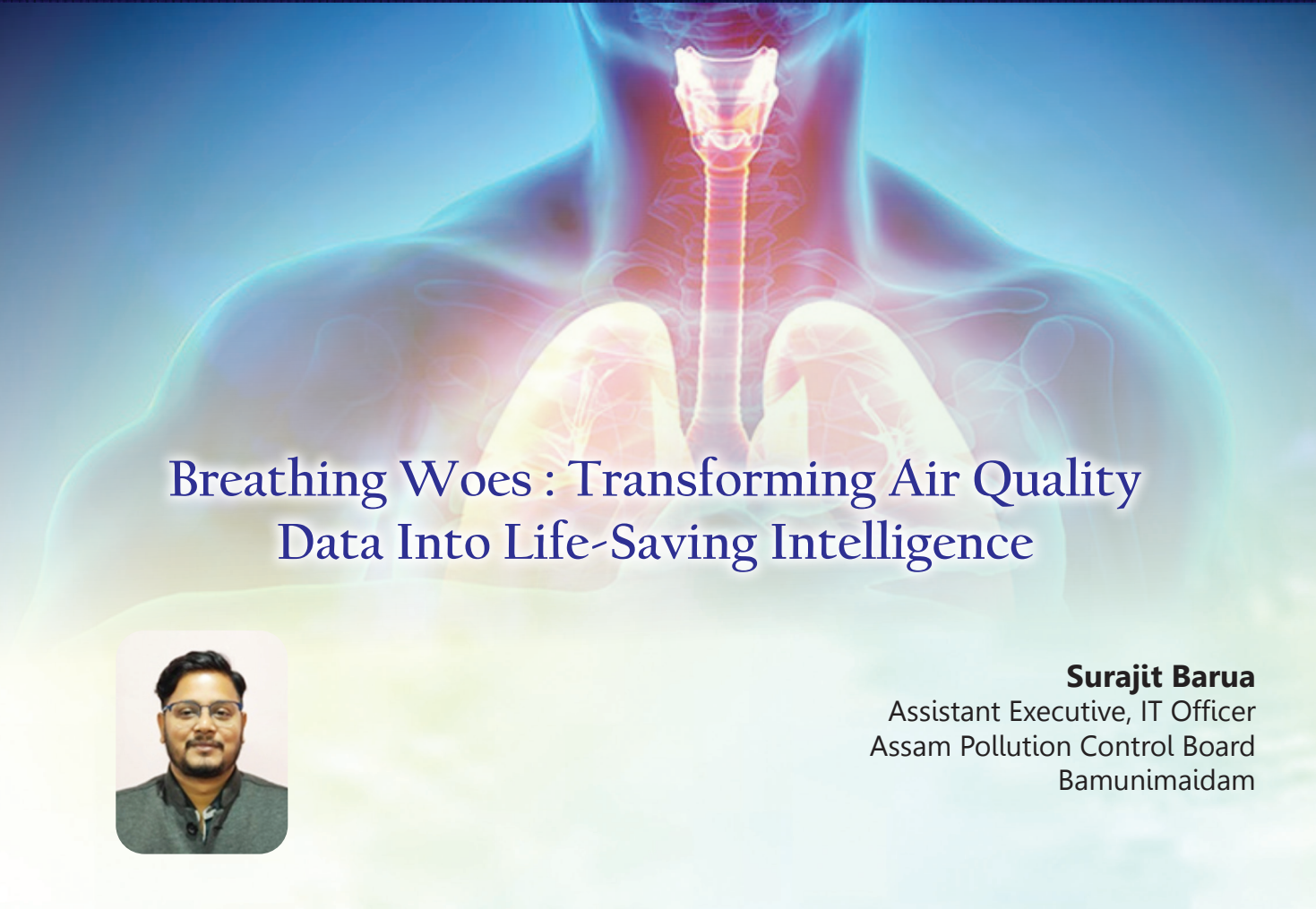
The successful implementation at Meghalaya Cement Limited demonstrates that Miyawaki plantations can serve as an effective nature-based solution for restoring ecological balance, improving biodiversity, enhancing green cover, and supporting climate resilience in the region.

With increasing environmental challenges and climate concerns, adoption of such sustainable ecological restoration practices can contribute significantly towards building a greener, healthier, and environmentally resilient future for North East India.



**CONSERVATION IS A
STATE OF HARMONY
BETWEEN MEN AND
LAND.**

– ALDO LEOPOLD



Breathing Woes : Transforming Air Quality Data Into Life-Saving Intelligence



Surajit Barua

Assistant Executive, IT Officer
Assam Pollution Control Board
Bamunimaidam

Air is the fundamental foundation of life on Earth. At present Air Pollution become one of the leading environmental threats. Every year, 1.72 million Indians die from breathing air that their own lungs cannot tolerate. This is not a projection — it is documented reality from the 2025 Lancet Countdown on Health and Climate Change. India accounts for nearly 70 percent of all global deaths linked to air pollution. The economic toll is equally devastating: \$339.4 billion lost annually, nearly ten percent of India's GDP.

These are not abstract statistics. Behind every number is a child with asthma, a construction worker whose lungs gave out at forty-five, an elderly woman whose heart failed during a pollution spike. Air pollution is the silent epidemic, accumulating quietly,

particle by particle, in lungs designed for clean air but forced to process the exhaust of rapid industrialization. The tragedy is that much of this suffering is preventable. India has invested heavily in air quality monitoring infrastructure over the past decade. The country now operates 595 real-time Continuous Ambient Air Quality Monitoring Stations across 32 states, generating millions of data points daily. The data is flowing. The sensors are working. But the intelligence is missing. Most Indian cities use monitoring stations simply to record what has already happened — a continuous documentation of crisis that almost no one acts on until it becomes unbearable.

Yet this same data, if analysed with artificial intelligence, could predict pollution spikes 24 to 72 hours in advance, identify

which emission sources are responsible, and trigger early warnings that allow people to protect themselves before toxic air fills their neighbourhoods. The technology exists. The infrastructure is in place. What India needs now is not more sensors, but smarter use of the ones it already has.

India's Monitoring Infrastructure: A Foundation Ready for Intelligence

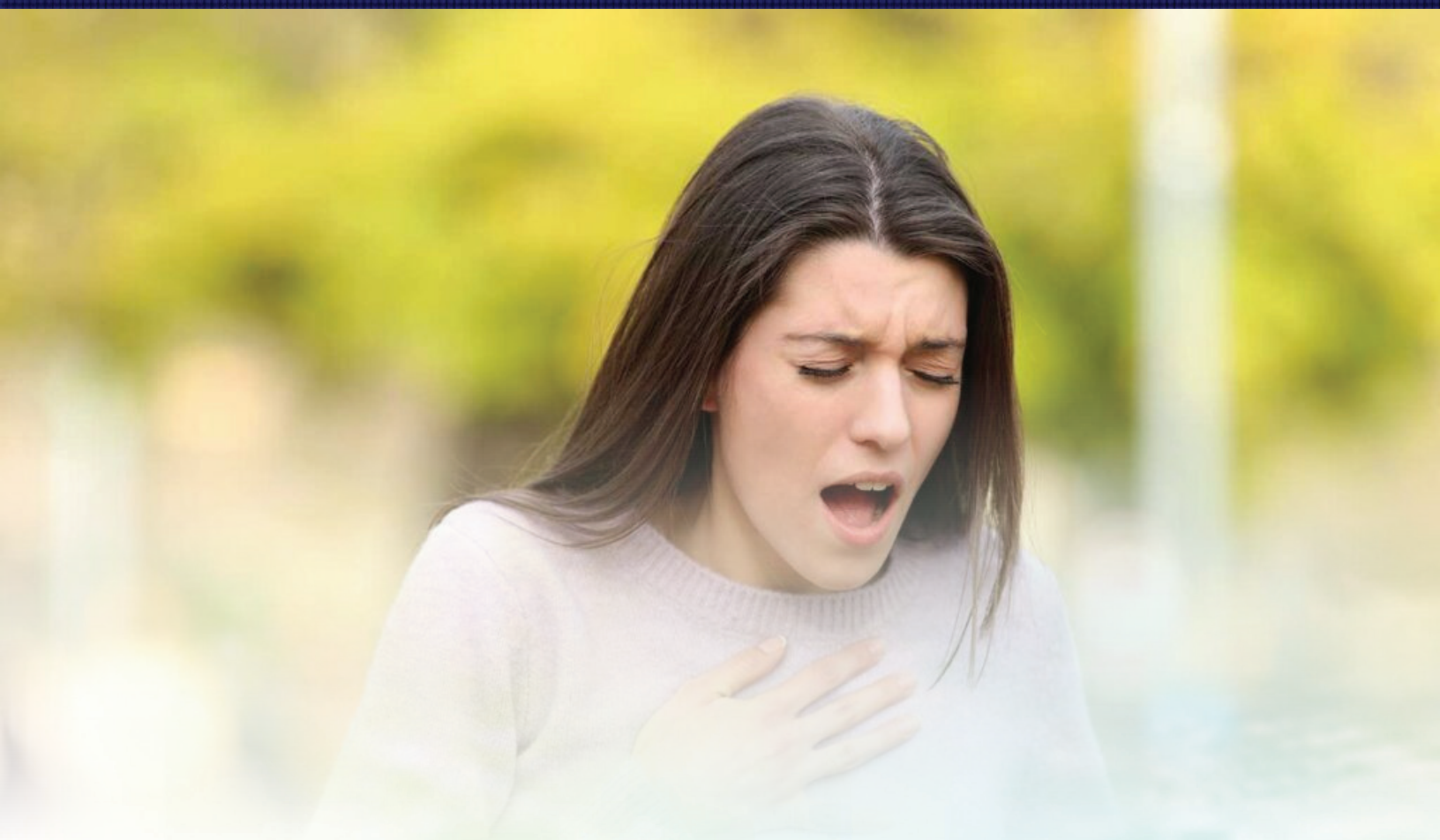
Manual air quality monitoring has been the backbone of India's air quality assessment for many years. It has helped in long-term trend analysis, regulatory reporting, compliance verification and scientific understanding of pollution levels. However, manual monitoring has certain limitations in the present context. Samples are collected periodically, analysed in laboratories and reported later. As a result, it may not capture sudden pollution peaks caused by traffic congestion, construction activities, industrial emissions, biomass burning, weather changes or festival-related activities. By the time the data is available, the pollution episode may have already affected the public. This delay makes manual monitoring useful for documentation, but less effective for immediate action.

Continuous Ambient Air Quality Monitoring Stations, or CAAQMS, address this gap by providing near real-time air quality data. These stations continuously measure key pollutants such as $PM_{2.5}$, PM_{10} , SO_x , NO_x , CO, O_2 and other parameters, and transmit the data to central servers. This allows regulators to understand how pollution changes throughout the day during traffic hours, industrial operations, weather variations and local activities. Unlike manual monitoring, CAAQMS helps authorities know the present air quality condition almost immediately, making the system more suitable for timely intervention.

The advantage of CAAQMS is not limited to real-time display of pollution levels; it supports several important areas of air quality management. It improves public awareness by allowing citizens, especially children, elderly people and patients with asthma or heart disease, to take precautions based on current air quality. It strengthens regulatory response by helping authorities detect sudden pollution spikes and plan field inspections while the incident is still active. It also supports hotspot identification, as repeated high values at a particular location may indicate pressure from traffic, industries, dust or burning. Further, hourly or sub-hourly data helps in trend and pattern analysis, showing morning traffic peaks, evening pollution build-up, seasonal changes and weekday-weekend variations.

CAAQMS data creates the foundation for AI- and Machine Learning-based air quality prediction because continuous stations generate large volumes of time-series observations. When this data is combined with meteorological parameters such as wind speed, wind direction, temperature, humidity and rainfall, AI models can learn pollution behaviour and forecast likely air quality conditions for the next 24 to 72 hours. This helps authorities move from a reactive system to a preventive system, where early warnings and control measures can be planned before AQI reaches "Very Poor" or "Severe" levels.

India's shift from manual to continuous monitoring has accelerated significantly, especially after the launch of the National Clean Air Programme in 2019, which prioritised stronger monitoring in non-attainment cities. From fewer than 20 CAAQMS stations in 2010, India now has 595 real-time stations across 289 cities as of May 2026, with 186 stations added between 2022 and



2026 alone. However, manual monitoring still remains important for laboratory-based analysis, gravimetric validation, chemical characterisation and legal/regulatory purposes. Therefore, the best approach is an integrated system where CAAQMS provides speed, continuity, public information, early warning and AI-ready data, while manual/NAMP stations provide validation, detailed analysis and regulatory reliability. Together, both systems can create a stronger and more intelligent air quality monitoring framework.

The Data Gap That Remains

Despite impressive CAAQMS expansion, significant gaps remain. Of India's 289 cities with continuous monitoring, 75 stations (12.6 percent) are currently inactive and 35 (5.9 percent) experience data transmission delays. Some states have em-

braced real-time monitoring enthusiastically — Maharashtra with 103 stations, Uttar Pradesh with 63 — while others lag far behind. The entire Northeast region, covering eight states and 46 million people, operates just 20 CAAQMS stations.

More fundamentally, even 595 CAAQMS stations cannot provide wall-to-wall coverage across India's 3.28 million square kilometers. Smaller cities, rural areas, and regions distant from major metros remain largely unmonitored in real time. This is where the next technological leap — integrating CAAQMS data with satellite observations through machine learning — becomes critical. Ground sensors provide accuracy and regulatory validity; satellites provide spatial coverage; AI models fuse both to create high-resolution pollution maps for areas without monitors.

Table 1: State-wise Distribution of CAAQMS Stations (As of May, 2026)

Rank	State/UT	Total	Live	Inactive	Delay	% Total
1	Maharashtra	103	82	11	10	17.3%
2	Uttar Pradesh	63	56	4	3	10.6%
3	Delhi	47	44	1	2	7.9%
4	Rajasthan	46	44	0	2	7.7%
5	Karnataka	42	24	15	3	7.1%
6	Tamil Nadu	37	15	22	0	6.2%
7	Bihar	35	30	2	3	5.9%
8	Haryana	31	25	3	3	5.2%
9	Madhya Pradesh	30	27	3	0	5.0%
10	Gujarat	22	21	1	0	3.7%
10	West Bengal	22	21	0	1	3.7%
12	Odisha	19	16	0	3	3.2%
13	Andhra Pradesh	17	13	2	2	2.9%
14	Chhattisgarh	14	13	0	1	2.4%
14	Telangana	14	13	1	0	2.4%
16	Assam	9	9	0	0	1.5%
16	Kerala	9	5	3	1	1.5%
18	Punjab	8	7	0	1	1.3%
19	Jharkhand	4	2	2	0	0.7%
20	Chandigarh	3	2	1	0	0.5%
20	Jammu & Kashmir	3	3	0	0	0.5%
20	Meghalaya	3	3	0	0	0.5%
20	Uttarakhand	3	3	0	0	0.5%
24	Manipur	2	0	2	0	0.3%
24	Tripura	2	1	1	0	0.3%
26	Andaman & Nicobar	1	0	1	0	0.2%
26	Arunachal Pradesh	1	1	0	0	0.2%
26	Himachal Pradesh	1	1	0	0	0.2%
26	Mizoram	1	1	0	0	0.2%
26	Nagaland	1	1	0	0	0.2%
26	Puducherry	1	1	0	0	0.2%
26	Sikkim	1	1	0	0	0.2%
	TOTAL	595	485	75	35	100%

Source: Central Pollution Control Board, Real-time CAAQMS Dashboard, May 13, 2026. Note: Northeast India states (Assam, Meghalaya, Manipur, Tripura, Arunachal Pradesh, Mizoram, Nagaland, Sikkim) highlighted in yellow

The numbers show concentrated monitoring in states with large populations and industrial activity. Maharashtra leads with 103 stations, followed by Uttar Pradesh (63), Delhi (47), and Rajasthan (46). These

four states account for 43 percent of India's monitoring infrastructure. The challenge is not the sensors — it is what comes next.

Advanced States and Global Success: Showing What Is Possible

Delhi's SAFAR System: When Delhi prepared for the 2010 Commonwealth Games, the System of Air Quality and Weather Forecasting and Research (SAFAR) was inaugurated as India's first operational air quality forecasting framework. By 2018, IITM, India Meteorological Department, and the US National Center for Atmospheric Research developed a 400-meter resolution PM_{2.5} forecasting system — so fine it distinguishes pollution levels between neighborhoods. The system achieves 83 percent accuracy in predicting "very poor" air quality episodes three days in advance, feeding into Delhi's Graded Response Action Plan to trigger preemptive measures like school closures and truck restrictions before pollution arrives.

Maharashtra's Dense Network: With 103 CAAQMS stations — the highest in India — Maharashtra has built infrastructure capable of supporting state-wide AI forecasting. Karnataka demonstrates that monitoring paired with effective governance produces results: six of India's top-10 cleanest cities are in Karnataka. Tamil Nadu added seven new stations in October 2024 alone, signaling rapid expansion ambition.

Beijing's Transformation: If any city proves what data-driven action achieves, it is Beijing. In 2013, Beijing's annual PM_{2.5} exceeded 101 $\mu\text{g}/\text{m}^3$. The Chinese government launched a comprehensive Air Pollution Prevention and Control Action Plan backed by \$100 billion. By 2021, PM_{2.5} dropped to 33 $\mu\text{g}/\text{m}^3$ — a 67 percent reduction. Heavily polluted days fell from 58 in 2013 to just 2 in 2024. The UN Environment Programme called it the "Beijing Miracle." Beijing's success rests on comprehensive source control (coal consumption dropped from 21.8 million tonnes to under 600,000 tonnes), data-

driven decision making through continuous monitoring and source apportionment, and regional coordination with surrounding provinces. Research shows Beijing's improvements will extend average resident life expectancy by 4.6 years — four additional years simply from breathing cleaner air. Beijing proved that data-driven air quality management works.

Northeast India: A Region Waiting for Attention

While some advanced states are moving towards real-time forecasting and data-driven air quality management, Northeast India still remains under-monitored. The eight Northeastern states, covering nearly 46 million people and 262,230 sq. km, have only 20 CAAQMS stations, which is just 3.4% of India's total real-time monitoring network despite covering about 8% of the country's geographical area. In comparison, Maharashtra alone has 103 stations, while the entire Northeast has only 20. Assam has 9 stations, but most other Northeastern states have very limited coverage; Arunachal Pradesh, Mizoram, Nagaland and Sikkim have only one station each, and Manipur's two stations are inactive. This limited monitoring creates a serious data and accountability gap. Without adequate real-time stations, regulators cannot properly verify local pollution trends, health authorities cannot prepare for pollution-linked emergencies, and citizens do not get enough evidence to demand timely action. Pollution sources such as industrial clusters, traffic corridors, biomass burning, construction dust and cross-border transport may remain poorly understood because the monitoring network is too sparse to capture regional variations.

However, the Northeast does not need to wait for a large network before improving air quality governance. Even the existing CAAQMS data can be used more intelligently through AI, GIS, satellite data and meteorological modelling. Regional transport modelling can help understand how emissions from areas like Byrnihat may affect Guwahati and nearby regions. Seasonal forecasting can identify high-risk periods, while satellite integration can fill monitoring gaps. The immediate need is to expand the network strategically and use modern analytics so that the region is no longer invisible in India's air quality management system.

Five Ways AI Can Transform Air Quality Data

India's 595 CAAQMS stations generate 14,000 data points hourly — 122 million observations annually. The technology to transform this into predictive intelligence already exists and is operational worldwide. What India needs is adoption.

- **Predictive Forecasting:** Machine learning models can analyze historical sensor data, meteorological forecasts, and traffic patterns to predict PM_{2.5} and ozone levels 24 to 72 hours ahead. Delhi's 400-meter SAFAR system achieves 83 percent accuracy. Similar systems could deploy in every major city using open-source models like WRF-Chem with TensorFlow or PyTorch. Forecasting enables proactive measures — suspending construction before pollution spikes, rerouting trucks, scheduling outdoor activities for clean air days, hospitals stocking medications before predicted waves. The technical barrier is modest; the computational infrastructure for a city like Bengaluru costs less than one CAAQMS station's annual budget.

- **Satellite Integration:** NASA's MODIS and ESA's Sentinel satellites measure aerosol optical depth daily at one-kilometer resolution. ISRO provides free satellite imagery through Bhuvan. Machine learning can fuse satellite observations with sparse ground data to generate high-resolution pollution maps for regions without monitors. IIT Gandhinagar researchers used satellite imagery and AI to detect 30,638 brick kilns across India — informal sources traditional inventories miss. For Northeast India's sparse 20-station network covering 262,000 square kilometers, satellite fusion could provide daily pollution estimates for every district.

- **Source Apportionment:** When pollution rises, authorities need to know which sources to target. Machine learning analyzing chemical composition, meteorological conditions, and temporal patterns can estimate contributions from vehicles, industries, biomass burning, construction, and transboundary transport in near real-time. A 2023 Delhi study using ML performed hourly source apportionment, revealing vehicles dominated mornings, industries peaked afternoons, biomass burning drove evenings — allowing time-specific interventions rather than blanket measures.

- **Regional Transport Modelling:** Air pollution ignores boundaries. AI-powered transport models simulate how wind carries pollutants across regions. For the Northeast's complex topography, models could map how Byrnihat's emissions reach Guwahati, how seasonal winds bring pollution from Bangladesh. This enables cooperative regulation — if 30 percent of Guwahati's pollution originates from Meghalaya, both states coordinate enforcement.

- **Public Health Integration:** Machine learning can analyze relationships between PM_{2.5}, temperature, humidity, and hospital

admissions to forecast respiratory emergencies 24-48 hours ahead. A Beijing 2022 analysis found this reduced emergency room overcrowding by 18 percent during pollution episodes. India's Ayushman Bharat Digital Mission builds unified health records; CAAQMS provides hourly readings; meteorological departments supply forecasts. Integration would enable automated alerts to patients with chronic conditions and hospital preparation before demand spikes.

Use of AI in Other Countries for Air Quality Management

Several countries are now using real-time air quality data not only for monitoring, but also for prediction, early warning and decision-making. The common approach is to combine continuous monitoring station data with meteorological information, satellite observations, emission inventories and machine learning models. This helps authorities understand not only the present air quality, but also the likely pollution situation in the next few hours or days.

In the **United States**, the EPA's AirNow system uses real-time data from air quality monitoring networks to provide public air quality information and forecasts. Air quality agencies across the country issue forecasts for pollutants such as ozone and particulate matter, which are then communicated to the public through maps and alerts. This helps citizens, schools and health agencies take precautionary action during poor air quality days. NOAA has also upgraded its air quality forecast guidance to extend forecasts up to **72 hours**, improving the ability to predict pollution episodes in advance.

In **Europe**, the Copernicus Atmosphere Monitoring Service (CAMS) provides daily air quality analyses and forecasts. It

monitors and forecasts European air quality as well as long-range transport of pollutants across the world. CAMS produces forecast products that are used by national agencies, smartphone applications, researchers and policy tools. It also provides four-day forecasts for regulated air pollutants, pollen and aerosol tracers across Europe. This shows how monitoring data can be converted into public information, policy support and health advisories.

In **China**, AI and deep learning models are widely used in research and operational air quality forecasting. Studies using Chinese city datasets have applied artificial neural networks, CNN-LSTM models and graph neural networks to predict $PM_{2.5}$ and PM_{10} concentrations using monitoring data, time variables and meteorological parameters. These models can learn both temporal patterns and spatial relationships between monitoring stations, which is useful for predicting pollution movement from one area to another. China has also announced plans to strengthen air quality forecasting and early warning systems as part of its broader pollution-control strategy.

In many countries, AI is also being used for source identification. When real-time monitoring data is combined with wind direction, pollutant ratios and emission information, machine learning models can help identify whether pollution is mainly coming from traffic, industry, biomass burning, dust or regional transport. This helps authorities take targeted action instead of applying general restrictions everywhere.

Another important use is satellite-based pollution mapping. Ground monitoring stations provide accurate local data, but they cannot cover every location. Countries in Europe, the United States and China combine satellite observations with ground

station data and AI models to estimate pollution levels in areas without monitors. This is especially useful for regional mapping, rural areas and cross-boundary pollution transport.

These examples show that the future of air quality management is moving from simple monitoring to predictive environmental governance. CAAQMS data becomes more powerful when it is linked with AI, meteorology, satellite data and health information. For India also, especially for under-monitored regions like the Northeast, this approach can help in early warning, hotspot identification, inspection planning, public alerts and evidence-based pollution control.

Path Forward:

India has already invested heavily in air quality monitoring infrastructure, with 595 CAAQMS stations generating nearly 122 million data points annually. The next priority must be to convert this raw data into intelligence. Pollution Control Boards need to move beyond routine compliance monitoring and strengthen their capacity in data analytics, AI/ML modelling, GIS, satellite-data integration and forecasting. A national air quality intelligence platform can

combine CAAQMS data, manual monitoring records, meteorological forecasts, satellite imagery, emission inventories and health information to generate daily forecasts, hotspot alerts, source-related insights and public health advisories. This will help shift air quality management from a reactive system to a preventive and evidence-based governance model.

The need is even more urgent for under-monitored regions such as the Northeast, where nearly 46 million people are covered by only 20 CAAQMS stations. The region cannot remain invisible while other parts of India move toward data-driven air quality management. Delhi has already shown that forecasting can work in Indian conditions, while states such as Maharashtra, Karnataka and Tamil Nadu have built stronger monitoring networks that can support advanced analytics. The way forward is clear: use existing data intelligently, expand monitoring where gaps exist, and apply AI to predict pollution before it becomes severe. Air quality data should not remain only as numbers on a dashboard; it must become a tool to protect lives, guide regulation and support timely environmental action.



*Plants can survive without humans but humans
can not survive without plants.*



Digital Biomonitoring : Can Technology Help Us Track Climate Damage in Real Time?



Namrata Kundu

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The River Sent a Warning. Nobody Was Listening.

India is home to over 400 river systems, yet a 2022–23 review by the Central Pollution Control Board (CPCB), covering 2,116 river locations, identified 296 polluted river stretches with 38% of monitored sites-failing even the basic Biochemical Oxygen Demand (BOD) standard of 3 mg/L (CPCB, 2023). These are not remote, unmapped water bodies. These are rivers that millions of Indians drink from, fish in, and depend on for agriculture every single day.

The contamination profile of these rivers has grown increasingly complex. In the Brahmaputra basin, microplastic concentrations have been recorded as high as 37,000

items per cubic metre at Tezpur, with sediment contamination reaching 2,889 items per kilogram at Guwahati (Springer Nature, 2025). Alongside microplastics, antibiotic pollution has emerged as a critical co-threat. Studies estimate that approximately 80% of India's rivers carry antibiotic concentrations high enough to pose measurable ecological and public health risks (National Herald India, 2025) creating conditions where antibiotic-resistant bacteria proliferate unchecked in aquatic environments.

What makes this crisis particularly difficult to manage is the lag between contamination and detection. Current monitoring in India relies predominantly on periodic manual sampling a method that captures snapshots rather than continuous trends. By

the time data is processed and acted upon, ecological damage is often already done.

Climate change is compressing this window further. Erratic monsoons, rising water temperatures, and increased flooding events are accelerating pollutant dispersal, disrupting aquatic microbial communities, and intensifying the conditions under which resistance genes spread. The challenge, therefore, is not just one of pollution it is one of speed of response.

This is precisely the gap that digital biomonitoring seeks to address. By integrating IoT-based sensor networks, drone-based ecosystem surveys, environmental DNA (eDNA) sequencing, and satellite remote sensing into unified analytical platforms, it is now possible to move from reactive monitoring to real-time environmental intelligence. On World Environment Day 2026, as the global community calls for accelerated climate action, digital biomonitoring represents one of the most concrete and scalable tools available to scientists, policymakers, and institutions working on the frontlines of environmental health.

Monitoring the Environment in the Age of Climate Change

Environmental monitoring has traditionally depended on field-based sampling scientists collecting water, soil, or biological specimens at defined intervals and submitting them for laboratory analysis. While this approach has provided valuable baseline data over decades, it operates on a timeline that is increasingly mismatched with the pace of climate-driven ecological change.

India's CPCB currently operates the National Water Quality Monitoring Programme (NWMP) across over 700 monitoring stations on rivers, lakes, and groundwater. However, as CPCB documentation

acknowledges, sampling at most stations occurs once a month at best. With manual sampling, a single analysis report takes days to generate. Real-time monitoring systems, by contrast, can deliver 50 to 95 data points per day from a single station, enabling timely and effective decision-making (CPCB, CSE India).

This gap is not a minor operational inefficiency it is a structural vulnerability. Climate change is altering the frequency, intensity, and distribution of pollution events. Flood pulses now carry heavier loads of agricultural runoff and industrial effluent into water bodies in shorter timeframes. Rising temperatures accelerate microbial growth, algal bloom formation, and the spread of waterborne pathogens. A monitoring system that checks a river once a month cannot detect, let alone respond to, these rapidly evolving conditions.

Digital biomonitoring is the convergence of biological sciences and digital technology to enable continuous, real-time, and spatially extensive environmental surveillance. It integrates hardware (sensors, drones, satellites) with software (bioinformatics pipelines, cloud-based dashboards, and machine learning models) to generate actionable environmental intelligence not just raw data. The following sections describe the four core pillars of this approach and their specific relevance to India's environmental challenges.

Four Technologies Redefining Environmental Surveillance

• IoT-Based Water Quality Sensors

Internet of Things (IoT)-based water quality sensors are electrochemical or optical devices deployed directly in water bodies to measure critical parameters pH, dissolved oxygen (DO), turbidity, conductivity,

nitrate levels, and in advanced configurations, heavy metal concentrations on a continuous basis. Data is transmitted wirelessly via GSM or GPRS to centralized servers, where it can be accessed in near real-time by scientists, regulators, and decision-makers.

India has made initial strides in this direction. Under the Namami Gange programme, real-time water quality monitoring stations have been piloted along the Ganga basin, measuring ten parameters including DO, BOD, pH, and temperature continuously. CPCB's central receiving station can access data from any of these stations remotely, with alarm systems triggered when parameters breach permissible thresholds. Scaling this model to other critically polluted river basins including the Brahmaputra, Damodar, and Hooghly is a logical and urgent next step.

• Drone-Based Ecosystem Surveys

Unmanned Aerial Vehicles (UAVs), commonly called drones, equipped with multispectral, hyperspectral, and thermal imaging sensors have emerged as powerful tools for large-scale, rapid ecosystem assessment. They can survey terrain and vegetation that is inaccessible or hazardous to ground-based teams dense wetlands, flooded riverbanks, coastal mangrove belts, and industrial buffer zones without disturbing the habitats being assessed.

In the context of environmental monitoring, drones serve several critical functions. Multispectral cameras detect changes in vegetation health through spectral indices like NDVI (Normalized Difference Vegetation Index) long before visible damage appears on the ground. Thermal sensors identify heat signatures indicative of industrial discharge or sub-surface contamination. Hyperspectral imaging can differenti-

ate between algal bloom species a capability increasingly important as warming waters intensify eutrophication events in India's lakes and reservoirs.

• Environmental DNA (eDNA) Monitoring

Environmental DNA (eDNA) monitoring is arguably the most scientifically transformative pillar of digital biomonitoring and most directly aligned with the expertise of molecular biologists and environmental scientists. Every organism sheds genetic material into its surroundings through skin cells, mucus, excreta, and other biological outputs. In aquatic environments, this shed DNA persists in the water column and sediment for hours to days, providing a molecular record of biological presence and community composition.

The operational workflow involves collecting water or sediment samples, extracting total environmental DNA, amplifying target sequences using PCR, and subjecting the amplified products to high-throughput sequencing. The resulting sequence data is then processed through bioinformatics pipelines tools such as QIIME2, DADA2, and MEGA to assign taxonomic identities and quantify the relative abundance of species or microbial groups present. This approach, known as eDNA metabarcoding, can simultaneously profile entire communities of bacteria, fungi, algae, invertebrates, and vertebrates from a single water sample.

The climate relevance of eDNA monitoring is significant and multidirectional. As water temperatures rise and monsoon patterns shift, species distributions change some taxa contract their ranges while others expand. eDNA metabarcoding can track these shifts continuously and non-invasive-

ly, providing early indicators of ecosystem stress before conventional biodiversity surveys would detect any change. Research published in Nature Communications (2025) demonstrated that airborne eDNA can now capture decades of ecosystem biodiversity change from environmental samples extending the technique beyond water into terrestrial monitoring.

For microbial community monitoring specifically, eDNA approaches are without peer. Changes in microbial community structure the balance between nitrifying bacteria, methanogens, sulfate-reducers, and pathogenic taxa are among the earliest and most sensitive indicators of ecosystem disruption. A river that is chemically within permissible limits may already be showing significant microbial dysbiosis detectable through eDNA sequencing. This makes eDNA monitoring a genuinely predictive tool, rather than merely a descriptive one.

"eDNA metabarcoding can simultaneously profile entire communities of bacteria, fungi, algae, and vertebrates from a single water sample making it a predictive tool, not merely a descriptive one."

For researchers working in north-east India where Brahmaputra tributaries support high endemic biodiversity under increasing anthropogenic pressure eDNA represents an opportunity to establish baseline community profiles, monitor trajectory changes, and detect the arrival of pollutant-adapted or invasive taxa, all without the logistical burden of conventional biological surveys.

• Satellite Remote Sensing

Satellite remote sensing provides the

broadest spatial and temporal perspective of the four pillars the capacity to observe environmental conditions across entire river basins, forest landscapes, and coastal zones, repeatedly and consistently over time. Platforms including ESA's Sentinel-2, NASA's Landsat-8/9, and ISRO's Resourcesat-2 carry optical, thermal, and radar sensors that generate detailed surface data at resolutions ranging from 10 to 30 meters.

For environmental monitoring in India, satellite data supports a range of critical applications. NDVI timeseries analysis reveals vegetation stress trajectories declining greenness across a wetland or forest patch may signal waterlogging, drought, or contamination-driven die-off, often months before field surveys would confirm it. Land Surface Temperature (LST) mapping identifies urban heat islands and industrial thermal discharge zones. Water body extent mapping tracks seasonal and long-term changes in lake and reservoir area. Turbidity indices derived from optical bands can estimate sediment load and algal bloom intensity in large river systems.

ISRO's National Remote Sensing Centre (NRSC) makes satellite data freely accessible through the Bhuvan geoportal, which provides multi-temporal imagery, vegetation indices, and flood inundation maps for the entire Indian subcontinent. Google Earth Engine (GEE), a cloud-based planetary-scale geospatial analysis platform, has further democratized satellite data analysis.

From Raw Data to Actionable Intelligence: The Role of Bioinformatics

Each of the four pillars described above generates a distinct data stream electrochemical sensor readings, drone imagery, DNA sequence files, and satellite raster

datasets. Individually, each provides valuable information. Integrated and interpreted through appropriate analytical platforms, they have the potential to constitute a comprehensive, real-time environmental health intelligence system.

The analytical brain of digital biomonitoring is where bioinformatics and data science become indispensable. The processing of eDNA metabarcoding data through pipelines such as QIIME2 and DADA2 involves quality filtering of raw sequence reads, denoising, taxonomic assignment against reference databases (SILVA, NCBI), and statistical analysis of community diversity metrics (alpha and beta diversity, species richness, phylogenetic distance). These outputs, when combined with physicochemical sensor data and satellite-derived indices, allow researchers to correlate biological community structure with environmental drivers in ways that neither dataset could support alone.

Key platforms supporting this integrated approach include Google Earth Engine for satellite data analysis at scale, QIIME2 and DADA2 for microbiome and eDNA community analysis, the Global Biodiversity Information Facility (GBIF) for species occurrence data integration, and CPCB's existing real-time water quality data infrastructure as a regulatory framework for sensor network deployment. Together, these tools form the foundation of a national-scale digital biomonitoring architecture one that India has the technical capacity to build, given sufficient institutional commitment and interdisciplinary expertise.

Where India Stands: Promise, Gaps, and the Path Forward

• Opportunities

India is positioned with several structural advantages for advancing digital biomonitoring. The country possesses one of the world's largest pools of data science and software engineering talent a capability that, when directed toward environmental applications, can significantly accelerate the development of analytical platforms and monitoring dashboards. ISRO's freely accessible satellite data infrastructure, distributed through the NRSC Bhuvan portal, removes a major cost barrier that limits environmental remote sensing in many developing countries.

At the policy level, national programmes including Namami Gange, the National Action Plan on Climate Change (NAPCC), and State Action Plans on Climate Change (SAPCC) have created institutional demand for improved environmental monitoring. India's commitments under the Paris Agreement further reinforce the need for robust, data-driven environmental tracking systems. A growing environmental technology startup ecosystem developing IoT-based water quality solutions, drone survey services, and AI-driven ecological analytics represents an emerging industry that academic researchers and regulatory bodies can productively engage with.

• Gaps

These opportunities, however, must be assessed against equally significant structural gaps. Sensor deployment infrastructure remains costly and is unevenly distributed, with rural and ecologically sensitive areas precisely those most in need of continuous monitoring often lacking the connectivity and power infrastructure that IoT

networks require. Interoperability between data systems operated by CPCB, State Pollution Control Boards, Forest Departments, and research institutions remains limited, resulting in fragmented datasets that are difficult to integrate for basin-level or landscape-level analysis. From a human capital perspective, perhaps the most critical gap is the shortage of professionals trained at the interface of molecular biology, environmental science, and computational data analysis. eDNA metabarcoding and satellite remote sensing both require researchers who can move fluently between wet laboratory protocols and bioinformatics command-line tools a skill combination that remains rare in India's environmental science workforce. Bridging this gap requires deliberate curriculum design at the postgraduate and doctoral levels, and institutional support for interdisciplinary research programmes that combine environmental field work with computational analysis. Finally, eDNA monitoring and metabarcoding-based bioassessment remain largely confined to research settings in India. Their integration into regulatory monitoring frameworks as standardised tools recognised by CPCB and State

Pollution Control Boards for biodiversity assessment and pollution impact evaluation is a necessary next step that will require both scientific validation and policy advocacy.

Listening to the Planet At the Speed It Needs

The environmental crisis facing India's river systems, wetlands, and coastal ecosystems is well documented. What has been less well-addressed is the monitoring infrastructure gap that slows detection, delays response, and limits the precision of intervention. Digital biomonitoring through the integration of IoT sensors, drone surveys, eDNA sequencing, and satellite remote sensing, anchored in robust bioinformatics analysis provides a technically credible, scientifically grounded path toward closing this gap. It is important to note that technology, in isolation, is not sufficient. The effectiveness of any monitoring system depends on the quality of the science underpinning it, the robustness of the analytical frameworks applied to its outputs, and the institutional mechanisms through which its findings are translated into policy and management action.



It is our collective
responsibility to
support and preserve
the environment in
which we all live.

DALAI LAMA



Birth of the EPR Regime in India: Advancing Circular Economy for Plastic Waste Management



Er. Arnab Mandal
Scientist-C
CPCB, Shillong



Dr. Shantanu Dutta
Regional Director
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Introduction

Plastic has become one of the most essential materials in modern society due to its versatility, durability, lightweight nature and reasonably low cost. It is extensively used in packaging, healthcare, agriculture, construction, transportation and consumer products. However, the unprecedented growth in plastic consumption over the past few decades has also generated enormous quantities of plastic waste, creating severe environmental and ecological challenges across the world.

India, being one of the fastest-growing economies and consumer markets, has experienced a rapid rise in plastic usage, especially in packaging materials. Mismanagement of plastic waste has resulted in environmental pollution, clogging of drainage systems, contamination of rivers and oceans, harm to wildlife, and increasing pressure on

urban waste management systems. These concerns highlighted the urgent need for a sustainable and scientifically managed plastic waste management framework.

Recognizing the gravity of the issue, the Government of India initiated a transformative shift towards a circular economy model through the introduction of the **Extended Producer Responsibility (EPR)** regime for plastic waste management. The concept of a **circular economy** focuses on minimizing waste generation and maximizing the reuse and recycling of resources. While the conventional linear economy model is based on “take-make-dispose,” the circular economy seeks to create a closed-loop system where products and materials remain in productive use for as long as possible. In India, NITI Aayog plays a major role in promoting circular economy principles as part of sustainable development and climate resilience strategies.

Plastic waste management emerged as a key sector requiring policy reforms and institutional mechanisms for circular resource utilization. For plastics, this means creating systems where plastic waste is collected, recycled, and reintroduced into the manufacturing cycle instead of being discarded into the environment.

Emergence of Extended Producer Responsibility (EPR)

The emergence of EPR marks the birth of a new environmental governance framework aimed at integrating sustainability, resource efficiency, and producer accountability into India's industrial and waste management systems. The EPR is an environmental policy approach in which producers are made responsible for the management of post-consumer waste generated from their products and packaging.

The EPR concept is based on:

- Polluter Pays Principle
- Lifecycle responsibility
- Sustainable resource management
- Producer accountability

Under EPR, the responsibility of producers extends beyond manufacturing and sale to include Collection of plastic waste, Recycling and reuse, environmentally sound disposal and extending Support for waste management systems. The EPR framework encourages industries to design products and packaging that are easier to recycle and environmentally sustainable.

The formal birth of the EPR regime for plastics in India began with the notification of the **Plastic Waste Management Rules, 2016** by the Ministry of Environment, Forest and Climate Change (MoE-

FCC). The Rules introduced several major reforms:

- Mandatory Extended Producer Responsibility
- Inclusion of rural areas under plastic waste management
- Responsibility of waste generators for segregation
- Promotion of collection and recycling systems
- Strengthening local body involvement

Most importantly, the Rules made **Producers, Importers, and Brand Owners (PIBOs)** responsible for plastic packaging waste generated from their products. The EPR regime thus represents a paradigm shift from municipal-centric waste management towards producer-led environmental responsibility.

Strengthening the EPR Framework

Although EPR was introduced in 2016 through the PWM Rules 2016, the framework gained operational strength through subsequent amendments and guidelines in the form of Plastic Waste Management (Amendment) Rules, 2022 including the "Guidelines on Extended Producer Responsibility for Plastic Packaging" notified by the MoEFCC on 16 February 2022. The amended Rules established a comprehensive national framework for implementation EPR for plastic packaging waste in India. The PWM Rules 2022 introduced the following:

- Mandatory registration of Producers, Importers and Brand Owners (PIBOs)
- Category-wise plastic packaging classification
- Annual EPR targets
- Recycling and reuse obligations
- Use of recycled plastic content
- Centralized online EPR portal
- EPR certificate mechanism

- Environmental compensation provisions for non-compliance

The PWM Rules 2022 marked a major policy shift towards circular economy and sustainable plastic waste management in India. Besides, these guidelines created a comprehensive regulatory framework for implementation and monitoring of EPR obligations across India.

Structure of the EPR framework:

The EPR Guidelines framed under the PWM Rules, 2022 provide a structured framework for implementing Extended Producer Responsibility for plastic packaging. The EPR framework applies to Producers, Importers, Brand Owners as well as Plastic Waste Processors (PWP). The respective roles and responsibilities of Producers, Importers and Brand Owners (PIBOs), Plastic Waste Processors (PWPs), recyclers,

Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCBs) or Pollution Control Committees (PCCs) are well defined in the EPR guidelines. Under this system, PIBOs and PWPs are required to register, report and fulfil their obligations a centralized EPR portal, designed and operated by the CPCB. Producers, Importers and Brand Owners (PIBOs) register on the portal, declare quantity of plastic packaging they place in the market and meet targets by working with registered Plastic Waste Processors.

Categorization of Plastic Packaging

For effective implementation of the EPR by the PIBOs, plastic packaging is divided into four broad categories. This categorization helps determine category-specific recycling obligations and compliance targets.



Figure 1. Four types of plastic packaging covered under the EPR framework.

Setting of EPR Targets

Under the EPR regime for plastic packaging in India, Producers, Importers, and Brand Owners (PIBOs) are assigned mandatory annual **EPR targets**for:

- Collection of plastic packaging waste
- Recycling
- Reuse
- End-of-life disposal
- Use of recycled plastic content

The targets increase progressively to improve sustainability performance and circularity.

The Centralized EPR Portal

CPCB has already developed a centralized online **EPR Portal for Plastic Packaging** for implementation and monitoring of the EPR regime under the Plastic Waste Management Rules, 2016 and subsequent amendments.

The portal facilitates:

- Registration of Producers, Importers, and Brand Owners (PIBOs)
- Registration of Plastic Waste Processors (PWPs)
- Filing of annual returns
- Submission of EPR targets and compliance reports
- Generation and transfer of EPR certificates
- Tracking and traceability of plastic waste management activities
- Monitoring and enforcement by regulatory authorities

The EPR portal is considered a major step towards strengthening circular economy practices and scientific plastic waste management in India. The portal has been designed to improve transparency, accountability, digital monitoring, and effective implementation of plastic waste management obligations across India.

Key numbers from the CPCB EPR Portal as in May 2026

Indicator	Status
Registered PIBOs on the EPR portal	62,192
Registered PWPs on the EPR portal	3,080
Plastic packaging waste recycled after EPR guidelines	about 207 lakh tonnes

EPR Certificates and Circular Economy Integration

A major innovation of the EPR framework is the introduction of EPR certificates generated by registered recyclers based on the quantity of plastic waste processed. PIBOs purchase these certificates to fulfil their statutory obligations.

This mechanism creates demand for recycled plastics, encourages investment in recycling infrastructure, formalizes waste

management systems and converts plastic waste into economic resources

Thus, the EPR regime operationalizes circular economy principles by integrating waste back into production cycles.

Environmental Benefits of the EPR Regime

The EPR regime for plastic packaging has emerged as a significant environmental policy initiative for promoting sustainable plastic waste management and advancing

circular economy principles in India. By making Producers, Importers, and Brand Owners (PIBOs) responsible for the collection, recycling, and environmentally sound management of plastic waste generated from their products, the EPR framework has strengthened accountability across the plastic value chain. One of the major environmental benefits of the EPR regime is the reduction of plastic pollution in terrestrial and aquatic ecosystems through organized collection and recycling systems. The framework promotes scientific processing and recovery of plastic waste, thereby reducing littering, open burning, landfill burden, and leakage of plastics into rivers and oceans. Increased recycling and reuse of plastics under the EPR system also help conserve natural resources and reduce dependence on virgin fossil-fuel-based raw materials. Furthermore, recycling consumes comparatively lower energy than production of virgin plastics, contributing to reduction in greenhouse gas emissions and supporting climate change mitigation efforts. The EPR regime additionally encourages eco-friendly packaging design, resource efficiency, and development of sustainable waste management infrastructure. By integrating circular economy principles into industrial production and waste management systems, the EPR framework is contributing significantly towards environmental protection, resource conservation, and long-term ecological sustainability in India.

Economic and Social Significance of EPR Regime

The implementation of the EPR regime for plastic packaging has considerable economic and social significance in addition to its environmental benefits. The EPR framework has stimulated the growth of the recycling and waste management sector

by creating a structured market for collection, segregation, recycling, and recovery of plastic waste. The introduction of EPR certificates and mandatory recycling targets has encouraged investment in recycling infrastructure, waste processing technologies and circular economy enterprises, thereby generating new economic opportunities and promoting green entrepreneurship. The system also supports resource efficiency by converting plastic waste into valuable secondary raw materials, reducing dependence on virgin polymers and contributing to sustainable industrial production. From a social perspective, EPR implementation has the potential to improve livelihoods of waste collectors, recyclers, and workers associated with the informal waste sector through gradual integration into organized waste management systems. Increased demand for plastic waste collection and recycling creates employment opportunities across collection, transportation, sorting, processing, and recycling activities. The EPR framework additionally promotes public awareness regarding waste segregation, recycling and responsible consumption practices, thereby encouraging greater community participation in environmental protection. By linking environmental responsibility with economic development and social inclusion, the EPR regime represents an important step towards sustainable and inclusive growth within the broader framework of circular economy development in India.

The framework also offers opportunities for integration of the informal waste sector into formal recycling systems.

Challenges in Implementation of EPR

The implementation of the EPR regime for plastic packaging in India, although progressive and transformative, faces several operational, institutional and infrastruc-

tural challenges. One of the major concerns is the integration of the large informal waste sector, which continues to handle a significant portion of plastic waste collection and recycling activities without adequate formal recognition, financial support, or social security. In many regions, insufficient infrastructure for segregation, collection, transportation, and scientific recycling of plastic waste limits effective implementation of EPR obligations. Traceability and verification of recycling data also remain critical challenges, particularly in preventing false reporting and fraudulent generation of EPR certificates. Difficult-to-recycle plastics, especially multi-layered and low-value plastic packaging, continue to pose technological and economic constraints for recyclers. Additionally, many small and medium-scale PIBOs face difficulties in understanding compliance procedures and meeting regulatory requirements. Effective monitoring and enforcement across thousands of stakeholders require robust digital systems, administrative capacity, and coordinated action by regulatory authorities including

CPCB and SPCB/PCC. Public awareness regarding waste segregation and responsible plastic disposal also remains limited in many areas. Addressing these challenges through stronger institutional mechanisms, improved infrastructure, technological innovation, stakeholder capacity building, and greater public participation will be essential for the long-term success of the EPR regime and circular economy transition in India.

The North-Eastern region has a special challenge. Waste generation is spread across hilly and dispersed settlements, while recycling and processing facilities are concentrated in only a few places. This makes transport, collection and verification more difficult.

The available data show that producer-side registration is increasing, but processing facilities are unevenly distributed. Assam has the highest number of registered PIBOs and PWPs. Meghalaya has large registered processing capacity. Several other states have PIBO registrations but no registered PWP capacity reported in the dataset.

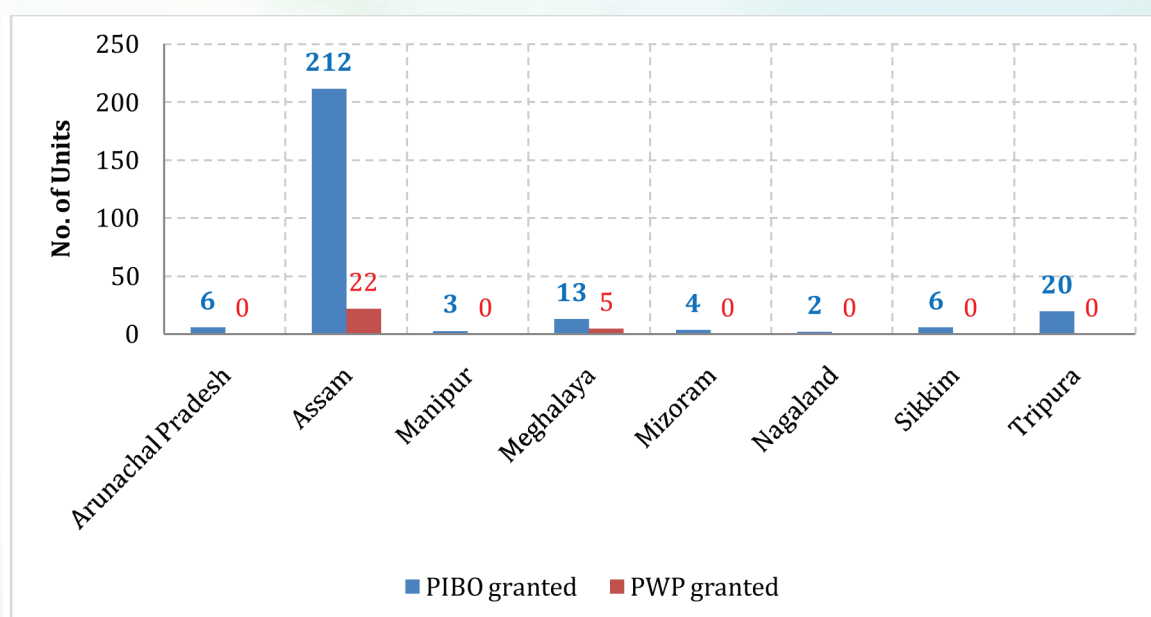
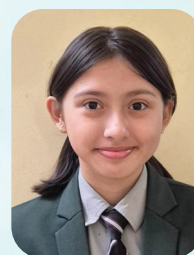


Fig: . Registration status of PIBOs and PWPs in North-Eastern States (as on FY 2024-25).

Conclusion

The birth of the EPR era in India marks a transformative phase in plastic waste management and environmental governance. Guided by the circular economy vision promoted by NITI Aayog and implemented through regulatory reforms of the Government of India, the EPR framework seeks to establish a sustainable and resource-efficient plastic management system.

By shifting responsibility towards producers and encouraging recycling, reuse, and resource recovery, the EPR regime represents a major step towards reducing plastic pollution, strengthening environmental sustainability, and promoting climate resilience. Although challenges remain, India's transition towards a circular economy for plastics has laid a strong foundation for a cleaner, greener, and more sustainable future.



Shreya Das
Class - VII

Hazardous Waste: Regulations, Disposal Challenges, and BCPL's Initiatives



Jutika Mahatta
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Industrial growth and technological advancement have not only contributed to economic development, but they have also increased the generation of hazardous waste. Hazardous waste poses serious risks to human health, ecosystems, and natural resources if not handled properly. Industries such as petrochemicals, pharmaceuticals, chemicals, mining, and manufacturing generate different forms of hazardous waste during their operational processes. Effective hazardous waste management has therefore become an essential component of environmental protection and sustainable industrial development.

What is Hazardous Waste?

Hazardous waste refers to waste materials that possess harmful characteristics such as toxicity, flammability, corrosiveness, reactivity, explosiveness, or infectious nature. These properties make such waste dangerous during handling, transportation, storage, treatment, or disposal.

Regulatory Framework for Hazardous Waste Management

The regulatory framework for hazardous waste management is anchored in the Basel Convention (1989), which aims to protect human health and the environment by regulating the transboundary movement

and disposal of hazardous wastes and promoting environmentally sound management, particularly limiting movement from developed to developing countries.

In India, hazardous waste is governed by the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, first notified in 2008 by the Ministry of Environment, Forest and Climate Change (MoEFCC) and amended periodically. These rules provide a comprehensive legal framework covering the generation, handling, storage, transportation, recycling, treatment, import, export, and disposal of hazardous and other wastes to ensure scientific and responsible management.

The rules classify wastes through multiple schedules. Schedule I identifies industries generating hazardous waste, while Schedule II defines hazardous characteristics based on concentration limits and toxicity. Schedule III regulates import and export in line with the Basel Convention, including requirements for prior informed consent, permissions, and documentation. Additional schedules address recyclable wastes, standards for used oil, prohibited imports, roles of authorities such as the Central Pollution Control Board (CPCB) and State Pollution Control Boards, and documentation required by Customs and the Directorate General of Foreign Trade (DGFT).

The rules include additional schedules and standardized forms to ensure effective regulation, compliance, and accountability in hazardous waste management. Schedules IV to VIII address key aspects such as recyclable hazardous wastes, quality standards for recycled used oil and fuel derived from waste oil, wastes prohibited from import into India, the roles and responsibilities of implementing authorities—including the Central Pollution Control Board (CPCB), State Pollution Control Boards, and Customs—and the documentation required for verification of permitted waste imports.

To support implementation and record-keeping, the rules prescribe a structured set of forms. These cover authorization and renewal of waste-related activities, issuance of approvals by State Pollution Control Boards, maintenance of records and annual returns, applications for import and export, and documentation for transboundary movement of waste. Additional specialized forms govern one-time import authorizations, labelling of hazardous waste containers, emergency response during transportation, domestic waste manifests, accident reporting, and appeals against regulatory decisions.

To ensure compliance and traceability, the rules prescribe standardized forms for authorization, record-keeping, annual returns, import/export applications, labelling, emergency response, accident reporting, and appeals. A key feature is the Manifest (Movement Document) System, which tracks hazardous waste during domestic transport from generator to final treatment or disposal facility, enhancing accountability and preventing illegal dumping.

The Manifest System, also known as the Movement Document System, which is applicable to the domestic transportation of hazardous and other wastes within the country. Under this system, the waste generator or sender is required to prepare seven colour-coded copies of the manifest (Form 10), all duly signed before transportation. The manifest accompanies the waste throughout its journey—from the generator to the transporter and ultimately to the recycler, treatment facility, or disposal site—enabling regulatory authorities to track waste movement at every stage. This system strengthens accountability, ensures transparency in waste handling, and significantly reduces the risk of illegal dumping, diversion, or improper management of hazardous waste.

Copy number with colour code	Purpose
(1)	(2)
Copy 1 (White)	To be forwarded by the sender to the State Pollution Control Board after signing all the seven copies.
Copy 2 (Yellow)	To be retained by the sender after taking signature on it from the transporter and the rest of the five signed copies to be carried by the transporter.
Copy 3 (Pink)	To be retained by the receiver (actual user or treatment storage and disposal facility operator) after receiving the waste and the remaining four copies are to be duly signed by the receiver.
Copy 4 (Orange)	To be handed over to the transporter by the receiver after accepting waste.
Copy 5 (Green)	To be sent by the receiver to the State Pollution Control Board.
Copy 6 (Blue)	To be sent by the receiver to the sender.
Copy 7 (Grey)	To be sent by the receiver to the State Pollution Control Board of the sender in case the sender is in another State.

Overall, India's hazardous waste rules establish an integrated and robust system for monitoring and regulating hazardous and other wastes across their entire life-cycle. Continuous compliance with updated amendments, schedules, and procedures is essential for industries and stakeholders to meet environmental and legal obligations.

Recent Development in Hazardous Waste Tracking System by CPCB

Central Pollution Control Board (CPCB) under the Ministry of Environment, Forest and Climate Change, Government of India establishes an online digital platform named as National Hazardous Waste Tracking System (NHWTS) Portal. The portal is developed to ensure effective tracking, monitoring, and management of hazardous waste generated, transported, recycled, treated, and disposed of across the country.

The NHWTS portal helps industries, recyclers, transporters, and State Pollution Control Boards maintain transparency and accountability in hazardous waste handling. Through this system, hazardous waste movement can be monitored in real time from the point of generation to its final disposal or recycling facility. It supports the implementation of the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016.

The major objectives of the NHWTS portal are to strengthen environmental compliance, prevent illegal dumping of hazardous waste, improve data management, and promote environmentally safe disposal practices. The portal also facilitates online manifest generation, authorization tracking, transporter details, waste quantity records, and reporting mechanisms for regulatory authorities. By digitizing the hazardous waste management process, the NHWTS portal has improved coordination between industries and pollution control authorities

while enhancing transparency, traceability, and environmental protection in India's hazardous waste management system. Each Hazardous Waste handler like Generator, Transporter, Co-Processor, Recycler, TSDF owner need to register and update in the NHWTS portal.

Challenges in Hazardous Waste Disposal

Hazardous waste disposal remains one of the most significant environmental challenges faced by industries as well as regulatory authorities. Several operational, technical, and infrastructural constraints hinder the effective management of hazardous waste, particularly in remote regions.

- As per regulatory requirements, hazardous waste generators are required to analyse waste samples in accordance with Table A of Hazardous and Other Wastes (Management and Transboundary Movement) Rules, covering nearly 70 parameters, to identify waste characteristics and determine appropriate disposal methods. However, a major challenge is the limited availability of certified laboratories capable of analysing all these parameters under a single facility.

- The disposal process is further constrained by the lack of adequate Treatment, Storage, and Disposal Facilities (TSDFs) in many regions. The non-availability of authorised co-processors, recyclers, incinerators, and re-processors approved by SPCB/CPCB reduces competition during bidding processes, ultimately leading to higher disposal costs. In some cases, even where facilities exist, the authorised hazardous waste categories of the disposal facility do not match those of the waste generator, creating regulatory and operational hurdles.

- Another major challenge is the limited number of agencies involved in the recovery of precious materials from hazardous waste.

Due to monopolistic practices, these agencies often do not participate in government tender procedures, turning potential recovery opportunities into disposal burdens.

- In the North-Eastern Region of India, the number of authorised hazardous waste transporters is limited, resulting in high transportation costs. In addition, inadequate awareness and insufficient technical knowledge among workers regarding safe handling practices often lead to improper packaging and labelling of hazardous waste, thereby increasing the risk of accidents.

- Improper segregation and storage of hazardous waste can result in accidents, leakages, fire hazards, and environmental contamination. Transportation of hazardous waste also poses significant risks, as spills or mishandling during transit may contaminate soil, water, and air. Furthermore, illegal dumping and unauthorised disposal practices exacerbate environmental degradation.

Improper hazardous waste management poses serious risks to human health and the environment. Therefore, the establishment of robust monitoring systems, improved infrastructure, technological advancements, increased awareness, and strict regulatory enforcement are essential to ensure safe and sustainable hazardous waste disposal.

BCPL's Efforts in Hazardous Waste Management

As a major petrochemical industry, BCPL generates different categories of hazardous waste during its operations. Managing these wastes responsibly has been an important environmental priority for the organization.

One of the major challenges faced by BCPL for several years was the absence of any Treatment, Storage and Disposal Facil-

ity (TSDF) in Assam and the wider North-Eastern region. Owing to this limitation, the company was compelled to scientifically store hazardous waste on-site while continuously exploring safe and compliant disposal options. In the initial phase, BCPL approached authorised agencies such as Geocycle India and the Ramky Group for disposal outside the region; however, high transportation costs and complex regulatory approval processes posed significant constraints.

To strengthen long-term hazardous waste management, BCPL constituted a Waste Management Committee (WMC) responsible for monitoring waste generation, segregation, regulatory compliance, and disposal activities. In addition, the company implemented a dedicated Waste Management Policy to ensure systematic, safe, and compliant handling of all waste streams.

Despite persistent challenges, BCPL remained committed to responsible hazardous waste management and actively explored alternative disposal solutions, including co-processing in cement industries. A notable achievement was realised through coordination with M/s Calcom Cement India Ltd., whereby approximately 75 metric tonnes of hazardous waste were successfully disposed of through trial coprocessing.

Further, to manage oily and chemical sludge generated during the treatment of oily water sewage, BCPL established a bioremediation treatment system, through which the hazardous waste was effectively converted into landfill-compatible soil.

The company also initiated disposal efforts through e-auction and government tendering platforms, including MSTC and GeM. Although several technical and regulatory challenges persisted, BCPL continued to adopt proactive and compliant measures to ensure environmentally safe and sustain-

able disposal of hazardous waste.

Through government tendering procedures, BCPL is currently able to dispose of three categories of hazardous waste at a TSDF located in West Bengal and through an authorised re-processor situated in Jharkhand, thereby strengthening its overall hazardous waste management framework.

Way Forward

A major breakthrough came in 2025 when the Pollution Control Board Assam, in association with M/s. MWML, initiated the installation of a TSDF facility at Lekai, Dibrugarh. This development provided a long-awaited and sustainable solution for industries in Assam and the North-Eastern region for scientific disposal of hazardous waste. Industries including BCPL were encouraged to obtain membership to the TSDF facility and utilize the infrastructure for safe disposal of different hazardous waste categories. The establishment of this facility significantly reduced dependency on interstate disposal mechanisms and created better opportunities for regulatory compliance, environmental protection, and long-term sustainability.

One major challenge that requires the attention of regulatory bodies and technology developers is the disposal of fixed-bed materials used in various chemical processes, such as molecular sieves, activated charcoal, resins, alumina, ceramic balls, and similar media. After use, these materials are commonly disposed of in landfills.

A wide range of industries generate such wastes, as these materials are extensively used as adsorbents or support media in industrial processes. The quantities generated are significant and continue to increase with industrial growth. At present, the absence of reuse or recovery mechanisms

has been leading to unnecessary landfill disposal and loss of potentially valuable materials.

If the principles of the circular economy are applied and suitable technologies are developed, these challenges can be effectively addressed. A buy-back or take-back mechanism, wherein manufacturers or suppliers reclaim spent fixed-bed materials for reuse or reprocessing within their production cycles, would significantly reduce disposal burdens. Such an approach would minimize landfill dependency, conserve resources, and enable environmentally sustainable and cost-effective management of these materials.

Therefore, the development of enabling technologies, supportive regulatory frameworks, and industry participation is essential to achieve sustainable disposal and resource recovery of spent fixed-bed materials.

In conclusion, BCPL's journey in hazardous waste management demonstrates strong commitment, environmental responsibility, and continuous improvement despite significant infrastructural and operational constraints. Through sustained coordination with regulatory authorities, authorised transporters, co-processors, cement industries, public sector undertakings, and waste management agencies, BCPL has progressively strengthened its hazardous waste management framework.

Going forward, continuous monitoring, adoption of advanced technologies, enhanced stakeholder coordination, and strict compliance with environmental regulations will be critical to achieving efficient and environmentally sound hazardous waste management. BCPL's experience can serve as a valuable model for industries operating in remote and infrastructure-constrained regions across the country.

Bamboo Composites: A Sustainable Revolution in Civil Engineering



Srijani Adhikari
SM (Civil)

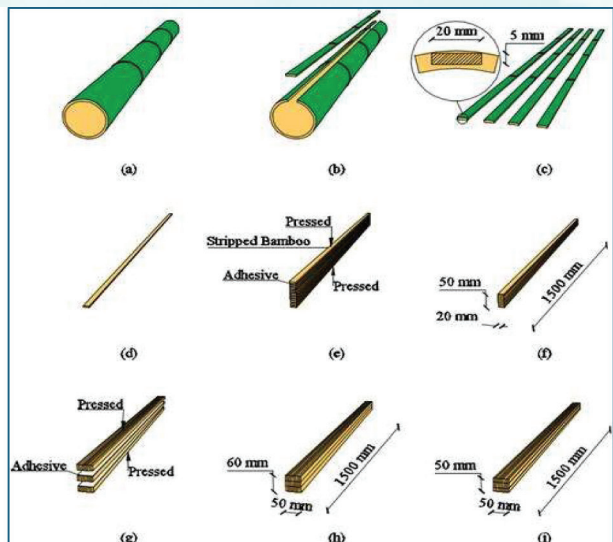
Bamboo composites are emerging as an innovative and sustainable material in modern civil engineering. They are produced by processing natural bamboo into strips or fibers and bonding them with resins under heat and pressure. This transformation overcomes the limitations of raw bamboo—such as susceptibility to moisture, pests, and irregular geometry—while enhancing

its strength, durability, and usability in construction.

One of the key advantages of bamboo composites is their high strength-to-weight ratio. Engineered bamboo products like laminated bamboo and bamboo scrimber exhibit mechanical properties comparable to timber and in some cases, even rival conventional materials used for non-



critical structural elements. Despite being lightweight, they are capable of carrying significant loads, making them suitable for beams, panels, flooring systems, and interior structural frameworks.



From an environmental perspective, bamboo composites offer significant benefits. Bamboo is a rapid renewable resource, maturing within 3–5 years, unlike

hardwood trees that take decades. It also absorbs substantial amounts of carbon dioxide during its growth cycle.

When used in construction, especially as a substitute for steel, concrete, or timber, bamboo composites contribute to a reduction in embodied carbon, supporting sustainable development goals. Additionally, the use of locally available bamboo reduces transportation energy and promotes regional economies.

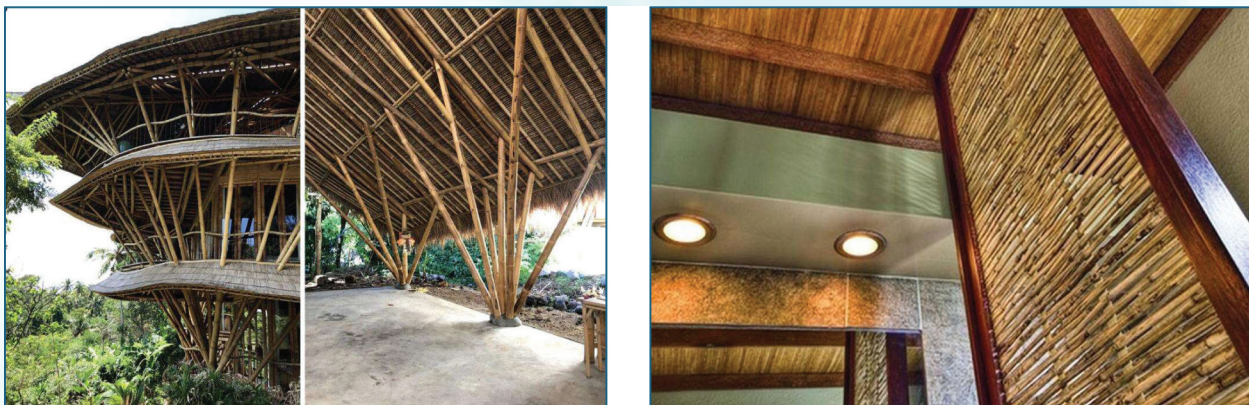
The incorporation of resins—such as phenolic or epoxy binders—plays a crucial role in enhancing the performance of bamboo composites. These resins improve resistance to moisture, fungi, and termite attacks, while also ensuring dimensional stability by reducing shrinkage and swelling. As a result, bamboo composites demonstrate improved longevity and reliability compared to untreated bamboo. However, the environmental impact of synthetic resins remains a concern, and ongoing research is



focused on developing biobased alternatives to make the material even more eco-friendly.

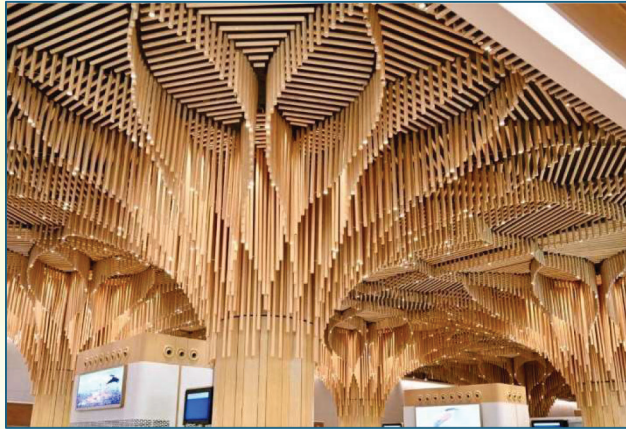
In civil engineering applications, bamboo composites are increasingly used in flooring, wall panels, formwork, furniture, and even structural components in low-

rise buildings. Their aesthetic appeal, characterized by a warm and natural finish, also makes them popular in interior architecture. Furthermore, prefabrication techniques using bamboo composites can reduce construction time and material



wastage, aligning with modern efficient building practices.

A notable real-life example of bamboo composite usage is the Lokpriya Gopinath Bordoloi International Airport, Guwahati. The newly developed terminal, often referred to as the “Bamboo Orchids”



design, integrates a significant quantity of locally sourced bamboo in engineered composite form. These materials are used in interior columns, ceilings, and architectural elements, showcasing both structural capability and cultural identity. The project highlights how bamboo composites



can be successfully applied in large-scale, modern infrastructure while maintaining sustainability and regional character.

Despite its advantages, bamboo composite technology faces certain challenges, including the need for standardized design codes, quality control in manufacturing, and long-term performance data. Nevertheless, with advancements in material science and increasing emphasis on green construction, bamboo composites hold immense potential as a viable alternative to

conventional building materials.

In conclusion, bamboo composites represent a promising intersection of traditional resources and modern engineering. By enhancing the natural properties of bamboo through technology, they provide a material that is not only strong and durable but also environmentally responsible—making them an important component of the future of sustainable civil engineering.



*In all things of nature there is something
of the marvelous.*

- Aristotle

Sustainable Public Procurement (SPP)



Arunjyoti Dutta
CM (C&P)



Debajyoti Das
SM (C&P)

Public Procurement (PP) in India is a cornerstone of governance and economic activity, accounting for nearly **20-22% of GDP (₹50-60 lakh crore annually)**. This large scale of expenditure by government organizations and Public Sector Undertakings (PSUs) gets a unique opportunity as well as a huge responsibility not just to procure goods and services economically but also to procure goods responsibly towards sustainability.

Traditionally, public procurement focused on the lowest cost. Today, procurement is evolving into a strategic function that integrates **economic efficiency, environmental sustainability and social responsibility**. This shift is embodied in the concept of **Sustainable Public Procurement (SPP)**.

Sustainable Public Procurement (SPP) & its key pillars:

Sustainable Public Procurement refers to the process of acquiring goods, services and works in a manner that achieves **value for money over the entire lifecycle** while minimizing environmental impact and promoting social well-being.

SPP considers the following three key pillars:

- **Economic:** Cost, quality, performance, lifecycle cost
- **Environmental:** Energy use, emissions, waste, resource efficiency
- **Social:** Labour standards, ethical sourcing, inclusivity

Unlike conventional procurement, SPP focuses on **Total Cost of Ownership (TCO)** rather than just the initial purchase price.

Why Sustainable Procurement Matters:

With increasing pressure on natural resources and rising environmental concerns, sustainable procurement helps organizations to reduce carbon footprint, minimize waste generation, improve energy efficiency and to achieve long-term cost savings. Even small procurement decisions such as switching to LED lighting or reducing paper consumption can create a **significant cumulative impact**.

Key Policy Framework Supporting SPP in GFR/DoE manual/GeM procurement:

Policy / Rule	Key Provision	Relevance to SPP
GFR Rule 144	Efficiency, economy, transparency	Foundation of procurement
GFR Rule 173	Lifecycle costing, performance evaluation	Promotes long-term value
GFR Rule 176	Buyback provisions	Enables circular procurement
GFR Rule 217	Disposal of goods	Ensures safe waste handling
GeM (Rule 149)	E-procurement platform	Transparent & green procurement
E-Waste Rules	Extended Producer Responsibility (EPR)	Responsible disposal
Battery Waste Rules	Take-back mechanism	Safe recycling

Circular Procurement: Buyback Models and BCPL:

One of the most practical applications of SPP is buyback procurement, where suppliers take back old equipment while supplying new items. This approach reduces procurement cost and ensures environmentally responsible disposal. This is mostly used in BCPL while procuring PC and its peripherals, procurement of battery etc. A brief analysis of buy back model can be better understood by taking a few examples as under:

Buyback Procurement - Cost & Sustainability Impact:

Item	Cost Without Buyback	Buyback Value	Net Cost	Key Benefit
Batteries (100 units)	₹ 10,00,000	₹ 2,00,000	₹ 8,00,000	Cost saving + recycling
Computers (50 units)	₹ 20,00,000	₹ 2,50,000	₹ 17,50,000	E-waste compliance

Impact:

- **Direct reduction in procurement cost:** Sustainable Public Procurement (SPP) helps reduce overall procurement costs by promoting energy-efficient, durable, and low-maintenance products. Although the initial purchase cost may sometimes be higher, the long-term operational and maintenance expenses are lower, resulting in overall cost savings.

- **Compliance with environmental regulations:** SPP supports organizations in complying with environmental laws, poli-

cies, and government regulations related to waste management, pollution control, energy efficiency, and sustainable resource utilization. This helps avoid legal penalties and improves environmental performance.

- **Promotion of circular economy:**

SPP encourages the buyback method, reuse, recycling, refurbishment, and recovery of materials, which supports circular economy practices. This reduces waste generation, conserves natural resources, and promotes sustainable production and consumption patterns.

Lifecycle Costing: A Smarter Procurement Approach:

Sustainable procurement emphasizes Lifecycle Costing (LCC) which considers all costs associated with a product over its lifetime.

Stage	Cost Component
Acquisition	Purchase cost
Operation	Energy, fuel, consumables
Maintenance	Repairs, servicing
Disposal	Scrap handling, recycling

Example:

A 5-star rated air conditioner may have a higher upfront cost but results in substantial electricity savings over time making it more economical in the long run.

BCPL's Sustainable Procurement Initiatives:

Brahmaputra Cracker and Polymer Limited (BCPL) has taken several proactive steps to integrate sustainability into its procurement processes and a few of the initiatives are :

a) Energy-Efficient Procurement:

- Procurement of 5 star-rated air conditioners
- Replacement of conventional lighting with LED systems

b) Circular Procurement Practices

- Buyback of batteries, computers, and printers
- Reduction of waste and improved cost efficiency

c) Resource Recovery

- Forward auction of used oil, plastic, and other scrap generated in the plant
- Auction of all used packing materials including card boards
- Revenue generation from waste

d) Renewable Energy Adoption

- Procurement of solar power and already installed in Admin building and C&P warehouse will be sourced with solar power and installation is ongoing.

e) Environmental Compliance

- Safe disposal of hazardous waste
- Engagement of agencies at BCPL for Energy audit, Water audit, EPR certification, consultancy service for net zero target, contract for monitoring of environmental parameters, contract for disposal of municipal and other solid waste, contract for disposal of hazardous waste to SPCB/CPCB authorized agencies etc.

Global Perspective and Learnings**• Challenges in the Implementation of Sustainable Public Procurement (SPP)**

The implementation of Sustainable Public Procurement (SPP) faces several challenges in organizations and industries. One major challenge is the perception that sustainable and eco-friendly products are more expensive than conventional products. Many organizations focus only on the initial purchase cost rather than the long-term savings and environmental benefits.

Another challenge is the limited technical expertise in lifecycle costing. Proper evaluation of total costs, including maintenance, operation, and disposal costs, requires skilled personnel and technical

knowledge, which may not always be available.

Lack of supplier readiness is also a significant issue. Many suppliers may not have adequate awareness, resources, or capability to provide sustainable and environmentally compliant products and services.

Additionally, organizations face difficulty in measuring the long-term benefits of sustainable procurement practices. Environmental and social benefits such as reduce pollution, energy savings, and waste reduction are often difficult to quantify and assess immediately.

These challenges highlight the need for better awareness, training, supplier development, and effective monitoring systems for successful implementation of SPP.

The Way Forward

To strengthen Sustainable Public Procurement, organizations should:

• Adopt lifecycle costing in procurement decisions:

Procurement decisions should consider the total cost of a product throughout its entire lifecycle, including purchase, operation, maintenance, and disposal costs, instead of only the initial purchase price. This helps in selecting more sustainable and cost-effective options in the long run.

• Enhance vendor awareness and participation:

Organizations should encourage suppliers and vendors to understand and follow sustainable procurement practices by conducting awareness programs, training sessions, and regular engagement activities. Increased vendor participation improves the availability of eco-friendly products and services.

- **Leverage platforms like GeM (now mandatory) for green procurement:**

The use of digital procurement platforms such as Government e-Marketplace (GeM) helps organizations procure environmentally sustainable products in a transparent and efficient manner. These platforms also support compliance with government policies related to green procurement.

- **More digitization and paperless working environment:**

Adopting digital systems for documentation, approvals, communication, and record-keeping reduces paper consumption, improves efficiency, and minimizes environmental impact. A paperless work culture also supports faster and more transparent operations.

- **Integrate monitoring and sustainability metrics:**

Organizations should establish measurable sustainability indicators such as energy efficiency, waste reduction, carbon

footprint, and supplier compliance. Continuous monitoring of these metrics helps assess procurement performance and ensures alignment with environmental goals.

- **Encourage innovation and circular economy practices:**

Procurement strategies should promote innovative and sustainable solutions, including reuse, recycling, refurbishment, and resource recovery. Circular economy practices help reduce waste generation, conserve natural resources, and create long-term environmental and economic benefits.

In Conclusion it needs to be understood that sustainable Public Procurement is no longer an option, and it is a strategic necessity. With strong policy backing through GFR, DoE guidelines, GeM implementation and environmental regulations, procurement can evolve into a powerful driver of sustainable development.



Circularity isn't just about recycling—it's about rethinking how we create, consume, and sustain value.

- Dr Ona Newton

Green Boiler Operations as Pathways to Sustainable Industrial Growth



Nandana Sarmah
Inspector of Boilers, Assam

As the global community unites to observe World Environment Day, the exigency for sustainable industrial development has assumed unprecedented prominence. For generations, the industrial boiler has served as the pulsating core of manufacturing, an indefatigable engine powering economic advancement and shaping the contours of the modern world. Yet, this industrial progress has historically imposed a considerable burden on the environment. Today, the urgent mandate to reinstate ecological balance has positioned the humble boiler at the forefront of a transformative transition.

The evolution toward green boiler operations is no longer a peripheral environmental aspiration; it has become a foundational pillar of sustainable industrial strategy. This transition signifies a profound departure from conventional, emission-intensive practices toward advanced systems

characterized by enhanced thermal efficiency, cleaner fuels, and significantly reduced environmental impact.

Historically, the generation of industrial steam and process heat has been intrinsically dependent on the combustion of fossil fuels, establishing boilers as substantial contributors to global greenhouse gas emissions. The soot-laden smokestacks of the industrial age stand as enduring emblems of a development model, that while instrumental in driving economic progress, is no longer compatible with the ecological imperatives of our time. To honour the true spirit of World Environment Day, industries must acknowledge that the decarbonization of thermal energy systems is not merely an environmental aspiration, but both an ethical imperative and a strategic economic necessity. The journey toward this sustainable industrial future will be shaped by techno-

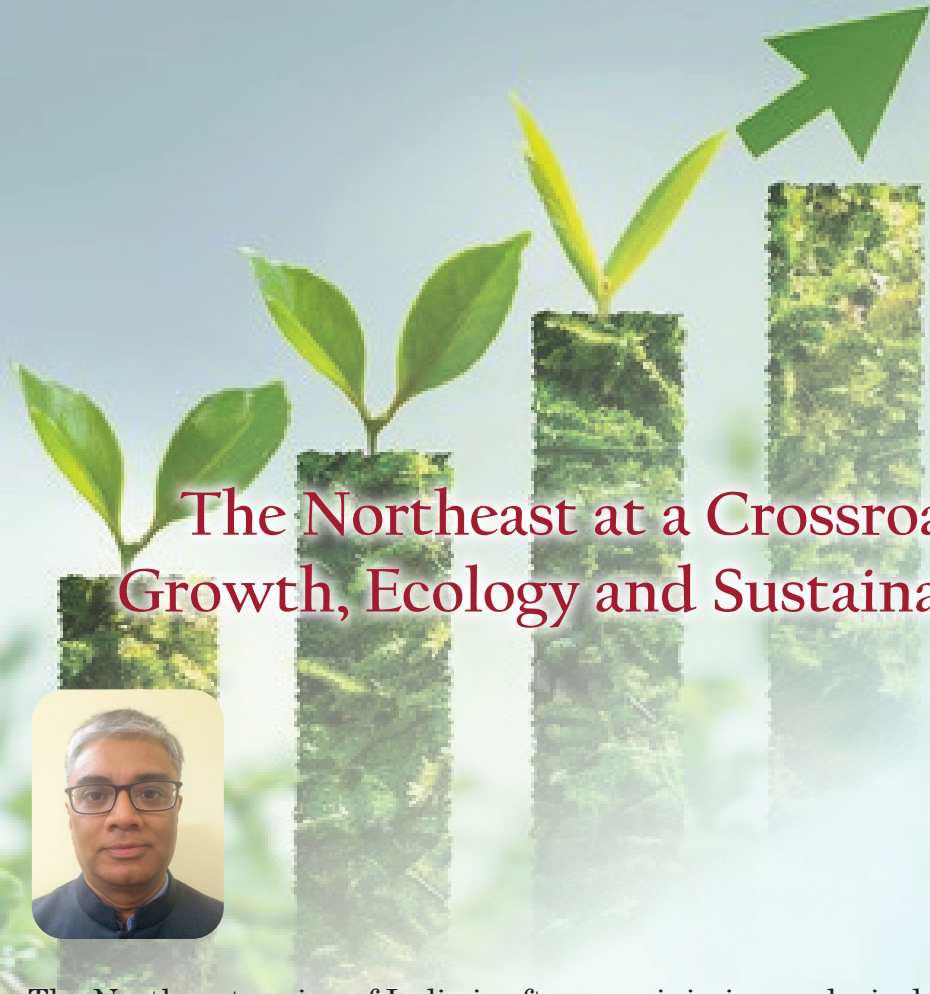
logical ingenuity, operational excellence, and an unwavering commitment to the principles of the circular economy.

The transformation of conventional boiler systems into environmentally sustainable, high-efficiency operations necessitates a multidimensional approach that harmonizes alternative fuels with state-of-the-art engineering. Among the most immediate and pragmatic pathways is the progressive replacement of coal and heavy fuel oil with cleaner, low-carbon energy sources. Sustainably sourced biomass, particularly derived from agricultural residues, offers a near carbon-neutral solution while simultaneously promoting resource circularity. Looking ahead, the landscape of industrial thermal generation is poised for profound change through the integration of biogas and green hydrogen, the next-generation fuels capable of delivering substantial energy output with minimal carbon emissions. Concomitantly in conventional boiler systems, a substantial proportion of valuable thermal energy is dissipated into the atmosphere through exhaust gases, representing both an economic inefficiency and an environmental liability. Green boiler operations address this inefficiency through the deployment of sophisticated economizers and advanced condensing technologies. By recovering and reutilizing the latent heat contained in flue gases to preheat boiler feedwater, industrial facilities can achieve marked reductions in fuel consumption while simultaneously mitigating greenhouse gas emissions and enhancing overall thermal performance. Furthermore, for industries in which the complete transition away from carbon-intensive fuels remains an evolving process, Carbon Capture and Utilization technologies provide an indispensable transitional solution. By capturing carbon dioxide at the point of emission before it is released through the stack

and redirecting it for productive industrial applications, facilities can substantially reduce their atmospheric footprint and advance meaningfully toward a lower-carbon operational paradigm.

A lingering misconception within industrial circles is that environmental responsibility is inherently at odds with commercial performance. Green boiler operations dismantle this fallacy. The very mechanisms that reduce a facility's carbon footprint viz. enhanced fuel efficiency, reduced waste heat, and optimized operational cycles, simultaneously yield substantial reductions in operating costs and enhance overall process efficiency. Additionally, as regulatory regimes across the globe increasingly impose stringent constraints and financial liabilities on carbon emissions, the adoption of sustainable thermal technologies serves as a strategic safeguard against future compliance burdens. In doing so, it strengthens corporate resilience and confers a distinct competitive advantage in a global marketplace that is progressively shaped by environmental accountability and sustainability-driven investment.

As we reaffirm our collective stewardship on World Environment Day, our ambition must extend beyond the preservation of natural resources toward the broader objective of industrial regeneration. The transformation of boiler operations from historical sources of environmental burden into exemplars of efficiency and sustainability stands as a compelling testament to human innovation and engineering excellence. By embracing these sustainable pathways, industries can ensure that the engines of progress continue to propel economic advancement while preserving the ecological integrity upon which future generations depend.



The Northeast at a Crossroads: Growth, Ecology and Sustainability



Abhijit Nath
GM (Chemical)

The Northeast region of India is often described as the country's ecological treasure house — a region blessed with dense forests, mighty rivers, fertile valleys, rich biodiversity and deeply ingrained indigenous traditions. Yet, beyond its scenic beauty lies something even more profound: a civilizational philosophy where nature is not viewed merely as a resource, but as a companion of human existence. The relationship between people and the environment of this region has historically been one of coexistence and balance.

Today, however, the region stands at a critical crossroads. Rapid urbanization, infrastructure expansion, climate change, and growing industrial aspirations are reshaping the environmental landscape of the Northeast. Simultaneously, industries are increasingly expected to grow responsibly,

minimize ecological impact and contribute positively to society. The challenge before us, therefore, is not whether development should happen, but how development can proceed while preserving the ecological and cultural identity of the region.

For centuries, the people of Northeast India have demonstrated a deep level of environmental consciousness embedded within their traditions. The indigenous Donyi-Polo faith of Arunachal Pradesh reveres the concept of balance and environmental harmony, while Khasi sacred groves in Meghalaya reflect community-led conservation practices that have survived generations. Across the region, forests, rivers, mountains and even specific trees are treated with deep respect, often associated with spiritual significance and social responsibility.

Traditional agricultural festivals further highlight this intimate relationship with nature. Bihu in Assam, Wangala in Meghalaya, and Chapchar Kut in Mizoram celebrate not only agricultural prosperity but also gratitude towards the environment that sustains life. These festivals evolved from an understanding that human survival depends on harmony with land, water and climate.

Equally remarkable are the traditional ecological practices developed by local communities over centuries. Bamboo-based drip irrigation systems in Meghalaya and Mizoram, rainwater harvesting techniques in hilly terrains, and indigenous wetland management systems illustrate how sustainability was practiced long before it became a global discourse. These examples remind us that environmental stewardship is deeply rooted in the region's heritage.

The Northeast is also a home to globally significant ecosystems, from Kaziranga's wetlands and Arunachal's forests to Loktak Lake in Manipur that demand careful protection. Yet these ecosystems face increasing pressure from changing climatic conditions, habitat fragmentation and unsustainable exploitation.

Climate change has emerged as one of the defining environmental challenges of our time. Rising temperatures, erratic rainfall, floods, droughts and ecological degradation are no longer distant possibilities; they are realities already being experienced across the world, including Northeast India. Environmental resilience — the ability to withstand and adapt to stress — will therefore become critical for future survival.

Environmental resilience is fundamentally linked to sustainable adaptation, innovation and responsible use of nature's

limited resources. Nature itself offers important lessons in resilience. Indigenous crop varieties such as deep-water paddy and drought-resistant millets have survived harsh climatic conditions through centuries of adaptation. Communities living in extreme environments, from deserts to high altitudes, have evolved lifestyles suited to their ecological realities. These examples reinforce an important truth: long-term survival depends not on domination over nature, but on learning to coexist with it.

Industries today must internalize this philosophy. Economic growth and environmental protection can no longer be viewed as opposing goals. Modern industry must become an active partner in sustainability by embracing cleaner technologies, improving resource efficiency, reducing waste generation and minimizing emissions. Globally, industries are increasingly transitioning towards circular economy principles models where waste from one process becomes a resource for another, thereby reducing environmental burden and conserving natural resources.

For the petrochemical sector in particular, this transition carries both responsibility and opportunity. Plastics and polymers have transformed modern life through applications in healthcare, agriculture, infrastructure, packaging and transportation. Yet concerns surrounding plastic waste and carbon emissions have also intensified. The future therefore lies not merely in production, but in responsible production — supported by recycling, circularity, innovation and sustainable material management.

Many promising initiatives are already emerging. Chemical recycling technologies, waste-to-value projects, renewable integration, carbon management strategies and energy efficiency improvements are re-

shaping the industrial sustainability landscape. The growing focus on Net Zero pathways and greenhouse gas reduction targets reflect a broader recognition that climate responsibility must become part of corporate strategy and governance.

At the same time, sustainability cannot remain confined within industrial boundaries alone. Public participation and community engagement are equally important. Environmental responsibility begins with everyday actions — reducing waste, conserving water, improving energy efficiency and protecting local ecosystems. A truly sustainable future requires collaboration between governments, industries, academic institutions, communities and citizens.

The Northeast offers immense potential in this regard. The region's traditional knowledge systems, biodiversity wealth and cultural ethos can complement modern scientific innovation to create unique sustainability models. Eco-tourism, bamboo-based industries, bio-resources, sustainable agriculture, wetland conservation and green infrastructure can generate economic opportunities while preserving ecological balance. The success of such initiatives depends on integrating local communities as active stakeholders rather than passive beneficiaries.

An inspiring example of this blend of tradition and sustainability is the emerging lotus silk industry of Manipur. Once a traditional craft, lotus silk production has evolved into a sustainable livelihood initia-

tive that combines ecological preservation with economic empowerment. The process utilizes lotus stems from Loktak Lake to produce eco-friendly textile fibres with minimal environmental impact. Beyond creating livelihood opportunities for local women, the initiative also encourages conservation of the lake ecosystem itself.

Ultimately, the path forward for Northeast India lies in achieving balance — balance between ecology and economy, modernization and tradition, industrial growth and environmental responsibility. Development cannot come at the cost of irreversible ecological damage, nor can environmental protection ignore the developmental aspirations of society. Sustainable progress requires a long-term vision where industry becomes a catalyst for resilience and inclusive growth.

Nature has always shaped the identity of the Northeast. Its rivers have nurtured civilizations, its forests have sustained communities, and its biodiversity has enriched cultural traditions. As the region moves towards a future of greater industrialization and economic integration, preserving this natural heritage becomes not merely an environmental obligation, but a moral responsibility.

Northeast India can emerge as a model for sustainable development — a region where nature and industry grow in harmony.



Mumbai Dabbawala: Delivering Sustainability Along with Meals



Bedabrata Borah
SM (Chemical)

Introduction

In today's rapidly urbanizing world, environmental conservation has become a global priority. Rising pollution levels, excessive waste generation, and increasing fuel consumption are forcing societies to re-think the way city's function.

Amid modern technological solutions, one traditional system from India continues to stand out as a remarkable example of sustainable living—the Mumbai Dabbawala Association network.

Known worldwide for its precision and discipline, the Mumbai Dabbawala system is more than just a lunch delivery service. It is a living example of how simple, community-based practices can support environmental sustainability.

Understanding the Dabbawala System

The history of Mumbai Dabbawala System goes back to 1890 when a Parsi banker in Bombay sought a way to receive home cooked meals at work. He hired Mahadeo Havaji Bachche for the task who eventually

started delivering tiffins over workplaces in a structured manner. For over a century, Mumbai Dabbawalas have been delivering freshly prepared home-cooked meals to office workers across the city.

Every day, thousands of tiffin boxes travel from homes to workplaces through a carefully coordinated network managed by nearly 5,000 Dabbawalas. Despite operating in one of the busiest cities in the world, the system is famous for its punctuality and near-perfect accuracy.

What makes this system truly inspiring is its environmentally responsible approach.

MUMBAI DABBAWALA SYSTEM: HELPING ENERGY CONSERVATION



- Minimal use of motor vehicles
- Low carbon footprint
- Reduced energy consumption

Green Transportation Methods

Unlike many modern delivery services that depend on motorcycles, vans, and fuel-powered transport, Dabbawalas mainly use our most economical and environment friendly ways of transportation. These ways include Bicycles, Wooden carts and hand-carts and the last but the most efficient one- Mumbai's suburban railway system. Because of this low-energy transportation model, the system produces very little pollution. Also, these modes of communication give Dabbawalas one incredible superpower, which is cheapest transportation cost.

Environmental Advantages:

- **Reduced carbon footprint:** very low CO2 emissions, helping reduce air pollution and climate change.
- **Lower air pollution levels:** almost zero emissions due to usage of rudimentary ways of commute including public transport.
- **Less fuel consumption:** they use existing infrastructures efficiently thereby ensuring sustainable land and energy resources.
- **Reduced traffic congestion:** community commute and almost fuel-free-last mile delivery ensures them to contribute to reduced traffic congestion and low noise pollution indirectly.

The Dabbawala network proves that efficient urban transportation does not always require heavy use of fossil fuels.

Reusable Tiffin Culture

One of the most eco-friendly aspects of the Dabbawala system is its dependence on reusable containers instead of disposable packaging. Meals are packed in durable stainless-steel tiffin carriers that are used

repeatedly for years.

Benefits of This Practice in Environmental aspects:

- Prevents plastic waste generation
- Reduces use of disposable materials
- Encourages a culture of reuse

At a time when cities struggle with plastic pollution, the Dabbawala model naturally follows sustainable waste-management principles.

Promoting Responsible Food Consumption

The system also encourages healthier and environmentally conscious food habits. Millions of corporate and government employees are enjoying home-style cooked meals which has reduced one of the unhealthiest habits of eating- packaged fast food and processed meals. This also reduces chances of many lifestyles induced diseases. By delivering homemade meals, it also reduces dependence on Single-use food packaging. It also promotes locally sourced food items such as fish, poultry and organic vegetables which indirectly empowers small scale businesses.

Additionally, home-cooked food generally requires fewer industrial processes, less packaging, and shorter supply chains, which helps lower environmental impact. Additionally, homemade meals often lead to less food wastage.

Simplicity with Maximum Efficiency

The success of the Dabbawala network is especially remarkable because it functions with minimum technology dependency. Instead of digital systems and automated machines, Dabbawalas use

Color-coded markings and manual sorting methods in all their tiffins, which help them to identify pickup location, its delivery destination along with final delivery area/building ensuring correct routing through multiple hands. This remarkable team coordination and discipline enable them to achieve Six Sigma level efficiency without digital footprints and with illiterate workers. This network is so remarkable that it handles approximately 200000 deliveries daily with the lowest of error rate. At every stage (sorting point, railway station, delivery area), markings are checked multiple



times which helps them to identify any mistake at a faster way. Then the incorrectly routed tiffins are resorted and redirected towards their correct destination.

Sustainable Impact:

Their work shows that sustainable systems can be built through organization,

trust, and human cooperation. This entire business is based upon basic human cognitive capabilities where sustainability goes side by side. They need negligible electricity to run, log, tally, sort or intimate on a soft copy basis where manual intervention is the best and proven technology till date. So, they produce minimum technological waste which require same sophistication during proper and safe disposal. Their operational energy requirements are also minimal as their modus operandi is completely manual and labour intensive during sorting, identification and tracking of the delivery.

Social and Economic Sustainability

Apart from environmental benefits, the Dabbawala system also contributes to society in meaningful ways.

- **Generates employment for thousands of people:** this is a unique model where all employees require assertive and proactive mental alertness in this job profile without any professional degree or any formal education. This helps the system to generate employment for thousands of people belonging to various economical hierarchies.

- **Requires low-cost infrastructure:** straight from kitchen to table model enables dabbawalas to perform without any physical warehouse or large-scale industrial kitchen which requires energy intensive maintenance. Thus, all stakeholders are happy due to preservation of original fabrics in a society.

- **Strengthens teamwork and community relationships:** this close-knit jigsaw model empowers everyone to fill their own puzzles, thus ensuring empathy and

accountability towards what they do daily. This basic human behaviour is the main fuel behind this juggernaut and can be studied or dissected under microscopic lens of supply chain management in modern tech savvy world for alternate business solutions.

This balance of social, economic, and environmental responsibility makes the system a globally respected model of sustainable urban living.

What the World Can Learn

The Mumbai Dabbawala system teaches several important lessons for the future:

- Sustainability does not always require expensive technology
- Traditional systems can offer modern environmental solutions
- Reuse and minimalism are powerful conservation tools

- Community cooperation can create highly efficient systems

Cities around the world can adopt similar eco-friendly logistics practices to reduce pollution and save resources.

Conclusion

On World Environment Day, the Mumbai Dabbawala system stands as a reminder that sustainable living begins with simple everyday actions. Through reusable containers, fuel-efficient transportation, low energy use, and community cooperation, the Dabbawalas have demonstrated how a traditional service can contribute significantly to environmental conservation.

Their journey proves that protecting the planet does not always require complex innovations—sometimes, the simplest systems create the greatest impact.



Butterfly Species Documented by Roshan Upadhyay

Enhancing Reliability and Sustainability in Effluent Treatment Plants (ETP) / Zero Liquid Discharge (ZLD) Systems: Key Challenges and Practical Solutions



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Background

Managing water and wastewater has become a 'costly affair' for most of the industries due to nonavailability of freshwater, increased water & energy costs, treatment costs and stringent environmental regulations. In States adjacent to Ganga River Basin, Industries are not allowed to discharge any effluent from their premises. As a result, the industries in these regions have adopted advanced wastewater treatment schemes with Reverse Osmosis (RO) to reuse its treated wastewater. The RO reject management is done by evaporating the rejects using combination of Multi Effect Evaporator, Crystallizers and solar ponds.

Today, many industries have achieved 'Zero Liquid Discharge (ZLD)' by adopting latest technologies and many more industries need to implement ZLD systems due to stricter compliances. However, in this exercise industries are bearing a recurrent substantial 'Operation & Maintenance' costs which directly affects the overall 'cost of production' of the units. Sometimes the ZLD

systems do not work properly due to wrong selection of design and lack of trained staff and industries struggle to maintain ZLD systems. It's been observed that the existing 'Zero Liquid Discharge' plants have significant potential for further improvements to achieve substantial cost savings. In this context, the present paper highlights important aspects which need to be taken care of while designing, selection of technology, trouble shooting and smooth Operation of ZLD systems so that they become more reliable & sustainable.

What is Zero Liquid Discharge (ZLD)?

Zero Liquid discharge (ZLD) implies that the industries are not discharging any effluent, either on land or in the water body or at any other place i.e. recycling the same in the process entirely without releasing any effluent (treated/untreated) into the environment.

As per CPCB the ZLD may be defined as "The entire quantity of effluent is treated to recover water and recovered water is reused in process and/or utilities, and only

solids are disposed of (or reused, if possible) in environmentally sound manner. Reuse of treated effluent for horticulture or agriculture purposes will be considered as discharge on land and not as means to achieve ZLD. Similarly, effluent of individual industries being sent to CETP for treatment will not be considered as ZLD.”¹

• Zero Liquid Discharge Meaning in Industrial Wastewater

Zero Liquid Discharge (ZLD) is a strategic, advanced wastewater management system designed to eliminate all liquid waste from industrial processes, ensuring none is released into the environment. It treats, purifies, and recycles virtually all water for reuse, reducing water consumption, lowering disposal costs, and ensuring compliance with strict environmental regulations.

ZLD systems in industries provide critical benefits by treating and recycling up to 95-99% of wastewater, resulting in nearly zero waste. Key advantages include meeting stringent environmental regulations, reducing freshwater consumption, cutting waste disposal costs, and recovering valuable by-products. These systems ensure environmental sustainability and operational efficiency.

To optimize water recovery and reduce waste, ZLD operates as a closed-loop treatment cycle that integrates several physical, chemical, and biological treatment processes. Primary and secondary treatment, sophisticated membrane technologies, thermal evaporation, crystallization, and solid separation units are usually included in the system. These procedures greatly lessen reliance on freshwater sources

by continuously recycling cleaned water back into industrial processes like cooling, boiler feed, process use, and washing.”²

Along with water recovery, Zero Liquid Discharge (ZLD) focuses on efficient use of resources and environmental safeguarding by transforming dissolved solids, salts, and pollutants into manageable solid forms. These solids can either be safely discarded in approved facilities or, when possible, repurposed for beneficial use. By removing liquid effluent discharge, ZLD systems assist industries in meeting strict environmental regulations, avert contamination of surface and groundwater, and contribute to long-term sustainability objectives.

• Need for Zero Liquid Discharge

Zero Liquid Discharge (ZLD) has emerged in India as a critical wastewater management strategy, particularly for water-intensive and pollution-prone industrial sectors. The adoption of ZLD systems in the Indian context is not driven by a single factor, but by a convergence of regulatory mandates, infrastructural limitations, socio-environmental pressures, water scarcity economics, and evolving sustainability and ESG expectations. Together, these drivers have transformed ZLD from a compliance-oriented solution into a strategic response to water risk and environmental accountability. The key drivers for adoption of ZLD system in Indian context are:

• **Stringent Regulatory Mandates :** In India, industrial wastewater discharge norms have become progressively stricter, driven by CPCB directives and SPCB enforcement. In many states, such as Tamil Nadu, Gujarat, Andhra Pradesh, and Maharashtra, chemical industries are required to operate under Zero Liquid Discharge norms,

with very high standards for Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and other pollutant parameters.

Non-compliance can result in penalties, cancellation of Consent to Operate (CTO), and even plant closure, as seen with dye and electroplating units in Ludhiana, where ZLD compliance is being enforced by the Punjab Pollution Control Board.

- **Water Scarcity and Resource Constraints :** India is classified as water-stressed or water-scarce in many regions. Chemical plants located in zones with limited freshwater availability face competition with agriculture, domestic use, and ecosystem needs. ZLD systems, by enabling 90%+ water reuse, reduce dependence on borewells or external water, thereby enhancing plant resilience and sustainability.

- **ESG and Corporate Sustainability Objectives :** Environmental, Social, and Governance (ESG) expectations are rising in Indian industries, especially among global supply chains. Companies that adopt ZLD can demonstrate reductions in freshwater consumption and wastewater pollution. ZLD implementation supports water stewardship metrics in ESG frameworks (e.g., GRI, CDP Water) and can strengthen brand value and investor confidence.

- **Public and NGO Pressure :** Communities and environmental advocates increasingly oppose industrial discharges into rivers, lakes, and groundwater. Public and media scrutiny can influence regulators to enforce stricter discharge norms, making ZLD not only a compliance activity but a social license to operate.

Economics of Water Use and Cost Savings : Although ZLD systems have high initial costs (CAPEX) and operational costs (OPEX), they can reduce long-term expenditure on water procurement and effluent disposal. By recycling water and capturing valuable by-products (e.g., salts), industries, particularly chemicals, can improve process economics and reduce dependency on external water sources, especially where water is expensive or rationed.

- **Site and Process Considerations :** The characteristics of influent wastewater, including pH, temperature, organic load, salinity, and presence of toxic compounds, heavily influence what treatment technologies should be selected. Highly saline or chemically complex streams common in chemical process industries often necessitate advanced treatment trains combining biological, membrane, and thermal processes.

In summary, the drivers for implementing ZLD in India extend well beyond regulatory compliance. They encompass infrastructural gaps, socio-environmental pressures, water scarcity realities, evolving water economics, and the strategic imperatives of ESG-driven business models. As water risks intensify due to climate variability, urbanization, and industrial growth, ZLD is increasingly being positioned not merely as an end-of-pipe treatment solution, but as a core element of integrated water management and long-term industrial sustainability in India. The Industry Decision-Making Guidelines for Implementing Zero Liquid Discharge (ZLD) in India is given below for reference.

Table 1: Industry Decision-Making Guide for Implementing Zero Liquid Discharge (ZLD) in India

<i>Issues / Drivers</i>	<i>Opportunities for Industry</i>	<i>Methodology / Strategic Approach</i>	<i>Expected Outcomes</i>
Regulatory mandates under MoEFCC Environmental Clearance conditions	Early compliance and reduced regulatory risk; faster approvals for expansions and brownfield modifications	Review EC conditions, sector-specific ZLD mandates, and SPCB directions; integrate ZLD into project design stage	Sustained regulatory compliance, lower risk of notices, closures, and litigation
SPCB directions and cluster-specific restrictions	Uniform compliance across industrial estates; reduced dependency on external disposal approvals	Conduct state-specific regulatory gap analysis; adopt ZLD where CETP/CEPT capacity is inadequate or uncertain	Improved regulatory certainty and operational continuity
Absence or inadequacy of CETP/CEPT and wastewater disposal infrastructure	Self-reliance in wastewater management; elimination of third-party treatment and disposal risks	Develop in-house ZLD systems with robust pre-treatment, membrane systems, and thermal concentration	Reduced operational disruptions; long-term cost stability
Limited availability of authorized discharge points (surface water/marine outfalls)	Complete elimination of liquid discharge liabilities	Adopt closed-loop water management with maximum reuse and internal recycling	Zero discharge to the environment; enhanced environmental performance
Community and farmer concerns regarding contamination of land and groundwater	Strengthened social license to operate; reduced conflict and reputational risk	Stakeholder engagement; transparent water balance disclosure; ZLD as a risk-mitigation commitment	Improved community relations; lower risk of protests and legal actions
Dependence on groundwater in water-stressed regions	Long-term water security and resilience	Implement ZLD with high water recovery efficiency; integrate with rainwater harvesting and reuse	Reduced freshwater abstraction; improved groundwater sustainability
Limited and unreliable public water supply	Operational reliability and business continuity	Design ZLD systems aligned with minimum freshwater intake targets	Reduced vulnerability to water supply disruptions

<i>Issues / Drivers</i>	<i>Opportunities for Industry</i>	<i>Methodology / Strategic Approach</i>	<i>Expected Outcomes</i>
Increasing industrial water tariffs	Reduction in recurring water procurement costs	Evaluate lifecycle water cost; optimize reuse and recycling through ZLD	Lower net water cost over project life
Full cost of water (treatment, pumping, energy, compliance)	Improved cost transparency and capital planning	Incorporate full water cost accounting into feasibility studies	Informed investment decisions; optimized CAPEX–OPEX balance
Water opportunity cost in competing demand regions	Alignment with regional water sustainability priorities	Apply water foot printing and basin-level water risk assessment	Reduced conflict with other water users; improved regional acceptance
The shadow price of water reflects future scarcity and regulation	Futureproofing against tightening regulations and climate risks	Integrate shadow water pricing into long-term financial models	Enhanced financial resilience; reduced stranded asset risk
ESG and sustainability commitments (CDP Water, water stewardship)	Improved ESG ratings and investor confidence	Align ZLD implementation with ESG metrics and disclosure frameworks	Stronger ESG performance and access to sustainable finance
Water-positive and net-zero water targets	Leadership positioning in sustainability	Combine ZLD with reuse, recharge, and offset initiatives	Net-positive water impact and brand differentiation
Increasing scrutiny from investors, customers, and lenders	Competitive advantage in global supply chains	Use ZLD outcomes as verifiable evidence in ESG and sustainability reporting	Improved market access and stakeholder trust

• Core Components of ZLD System

A complete zero liquid discharge (ZLD) system needs multiple specialized treatment stages that work together to eliminate liquid waste. Each component has a vital role in removing contaminants, concentrating dissolved solids, and recovering water.

Zero Liquid Discharge (ZLD) systems are designed to eliminate liquid waste, ensuring maximum water recovery through a combination of physical, chemical, and thermal processes. Core components include pretreatment (clarifiers, filters) to remove solids, membranes (Reverse Osmosis/Ultra-filtration) for concentration, and thermal equipment (evaporators/crystallizers) to convert remaining brine into solid waste.

• Key Core Components of a ZLD System:

a. Pre-treatment System: Removes suspended solids, heavy metals, hardness, and silica using clarifiers, chemical feeds (coagulation/flocculation), and filters to prevent membrane fouling.

b. Membrane Filtration (Concentration Phase): Utilizes Ultrafiltration (UF) to remove trace suspended solids and Reverse Osmosis (RO) to separate the bulk of dissolved solids, creating a concentrated brine stream.

c. Brine Concentrator: Further reduces the volume of the wastewater by concentrating the reject from the RO system.

d. Evaporator: Uses heat (often through Mechanical Vapor Recompression - MVR) to vaporize remaining water, concentrating the waste to a near-solid state.

e. Crystallizer: The final stage that boils off remaining liquid to produce solid, dry cake for disposal or potential reuse.

f. Filter Press/Dryer: Used to separate, dewater, and concentrate solids from the effluent.

Enhancing Reliability and Sustainability in Effluent Treatment Plants (ETP) / Zero Liquid Discharge (ZLD) Systems

Selection and operation of Effluent Treatment Plant (ETP) and Zero Liquid Discharge (ZLD) systems pose complex, interlinked challenges for the industry. First, choosing the right treatment scheme is critical for reliable, sustained operations. Industries must match schemes to variable influent chemistry, flow regimes, and downstream disposal constraints. Mis-sized units, inappropriate technology choices, or lack of contingency for seasonal or process-driven fluctuations lead to chronic underperformance, frequent interventions, and higher lifecycle costs.

Ease of operation and user-friendliness are often overlooked during design. Complex control sequences, poor accessibility to critical instrumentation, and overly manual maintenance routines increase dependency on skilled operators. High staff turnover or limited in-house expertise transforms routine tasks into vulnerabilities, raising the probability of operational lapses and non-compliance.

Operational issues such as dynamic pollutant loads, corrosion and scaling aggressively affect equipment longevity and performance. Sudden spikes in toxics, oil and grease, or salinity force frequent chemical dosing, upset biological processes, and accelerate fouling. Corrosion, driven by pH swings, chlorides, and oxidants, shortens equipment life and inflates maintenance costs. Scaling in membranes and evaporators reduces throughput and energy efficiency, demanding costly cleanings and downtime.

Energy consumption and carbon footprint are rising concerns. RO trains, thermal evaporators, and mechanical concentrators are energy-intensive; without integrated energy recovery and optimization, OPEX and emissions escalate. Pressure on industries to meet ESG targets and regulatory expectations increasingly ties environmental performance to business risk and finance, making energy-efficient design non-negotiable.

Digital technologies and AI offer solutions,

real-time monitoring, predictive maintenance, and process optimisation, but adoption faces hurdles. Many plants lack robust sensor networks, have fragmented data systems, or suffer poor data quality. Developing and validating predictive models requires historical data, cross-disciplinary expertise, and change management to integrate AI outputs into operations. Cybersecurity and vendor lock-in are additional concerns.

Challenges in ETP/ZLD Systems and Practical Solutions

Key Challenge Area	Description of Challenges	Practical Solutions / Best Practices
1. Selection of the Right Treatment Scheme	Difficulty in matching treatment schemes with variable influent quality, process fluctuations, and disposal constraints. Mis-sizing or wrong technology selection leads to chronic underperformance.	Use technology selection matrices, pilot tests, and data-driven feasibility studies; adopt modular or hybrid systems; incorporate flexibility for load variations; ensure expert review during the design stage.
2. Ease of Operation & User-Friendliness	Complex control systems, inaccessible equipment layouts, excessive manual interventions, and dependence on highly skilled operators.	Improve equipment layout and accessibility; automate critical sequences; standardize SOPs; provide intuitive HMLs; design with operator ergonomics and maintainability in mind.
3. Operational Issues: Dynamic Loads, Corrosion & Scaling	Shock loads affect biological stability; corrosion reduces equipment life; scaling reduces RO and evaporator performance, increasing downtime.	Incorporate equalization and buffering systems; strengthen feed conditioning; use corrosion-resistant materials; adopt anti-scalant strategies; implement regular monitoring and predictive maintenance.
4. Energy Consumption & Carbon Footprint	High energy demand of RO, MEE/MVR, and evaporators increases OPEX and emissions; lack of energy recovery systems.	Integrate energy recovery devices; optimize RO recovery; select energy-efficient evaporators; perform energy audits; incorporate renewable energy options and align design with ESG goals.
5. Need for Digital Technologies & AI	Limited sensor networks, poor data quality, lack of historical datasets, and difficulty integrating predictive tools into operations.	Upgrade instrumentation; implement IoT-based dashboards; ensure structured data collection; adopt AI-driven predictive analytics; train teams on digital workflows; strengthen cybersecurity.
6. Capacity Building & Skills Gap	Design teams and mid-level operators often lack a holistic understanding of process integration, costing, and troubleshooting.	Specialized training programs; hands-on case studies; cross-functional learning; exposure to design-to-operation concepts; continuous skill enhancement modules.

Federation of Indian Chambers of Commerce & Industry (FICCI) is one of the apex chambers of commerce & industry in the country. FICCI is an accredited / certified water auditing agency by State Ground Water Regulations Authority /CGWA, Ministry of Jal Shakti, Government of India for undertaking compliance water audit studies of industries.

FICCI is one of the organizations which has vast experience in Water Audit Services

spread around almost in every sector providing Water Neutrality Roadmap and its certifications in line with ESG framework adopted by Indian Corporate Groups.

The author may be approached for any of the above services as well as for online discussions for seeking any techno-commercial proposals for your Industry or Corporate Group at Surender Kumar Verma, Additional Director, FICCI, M-09818186253 E-surender.verma@ficci.com and surenderkverma@gmail.com.

! Status report in compliance of Hon'ble NGT order dated 08.02.2022 In the matter of Beant Singh Bajwa, The President, National Anti-Corruption Council Versus State of Punjab (NGT order dated 08.02.2022 in O.A No. 682 /2019).

!! <https://susbio.in/zero-liquid-discharge-implementation/>



Photography by Hrishikesh Gupta, SM (Chemical)

Water Pollution: A Growing Threat to Human Survival



Nilima Baruah
Environmental Scientist
Assam Pollution Control Board

Water is life. Every living being on Earth depends on clean and safe water for survival. Yet, in many places today, clean water is becoming increasingly difficult to access. The situation is deeply concerning in cities like Guwahati, where heavy rainfall for even an hour often leads to severe water logging. Water fills roads, lanes, and every corner of the city. Alongside the mighty Brahmaputra River, Guwahati is surrounded by numerous natural water bodies. Ironically, despite being rich in water resources, many people still struggle to obtain clean drinking water.

Today, while one section of society depends on advanced purification systems such as RO filters, another section continues to search for safe and drinkable water. This contradiction clearly reflects the growing crisis of water pollution — one of the most serious environmental challenges of our time.

Water pollution occurs when harmful substances such as industrial waste, sewage, plastics, chemicals, pesticides, oils, and untreated garbage contaminate rivers, lakes, ponds, and groundwater. Rapid urbanization, improper waste disposal, and lack of public awareness have worsened the

condition significantly. Human negligence has turned many valuable water sources into dumping grounds.

The impacts of water pollution are alarming. Contaminated water spreads dangerous diseases such as cholera, typhoid, diarrhea, and hepatitis. Polluted rivers also affect aquatic life, destroying ecosystems and reducing biodiversity. In addition, toxic heavy metals and chemicals entering the food chain can create long-term health problems in humans. If the situation continues unchecked, future generations may face severe scarcity of safe drinking water.

Organizations like the **Central and-State Pollution Control Boards** are continuously working to address this issue. The Boards regularly monitor industries, hotels, hospitals, and other establishments to ensure compliance with environmental laws. Monthly monitoring programs are conducted for natural water bodies across the state. During festivals and special events that may affect rivers and lakes, additional monitoring and restoration measures are implemented in coordination with other government departments. Public complaints regarding pollution are also taken seriously, and necessary actions are taken promptly.

The Central Laboratory of the Board examines 44 important water quality parameters, including pH, BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TDS (Total Dissolved Solids), and heavy metals such as copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn). These parameters must remain within prescribed limits for water to be considered safe and usable. For instance, the BOD level in river water should ideally remain below 3 mg/L, while chloride content in drinking water should not exceed permissible limit i.e., 250 mg/L (According to BIS Indian Standard).

However, despite scientific monitoring and administrative efforts, the results are often not as effective as expected. One major reason is the lack of environmental awareness among people. Improper waste disposal and poor waste segregation continue to pollute drains, rivers, and wetlands. Plastic waste, untreated sewage and household garbage frequently end up in water bodies, worsening the crisis.

Environmental conservation is not solely the responsibility of government agencies; it is a collective duty of every citizen. Protecting water sources means ensuring that no untreated liquid or solid waste is directly discharged into rivers, lakes, or ponds. Waste should be scientifically treated, recycled, or reused wherever possible.

Small individual actions can create a large impact. Avoiding plastic disposal into drains, conserving water, practicing proper waste segregation, reducing chemical usage, and spreading awareness are simple yet powerful steps toward protecting our environment. Sustainable habits developed today can help secure a cleaner and healthier future tomorrow.

Clean water is not a luxury — it is a basic human necessity. If we fail to protect our water resources now, future generations may inherit a world where water exists everywhere, but not a single drop is safe enough to drink. The time to act is now, before the silent crisis becomes irreversible.

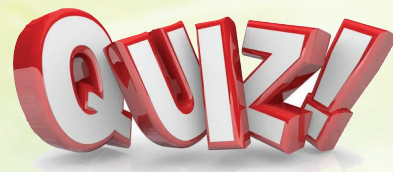


APCB officials during analysis of water samples in the central laboratory of the Board



APCB officials during water sample collection

Environment Awareness Quiz



Prepared by-
Sampreeti Gogoi
Manager (Chemical)

How Green Are You?

A fun and slightly tricky quiz to test how environmentally aware you really are!

Answer honestly, calculate your score, and find out which Green Personality you belong to.

• How to Play

- Read each question carefully
- Choose the option you think is correct
- Write down your answers
- Give yourself 1 point for every correct answer
- Add your total score at the end
- Check your result in the Green ScoreCard

QUIZ QUESTIONS

1. Which layer of Earth protects us from harmful UV rays?

- | | |
|----------------|----------------|
| A. Troposphere | B. Ozone Layer |
| C. Lithosphere | D. Hydrosphere |

2. India launched “Mission LiFE” to encourage people to:

- A. Adopt eco-friendly lifestyles and daily habits
- B. Adopt sustainable lifestyles and habits
- C. Follow environmentally conscious habits in everyday life
- D. Promote climate-friendly behaviour and sustainable choices

3. The “ozone hole” mainly forms over which region?

- A. Sahara Desert
- B. Antarctica
- C. Amazon Rainforest
- D. Indian Ocean

4. What does “net zero” mean in climate discussions?

- A. Using zero discharge policy
- B. Achieving carbon neutrality through emission reduction and absorption
- C. Balancing emitted greenhouse gases with equivalent removal efforts
- D. Reaching a state where net greenhouse gas emissions are effectively zero

5. Which of these is the best everyday way to reduce plastic waste?

- A. Reusing plastic bottles forever
- B. Carrying your own reusable bottle
- C. Throwing plastic in the “dry waste” bin without checking
- D. Burning plastic at home

6. Which action is likely to have the greatest long-term impact on reducing urban air pollution?

- A. Increasing the number of private electric cars
- B. Expanding public transportation and green mobility
- C. Building more parking spaces in cities
- D. Using air purifiers in public places

7. Which approach is most effective for reducing household water wastage?

- A. Practicing efficient water use in daily activities
- B. Adopting controlled water consumption habits
- C. Using water responsibly through conservation practices
- D. Following sustainable methods to minimize water use

8. Which travel habit is usually more eco-friendly?

- A. Sharing rides whenever possible
- B. Using public transport for regular travel
- C. Choosing transportation with lower fuel consumption
- D. Reducing the number of individual vehicle trips

9. The term “COP” often seen in climate news refers to:

- A. Council of Parties
- B. Conference of the Parties
- C. Convention of Parties
- D. Committee of the Parties

10. What is the main cause of acid rain?

- A. Oxygen pollution
- B. Sulphur dioxide and nitrogen oxides
- C. Water vapor
- D. Dust particles only

Answer at Page No. 88

• Green Score Card**0 – 4 Points → The Beginner Seed**

You're just starting your environmental awareness journey.

Nature is calling... and maybe it's time to pick up!

A little more awareness can make a big difference.

Your Mission:

Start with small habits—save water, reduce plastic, and stay updated on environmental news.

5 – 7 Points → The Growing Green Mind

You care about the environment and have decent awareness, but there's still room to grow!

You're on the right path—just keep watering your green habits.

Your Mission:

Turn awareness into action.

Consistency is where real change happens.

8 – 10 Points → The Planet Protector

Impressive!

You're highly aware and environmentally responsible.

You understand that protecting nature isn't a trend—it's a responsibility.

Your Mission:

Lead by example and inspire others to live greener too.

• Final Thought

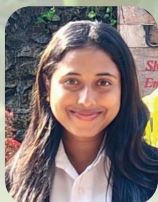
The Earth doesn't need a few people doing sustainability perfectly.

It needs millions doing it imperfectly—but consistently.

Production Of Bio-Ethanol From Water Hyacinth Using Sodium Hydro-Oxide (NaOH)



Abhisikha Bora



Manjeeta Borah



Champak Hazarika



Jyotirmoy Baruah

The global demand for energy is increasing rapidly, while fossil fuel reserves are declining. Bioethanol has emerged as a promising alternative fuel due to its renewable nature and lower greenhouse gas emissions. Conventional bioethanol production uses food-based raw materials such as sugarcane and corn, which leads to food-fuel conflicts.

Water hyacinth (*Eichhornia crassipes*) is an invasive aquatic plant that grows rapidly in water bodies, causing blockage of waterways, reduction of dissolved oxygen, and loss of aquatic biodiversity. Its high cellulose content makes it a suitable lignocellulosic biomass for bioethanol production. This project aims to convert this problematic weed into a valuable energy resource.

The team comprises of four members Abhisikha Borah, Manjeeta Borah, Champak Hazarika, Jyotirmoy Baruah of 8th Semester Chemical Engineering Department of Bineswar Brahma Engineering College under the guidance of Mr. Amarjit Das, B.E, MTech (Assistant Professor, Bineswar Brahma Engineering College) have done a project on “Production of Bio-ethanol from Water Hyacinth using Sodium Hydroxide” as a part of their academic research .

Water Hyacinth as a Biomass Source

Water Hyacinth (WH) is considered a lignocellulosic biomass because it contains Cellulose , Hemicellulose and Lignin. Cellulose and hemicellulose can be converted into fermentable sugars, which are further used to produce ethanol.

Comparison between Food and non food bio ethanol

<u>SOURCE</u>	<u>TYP E</u>	<u>ETHANOL YIELD (v/v)</u>	<u>PROCESS</u>
Sugarcane Juice	1G	8-10 %	Sugar fermentation
Sugarcane Bagasse	2G	5.90-6.81 %	P+H+F
Water Hyacinth	2G	4-5 %	P+H+F

Process of Bioethanol Production from Water Hyacinth

• Collection & Preparation

Water hyacinth is collected from ponds, lakes, rivers, or other water bodies and washed thoroughly with clean water to remove dirt, mud, and other impurities. Since the plant contains a high amount of moisture, it is dried under sunlight or in a hot air oven to reduce the water content. Proper drying helps prevent microbial growth and improves the efficiency of further processing steps. After drying, the biomass is cut into small pieces and ground into fine powder. Grinding increases the surface area of the biomass, making chemical and enzymatic treatments more effective during bioethanol production.

• NaOH Pretreatment

The dried biomass is treated with dilute sodium hydroxide (NaOH) solution at temperatures around 90–120°C for about 30 minutes. This alkaline pretreatment helps in removing lignin and part of the hemicellulose present in the plant cell wall. As a result, the rigid structure of the biomass is broken down, and cellulose becomes more exposed and accessible for hydrolysis and

enzyme action. Pretreatment is an important step because it improves the efficiency of sugar release in the later stages of the process.

• Acid Hydrolysis

After NaOH pretreatment, the biomass becomes highly basic in nature. Therefore, dilute Sulphuric Acid (H_2SO_4) is added to neutralize the solution and maintain a suitable pH. Acid hydrolysis helps in breaking down complex carbohydrates and polysaccharides into smaller sugar molecules such as glucose and xylose, which are easier to ferment. This step increases the quantity of fermentable sugars available for ethanol production and prepares the biomass for enzymatic saccharification.

• Enzymatic Saccharification

In this step, cellulase enzyme is added to the pretreated biomass under controlled temperature and pH conditions. The enzyme acts on cellulose and converts it into simple fermentable sugars such as glucose. Saccharification is usually carried out for several hours to obtain maximum sugar yield. This process is eco-friendly and highly efficient because enzymes specifically target cellulose without producing harmful by-

products. The sugar-rich solution obtained after saccharification is then used for fermentation.

• Fermentation

The sugar-rich solution is fermented using yeast (*Saccharomyces cerevisiae*) under anaerobic conditions at 27–30°C for 48–72 hours. During fermentation, the yeast utilizes glucose as a food source and converts it into ethanol and carbon dioxide. Proper temperature, pH, and fermentation time are maintained to achieve maximum ethanol production. The chemical reaction involved in fermentation is:

At the end of fermentation, the solution obtained is called fermented broth, which contains ethanol along with water and other impurities.

• Fractional Distillation

The fermented broth contains ethanol mixed with water, yeast cells, and other impurities. Fractional distillation is carried out to separate and purify ethanol based on differences in boiling points. Since ethanol has a lower boiling point than water, it vaporizes first when heated. The ethanol vapours are then condensed and collected separately. This process increases the purity of ethanol and produces bioethanol suitable for fuel and industrial applications



Role of NaOH In Bioethanol Production

In this process Sodium Hydroxide (NaOH) is used for alkaline pretreatment of water hyacinth. NaOH helps in Removal of lignin, breaking down the rigid structure of biomass, also increase in cellulose accessibility. It also helps in improving sugar yield during hydrolysis.

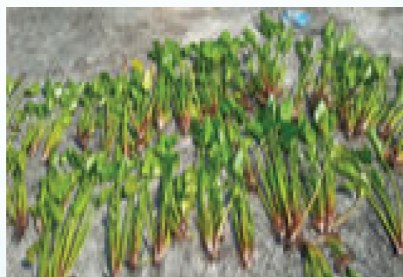


Fig: Biomass (WH)



Fig: Filtration of WH residue

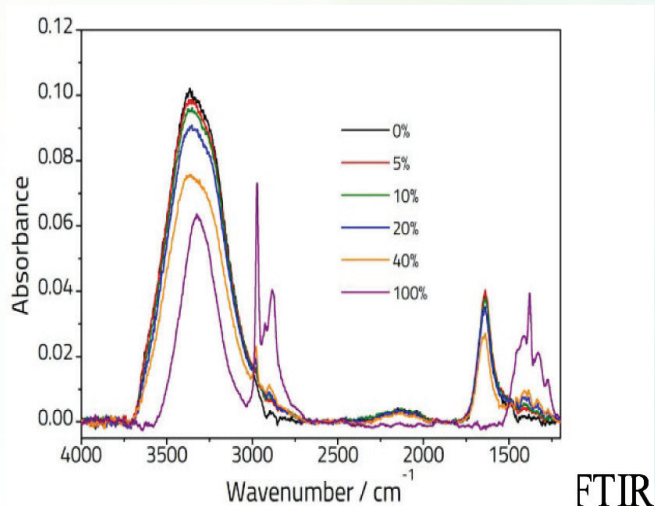


Fig: Fermentation Broth

Result

• FTIR : Fourier Transform Infra-Red Spectroscopy

The FTIR spectrum of bioethanol produced from water hyacinth using sodium hydroxide pretreatment shows important peaks that confirm the presence of ethanol and structural changes in the biomass. The broad peak around $3200\text{--}3600\text{ cm}^{-1}$ indicates O–H stretching of alcohol groups, while the peaks near 2900 cm^{-1} represent C–H stretching vibrations characteristic of ethanol. Changes in peak intensity at different NaOH concentrations suggest the removal of lignin and hemicellulose from the biomass. The treated samples showed stronger alcohol-related peaks, indicating that sodium hydroxide pretreatment improved the conversion of water hyacinth into bioethanol.

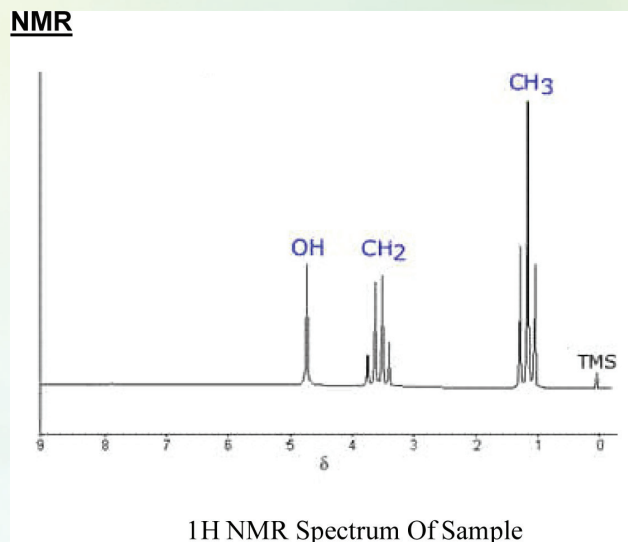


• NMR : Nuclear Magnetic Resonance Spectroscopy

NMR Analysis Result: The NMR spectrum further confirmed the presence of bioethanol in the fermented sample. A characteristic peak around $\delta\ 1.0\text{--}1.2\text{ ppm}$

corresponded to the CH_3 (methyl) group of ethanol. Peaks observed near $\delta\ 3.4\text{--}3.8\text{ ppm}$ represented the CH_2 group attached to oxygen in ethanol. A broad signal due to the OH proton was also observed. These characteristic proton signals confirmed the successful production of bioethanol from water hyacinth after NaOH pretreatment and fermentation.

NMR



Applications & Importance of Bio Ethanol

Bioethanol produced from water hyacinth can be used as an alternative renewable fuel or blended with petrol to reduce dependence on fossil fuels. It is environmentally friendly and produces lower greenhouse gas emissions compared to conventional fuels. The use of water hyacinth for bioethanol production also helps in controlling the excessive growth of this invasive aquatic weed in water bodies. Thus, the process not only provides a sustainable energy source but also contributes to waste management and environmental protection.

Conclusion

The production of bioethanol from water hyacinth represents a sustainable and eco-friendly solution to both energy scarcity and environmental pollution. By utilizing an invasive aquatic weed, the process eliminates food-fuel conflict while generating renewable energy. The NaOH pretreatment helped break down lignin and improve cellulose accessibility, enhancing the efficiency of hydrolysis and fermentation processes. This project not only highlights the potential of converting waste biomass into valuable biofuel but also contributes to environmental management by reducing water pollution caused by excessive growth of water hyacinth. Overall, the study proves that bioethanol production from water hyacinth is an economical and promising alternative to conventional fossil fuels for future energy demands.

Achievement:

It is an honour to share that our project secured 3rd prize at the National Level across India at the Anveshana Program organized by Agastya International Foundation in Bhubaneswar. Competing against 40 teams from various engineering institutes and colleges from across the country, our project “Production of Bioethanol from Water Hyacinth using NaOH” stood among the best.

Grateful for this recognition, proud of our team’s effort and grateful for the guidance from our guide Mr. Amarjit Das and motivated to continue exploring innovative and sustainable solutions. This achievement has strengthened our confidence to work further in the field of renewable energy and sustainable development. Looking forward to learning, innovating, and contributing through research-driven ideas in the future.



Indian Refinery Expansion – A Booming Opportunity for Investment in Green Hydrogen



Kalyan Ch. Nath
CM (Project)



Sabitri Bhattacharjee
CM (Project)

As climate policies both domestically and abroad continue to tighten, refiners in India—home to one of the largest global refining hubs—are rapidly advancing decarbonization efforts, with adoption of green hydrogen poised to play a vital role in achieving the nation's 2070 net-zero target.

Responsible for about 4% - 6% of total global greenhouse gas (GHG) emissions, decarbonizing the international refining industry forms a key part of global climate policy initiatives. While the sector's implementation of green hydrogen will help reduce dependence on fossil fuels and scale up the use of renewable energy—if properly executed—it also presents Indian refineries with long-term economic and strategic opportunities, including unlocking new markets and attracting future outside investments.

Ensuring refiners' transition to green hydrogen is successful, however, requires developing a supportive framework of sound

policy, financial incentives, production mandates, reliable pricing systems, infrastructure development, further research and development on emerging technologies, and public-private partnerships.

In addition to providing an overview of India's refining industry and its use of hydrogen, this article introduces opportunities for and roadblocks to expedited integration of green hydrogen by domestic refineries.

India's refineries

Vital to national energy security for the reliable supply of transportation fuels and petrochemical feedstocks to meet the demand of both domestic and export markets, India's refining sector represents the world's fourth-largest hub, its 22 operable refineries featuring a combined crude processing capacity of about 256.8 million tonnes/year.

Hydrogen Consumption

Refineries rely on hydrogen to enable hydrocracking and desulfurization processes for producing cleaner fuels. Most volumes are consumed by secondary processing units, including:

- Naphtha, diesel, and vacuum gas oil (VGO) hydrotreaters.
- Hydrocrackers (full conversion and once-through conversion crackers).
- Prime Gasoline units.
- Catalytic dewaxing units.
- Isomerization units.

Used by hydrotreaters to remove impurities from naphtha, kerosine, and diesel, hydrogen is employed by dewaxing and isomerization processes for product-value upgradation (e.g. ultralow sulphur diesel), as well as for cracking heavier hydrocarbons (e.g., VGO) into lighter hydrocarbon products (naphtha, distillates).

Most hydrogen consumed by Indian refineries is produced using carbon-intensive steam methane reforming (SMR), a natural gas-dependent process that emits an average of 9–12 tonnes of carbon dioxide (CO₂) for every 1 tonne of hydrogen produced. With its 6 million Tonne per year demand, India is currently one of the largest global hydrogen markets.

Most hydrogen consumed by Indian refineries is grey hydrogen, which is produced from natural gas without using carbon-abatement technologies.

Green Hydrogen

India's refineries afford varied opportunities for production and consumption of green hydrogen, which is produced via electrolysis using water and electricity generated by renewable or nuclear energy. In addition to drastically cutting individual-site emissions, a switch to green hydrogen

by domestic refineries would enable India to expedite attaining its net-zero ambitions.

Under the National Green Hydrogen Mission (NGHM), India commissioned approximately 8,000 tonnes per annum (TPA) of green hydrogen production capacity as of February 2026.

The Government of India has made it mandatory for refineries and fertilizer plants to gradually replace grey hydrogen with green hydrogen, aiming to shift from fossil-fuel-based feedstock to renewable energy sources. This initiative is driven by the National Green Hydrogen Mission (NGHM), launched in January 2023, which aims to make India a global hub for green hydrogen production.

Key Details of the Mandatory Shift:

- **Initial Targets:** The draft policy initially proposed that refineries must replace a minimum percentage of their hydrogen consumption with green hydrogen, starting around 2023/24, with proposals to increase this share significantly over the next five years.

- **Long-Term Goal:** By 2030, the government aims to achieve 5 Million Metric Tonnes (MMT) of green hydrogen production annually, supported by 125 GW of dedicated renewable energy capacity.

- **Refinery Focus:** Oil refineries, which use massive amounts of hydrogen for desulfurization and hydrocracking, are identified as the primary, early adopters of this mandate.

- **Mandate Mechanism:** The mandatory purchase is designed to be part of an overarching framework that requires designated consumers to meet a percentage of their total hydrogen consumption through green alternatives.

Refinery Capacity Expansion (upto 2040)

India's refining capacity is projected to reach 400–450 million metric tonnes per annum (MMTPA) by 2040. In tandem, the demand for Green Hydrogen (GH₂) within these refineries is expected to grow as India enforces decarbonisation mandates and expands its clean energy infrastructure.

The Indian government plans to nearly double its current refining capacity of approximately 258 MMTPA to meet rising domestic fuel and petrochemical demand.

- **Target Capacity:** Long-term projections aim for 450 MMTPA to consolidate India's position as one of the top three global refining hubs.

- **Strategic Growth:** Future refineries are being designed as integrated complexes that produce both traditional petroleum products and renewable energy solutions like green hydrogen.

- **Key Projects:** Major additions include brownfield expansions (approx. 142 MMT) and greenfield projects such as the 60 MMTPA West Coast Refinery and the 9 MMTPA Barmer Refinery.

Green Hydrogen Demand in Refineries

Refineries are currently one of the largest consumers of hydrogen (mostly "grey" hydrogen from fossil fuels) and are central to India's National Green Hydrogen Mission.

- **Projected Demand:** Total green hydrogen demand in India is estimated to reach 22.1 MMTPA by 2040. For the refinery sector specifically, demand is projected to grow from current levels to approximately 8.54 MMTPA by 2050.

- **Substitution Mandates:** The govern-

ment is considering mandates requiring oil refineries to replace a portion of their fuel consumption with GH₂—starting at 3% in 2025 and scaling up to 30% by 2035.

Refining giants like Indian Oil (IOCL) and Bharat Petroleum (BPCL) have already set aggressive net-zero targets for 2046 and 2040, respectively, positioning green hydrogen as a core component for their future operations.

Adoption by the sector, however, continues to lag. Green hydrogen costs are very high (\$4–6/kg) relative to grey hydrogen (\$1.50/kg). India also still lacks a well-established domestic infrastructure and stable supply of renewable energy to accommodate green-hydrogen transportation and production.

While Indian refiners will require more-competitive pricing before committing to adopting green hydrogen at scale, some domestic refineries are testing green-hydrogen integration in pilot projects, including IOCL, which is one among several operators working to develop solar-based electrolyzers to produce green hydrogen across its refining system. IOCL has launched plans to set up a 10,000-TPY green-hydrogen plant at its Panipat refinery in Haryana. RIL has similarly revealed a shift in emphasis toward green hydrogen for its Jamnagar Refinery as part of the operator's renewable-energy investments.

However, in recent days, in a key development, India has recorded its lowest-ever discovered price for green hydrogen at ₹279 (~\$3.08)/kg in a tender for 10,000 tonnes per year supply to Numaligarh Refinery in Assam.



Further, according to a report by the Institute for Energy Economics and Financial Analysis, the cost of green hydrogen in India, the country that is aiming big in the renewable energy space, is expected to fall by up to 40 per cent with the support and government incentives

India isn't just joining the green hydrogen race – it's setting the pace. With its mix of ambitious policies, renewable energy capacity, and a clear vision for export and domestic use, the country is positioning itself as a serious global contender. Initiatives like the National Green Hydrogen Mission demonstrate that the government is working in mission mode to make it happen.

Conclusion

Green Hydrogen plays a crucial role in decarbonisation and a sustainable energy transition, including the phase-out of fossil fuels. At the same time, this shift not only lowers the carbon footprint of refineries but also helps refineries comply with emerging standards and regulations for low carbon fuels. It can supply even energy intensive industries with climate friendly energy.

For investors, this is a promising sector despite lot of challenges in carbon-abatement technologies as the world shifts toward low-carbon solutions, and opportunities outweigh the obstacles in coming days.



All we have to do is wakeup and change.

- Greta Thunberg

भारत की ऊर्जा के अगले मोर्चे का निर्माण



कौशल कुमार मौर्य
उप प्रबंधक (रसायन)

ग्रीन हाइड्रोजन

ग्रीन हाइड्रोजन वह हाइड्रोजन है जो जीवाश्म ईंधन की बजाय नवीकरणीय ऊर्जा—जैसे सौर या पवन ऊर्जा—उपयोग करके बनाई जाती है। इस प्रक्रिया में पानी को इलेक्ट्रोलिसिस के जरिए हाइड्रोजन और ऑक्सीजन में विभाजित किया जाता है, जिसमें बिजली सोलर पैनल या विंड टर्बाइन से आती है। भारत सरकार द्वारा तय मानकों के अनुसार, इस तरीके से बनी हाइड्रोजन को “ग्रीन” तभी माना जाता है जब पूरी प्रक्रिया से होने वाला कुल उत्सर्जन बहुत कम हो—यानी हर 1 किलोग्राम हाइड्रोजन उत्पादन पर अधिकतम 2 किलोग्राम CO₂ समतुल्य (पिछले 12 महीनों के औसत के आधार पर)।

ग्रीन हाइड्रोजन बायोमास (जैसे कृषि अपशिष्ट) को हाइड्रोजन में बदलकर भी बनाई जा सकती है, बशर्ते उत्सर्जन इसी सीमा के भीतर रहे।

ग्रीन हाइड्रोजन भारत के स्वच्छ ऊर्जा परिवर्तन का एक महत्वपूर्ण स्तंभ बनकर उभरा है, खासकर उन क्षेत्रों के लिए जहाँ उत्सर्जन कम करना कठिन है, जैसे इस्पात, उर्वरक, रिफाइनिंग, शिपिंग और भारी परिवहन।

भारत ने नेशनल ग्रीन हाइड्रोजन मिशन (NGHM) के तहत 2030 तक हर साल 5 मिलियन मीट्रिक टन (MMT) ग्रीन हाइड्रोजन उत्पादन का लक्ष्य तय किया है, जिसे 2023 में शुरू किया गया था। इस मिशन से उम्मीद है कि

- ₹ 8 लाख करोड़ से अधिक का निवेश आकर्षित होगा
- ₹1 लाख करोड़ से ज्यादा के जीवाश्म ईंधन आयात में कमी आएगी
- 2030 तक हर साल लगभग 50 MMT ग्रीनहाउस गैस उत्सर्जन से बचाव होगा

इस विस्तार को समर्थन देने के लिए सरकार ने वित्त वर्ष 2029–30 तक ₹19,744 करोड़ का प्रावधान मंजूर किया है, जिसमें ₹17,490 करोड़ SIGHT कार्यक्रम के तहत शामिल हैं। यह कार्यक्रम घरेलू इलेक्ट्रोलाइजर निर्माण और हाइड्रोजन उत्पादन के लिए प्रोत्साहन प्रदान करता है।

कार्यान्वयन पहले ही शुरू हो चुका है

- भारत का पहला पोर्ट-आधारित ग्रीन हाइड्रोजन पायलट शुरू किया जा चुका है।
- 10 मार्गों पर बसों और ट्रकों के साथ हाइड्रोजन मोबिलिटी पायलट संचालित हो रहे हैं।

- ग्रीन हाइड्रोजन सर्टिफिकेशन योजना (2025) यह सुनिश्चित करती है कि भारत में उत्पादित हाइड्रोजन निर्धारित उत्सर्जन मानकों पर खरी उतरे, जिससे घरेलू और निर्यात बाजारों में विश्वसनीयता मजबूत होती है।

ग्रीन हाइड्रोजन नवीकरणीय ऊर्जा विस्तार को औद्योगिक डीकार्बोनाइजेशन से जोड़ती है। इसे केवल पर्यावरणीय समाधान ही नहीं, बल्कि ऊर्जा सुरक्षा, विनिर्माण वृद्धि और वैश्विक प्रतिस्पर्धा के लिए एक रणनीतिक साधन के रूप में भी देखा जा रहा है। परमाणु, सौर और पवन ऊर्जा, ग्रीन हाइड्रोजन, बैटरी भंडारण और महत्वपूर्ण खनिज—ये सभी ऊर्जा सुरक्षा और ऊर्जा परिवर्तन की आवश्यकताओं को पूरा करने में महत्वपूर्ण भूमिका निभाते हैं। इन सभी प्रयासों के साथ, ग्रीन हाइड्रोजन भारत के विकसित होते ऊर्जा परिदृश्य में अगले महत्वपूर्ण मोर्चे के रूप में उभर रहा है।

परमाणु ऊर्जा विधायी आधुनिकीकरण और बेसलोड विस्तार

परमाणु ऊर्जा लगातार और चौबीसों घंटे बिजली उपलब्ध कराती है तथा इससे ग्रीनहाउस गैस उत्सर्जन बहुत कम होता है। जैसे-जैसे नवीकरणीय ऊर्जा का विस्तार हो रहा है, परमाणु ऊर्जा ग्रिड की स्थिरता बनाए रखने और भरोसेमंद बेसलोड आपूर्ति सुनिश्चित करने में महत्वपूर्ण भूमिका निभा रही है।

भारत की वर्तमान परमाणु क्षमता 8.78 गीगावाट है। नए रिएक्टरों के निर्माण के साथ यह क्षमता 2031-32 तक बढ़कर 22.38 गीगावाट होने का अनुमान है। सरकार ने 2047 तक 100 गीगावाट हासिल करने के लक्ष्य के साथ

एक दीर्घकालिक न्यूक्लियर एनर्जी मिशन की भी घोषणा की है, जो स्वच्छ ऊर्जा और ऊर्जा सुरक्षा के राष्ट्रीय लक्ष्यों के अनुरूप है।

इस विस्तार को समर्थन देने वाला एक प्रमुख संस्थागत सुधार सस्टेनेबल हार्नेसिंग एंड एडवांसमेंट ऑफ न्यूक्लियर एनर्जी फॉर ट्रांसफॉर्मिंग इंडिया' (SHANTI) अधिनियम, 2025 है। यह अधिनियम भारत के परमाणु कानूनी ढांचे को एकीकृत और आधुनिक बनाता है। यह:

- नियामकीय निगरानी के तहत सीमित निजी क्षेत्र की भागीदारी की अनुमति देता है
- एटॉमिक एनर्जी रेगुलेटरी बोर्ड (AERB) को वैधानिक मान्यता प्रदान करता है
- चरणबद्ध देयता ढांचा लागू करता है
- सुरक्षा, संरक्षा और संरक्षण उपायों को मजबूत बनाता है
- संवेदनशील परमाणु ईंधन-चक्र गतिविधियों पर संप्रभु नियंत्रण बनाए रखता है

बड़े रिएक्टरों के साथ-साथ, न्यूक्लियर एनर्जी मिशन स्मॉल मॉड्यूलर रिएक्टर (SMRs) का विकास, जिनका लक्ष्य 2033 तक कम से कम पाँच स्वदेशी डिज़ाइन वाले एसएमआर तैयार करना है। ये उन्नत रिएक्टर अधिक लचीले, विस्तार योग्य और विभिन्न ऊर्जा आवश्यकताओं के लिए उपयुक्त बनाए गए हैं।

ऊर्जा दक्षता को मजबूत बनाना और कार्बन बाजारों का विकास

ऊर्जा दक्षता केवल स्वच्छ ऊर्जा उत्पादन तक सीमित नहीं है, बल्कि ऊर्जा का समझदारी से उपयोग करना भी है। इसका अर्थ है कम बिजली, ईंधन या ऊष्मा का इस्तेमाल करते हुए वही काम

करना। इससे लागत कम होती है और प्रणाली की विश्वसनीयता बढ़ती है, जबकि ऊर्जा संरक्षण का उद्देश्य अपव्यय से बचना होता है।

भारत ने वर्षों में नीतिगत सुधारों और बाज़ार आधारित तंत्रों के माध्यम से अपनी ऊर्जा दक्षता व्यवस्था को मजबूत किया है। एक बड़ा बदलाव परफॉर्म, अचीव एंड ट्रेड (PAT) योजना से कार्बन क्रेडिट ट्रेडिंग योजना (CCTS) की ओर संक्रमण रहा है। CCTS के तहत

- अधिक उत्सर्जन वाले उद्योगों को ग्रीनहाउस गैस तीव्रता के लक्ष्य दिए जाते हैं।
- जो इकाइयाँ लक्ष्य से बेहतर प्रदर्शन करती हैं, उन्हें व्यापार योग्य कार्बन क्रेडिट मिलते हैं।
- इन क्रेडिट्स की खरीद-फरोख्त की जा सकती है, जिससे दक्षता सुधार के लिए बाज़ार आधारित प्रोत्साहन मिलता है।

घरेलू स्तर पर भी ऊर्जा दक्षता कार्यक्रम लागू किए जा रहे हैं, ताकि लोग अधिक दक्ष उपकरण और प्रकाश व्यवस्था अपनाएँ। उजाला कार्यक्रम के तहत 36.87 करोड़ एलईडी बल्ब वितरित किए गए हैं, जिससे-

- हर साल 47,883 मिलियन kWh ऊर्जा की बचत होती है
- प्रति वर्ष 3.88 मिलियन टन CO₂ उत्सर्जन में कमी आती है

भारत की परमाणु यात्रा में एक नया अध्याय प्रोटोटाइप फास्ट ब्रीडर रिएक्टर :

भारत के परमाणु ऊर्जा कार्यक्रम के लिए एक ऐतिहासिक उपलब्धि में 500 मेगावाट के प्रोटोटाइप फास्ट ब्रीडर रिएक्टर (पी एफ बी आर) ने 6 अप्रैल, 2026 को रात 8-25 बजे

सफलतापूर्वक प्रथम क्रिटिकैलिटी (नियंत्रित विखंडन शृंखला प्रतिक्रिया की शुरुआत) प्राप्त कर ली है, जो दीर्घकालिक ऊर्जा सुरक्षा प्रदान करने और स्वदेशी परमाणु प्रौद्योगिकी क्षमताओं को आगे बढ़ाने की दिशा में एक ऐतिहासिक कदम है।

फास्ट ब्रीडर रिएक्टर (पी एफ बी आर) भारत की दीर्घकालिक परमाणु रणनीति का एक महत्वपूर्ण हिस्सा है। पारंपरिक थर्मल रिएक्टरों के विपरीत, पीएफबीआर यूरेनियम-प्लूटोनियम मिक्स्ड ऑक्साइड (एम ओ एक्स) ईंधन का उपयोग करता है। पी एफ बी आर का कोर यूरेनियम-238 की परत से घिरा होता है। तीव्र न्यूट्रॉन उपजाऊ यूरेनियम-238 को विखंडनीय प्लूटोनियम-239 में परिवर्तित करते हैं, जिससे रिएक्टर अपनी खपत से अधिक ईंधन का उत्पादन कर पाता है। रिएक्टर को अंततः परत में मौजूद थोरियम-232 का उपयोग करने के लिए डिज़ाइन किया गया है। रूपांतरण के माध्यम से थोरियम-232 यूरेनियम-233 में परिवर्तित हो जाएगा, जो भारत के परमाणु ऊर्जा कार्यक्रम के तीसरे चरण के लिए ईंधन का काम करेगा।

यह अनूठी क्षमता परमाणु ईंधन संसाधनों के उपयोग को काफी हद तक बढ़ाती है और देश को अपने सीमित यूरेनियम भंडार से कहीं अधिक ऊर्जा निकालने में सक्षम बनाती है, साथ ही भविष्य में थोरियम के बड़े पैमाने पर उपयोग के लिए भी तैयारी करती है।

प्रथम चरण की महत्वपूर्णता प्राप्त करने के साथ भारत अपने तीन-चरणीय परमाणु ऊर्जा कार्यक्रम की पूर्ण क्षमता को साकार करने के करीब पहुंच गया है। फास्ट ब्रीडर तकनीक वर्तमान में मौजूद भारी जल रिएक्टरों और भविष्य में स्थापित होने वाले थोरियम-आधारित रिएक्टरों के बीच एक महत्वपूर्ण कड़ी का काम करती है,

जिससे देश के प्रचुर थोरियम संसाधनों का लाभ उठाकर दीर्घकालिक स्वच्छ ऊर्जा का उत्पादन किया जा सकेगा।

वैश्विक नेतृत्व और रणनीतिक साझेदारियाँ:

जैसे-जैसे भारत अपने घरेलू ऊर्जा परिवर्तन को मजबूत कर रहा है, वह स्वच्छ ऊर्जा, वहनीयता और स्थिरता पर वैश्विक विमर्श को भी दिशा दे रहा है। अंतरराष्ट्रीय साझेदारियाँ राष्ट्रीय सुधारों को पूरक बनाती हैं और भारत को वैश्विक ऊर्जा समाधानों में सक्रिय योगदानकर्ता के रूप में स्थापित करती हैं।

भारत जी 20 एनर्जी ट्रांजिशन वर्किंग ग्रुप जैसे बहुपक्षीय मंचों में अग्रणी भूमिका निभाता है, जहाँ उसने स्वच्छ ईंधन और ऊर्जा सुरक्षा पर सहयोग को आगे बढ़ाया है। अपनी जी20 अध्यक्षता के दौरान भारत ने ग्लोबल बायोफ्यूल्स एलायंस (GBA) की शुरुआत की, जिसमें अब 25 देश और 12 अंतरराष्ट्रीय संगठन शामिल हैं, जो दुनिया भर में किफायती और कम-कार्बन जैव ईंधन को बढ़ावा दे रहे हैं।

ऊर्जा दक्षता के क्षेत्र में भी भारत ने 2024 में इंटरनेशनल एनर्जी एफिशिएंसी हब से जुड़कर सहयोग को मजबूत किया है, जिससे घरेलू पहलों को वैश्विक सर्वोत्तम प्रथाओं के साथ जोड़ा जा रहा है।

UNFCCC ढाँचे के तहत भारत ने 2070 तक नेट-जीरो हासिल करने और 2030 तक GDP की उत्सर्जन तीव्रता में 45% कमी लाने का संकल्प लिया है, जो विकास और जलवायु जिम्मेदारी के बीच संतुलित दृष्टिकोण को दर्शाता है।

इन सभी पहलों के साथ भारत सस्ती स्वच्छ ऊर्जा, न्यायसंगत जलवायु वित्त और तकनीक तक पहुँच के मुद्दों पर वैश्विक दक्षिण की एक रचनात्मक आवाज़ के रूप में उभर रहा है।

निष्कर्ष

भारत का पर्यावरणीय बदलाव उसके पैमाने, संस्थागत मजबूती और निरंतर प्रतिबद्धता को दर्शाता है। नवीकरणीय ऊर्जा का रिकॉर्ड विस्तार, सक्रिय कार्बन बाज़ार, प्रदूषण नियंत्रण को मजबूत बनाना, संरक्षित क्षेत्रों का विस्तार, प्रजातियों को बचाने के कार्यक्रम, वनों और मैंग्रोव का पुनरुद्धार, आर्द्रभूमि का संरक्षण और नागरिकों की भागीदारी—ये सभी मिलकर एक व्यापक पर्यावरणीय रणनीति को परिभाषित करते हैं।

2050 तक प्रकृति के साथ तालमेल बिठाकर रहने के भारत के दृष्टिकोण को, विभिन्न क्षेत्रों में किए जा रहे ठोस और मापने योग्य कार्यों का समर्थन प्राप्त है। घरेलू स्तर पर कार्यान्वयन को वैश्विक सहयोग के साथ जोड़ते हुए, भारत ने वर्तमान और भावी पीढ़ियों के लिए जलवायु स्थिरता, जैव विविधता संरक्षण और संवहनीय विकास में अपना योगदान लगातार जारी रखा है।

Environment Awareness Quiz



ANSWER KEY

- | | | |
|-------|------|------|
| 1. B | 2. B | 3. B |
| 4. C | 5. B | 6. B |
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Powering the Future : Can India's Green Hydrogen Mission Rewrite the Rules of Clean Energy?



Malay Nayek
DGM (Chemical)

A Molecule That Could Change Everything

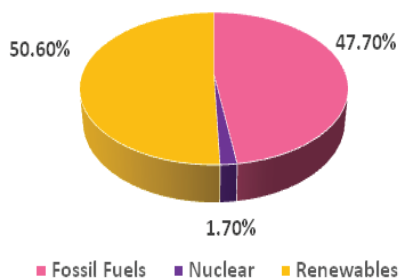
For decades, the image of India's industrial rise has been inseparable from the plume of a coal chimney. That cheap, dirty fuel powered steel plants, turned turbines, and lifted hundreds of millions out of poverty. But the cost has been catastrophic: choking air, warming oceans, and a growing global consensus that the age of fossil fuels must end. Yet, ending coal is not as simple as switching off a switch. Renewables like solar and wind are now abundant and cheap, but they cannot yet deliver the round the clock, high temperature heat required by a steel mill or a refinery. Batteries handle a few hours of storage, but not weeks. This is where green hydrogen enters—not as a miracle cure, but as an essential complement to the renewable revolution.

India's National Green Hydrogen Mission (NGHM), launched in 2023 with an initial outlay of ₹19,744 crore (approximately \$2.3 billion), is arguably the country's most ambitious clean energy gamble.

The goal: produce 5 million metric tonnes (MMT) of green hydrogen annually by 2030, add 125 GW of renewable energy capacity for electrolysis, and capture 10% of the global green hydrogen market. By early 2026, the mission had already awarded incentives for nearly 862,000 tonnes per annum (TPA) of production capacity and 3 GW of electrolyser manufacturing. But can India truly rewrite the rules of clean energy, or will the mission be remembered as an expensive detour?

India's Energy Landscape: The Case for a Hydrogen Disruption

India's power sector has undergone a remarkable transformation. As of October 2025, total installed generation capacity crossed 505 GW, with non fossil fuel sources accounting for over 52% – a milestone achieved five years ahead of the Paris Agreement target. Between April and September 2025 alone, the country added 28 GW of clean energy capacity, compared to just 5.1 GW from fossil sources. Renewable capacity reached 237 GW by June 2025, including 119 GW of solar and 52 GW of wind.

India: Installed Power Capacity (As on Jan 2026)

Fig 1: India's total power generation

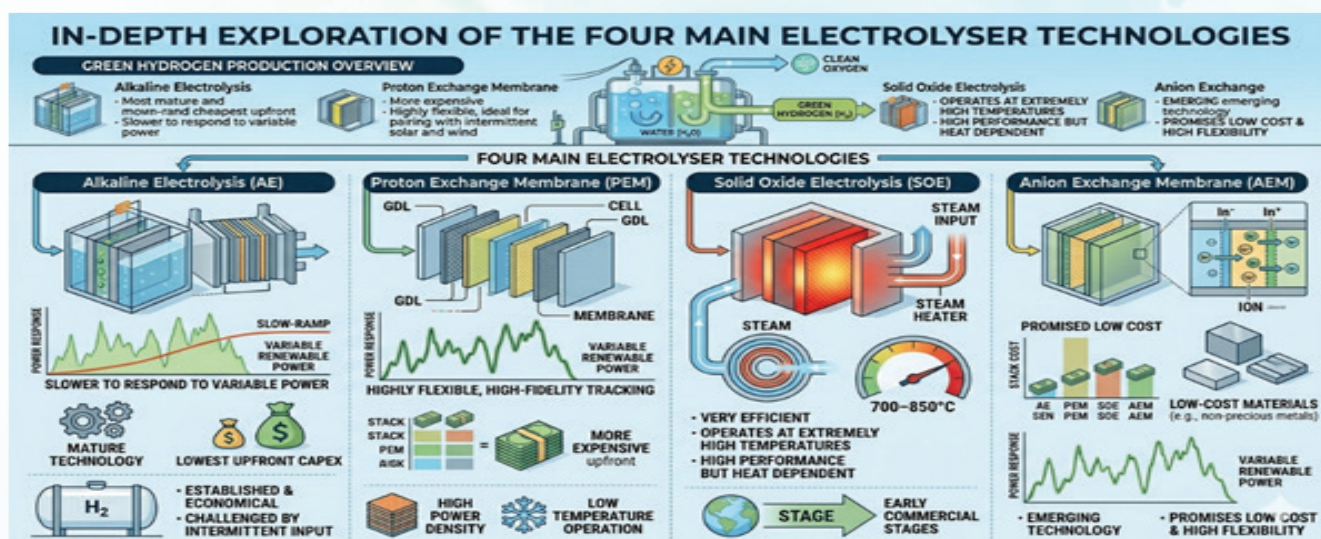
Yet coal still dominates actual electricity generation. The intermittency of solar and wind forces grid operators to keep coal plants on standby. More critically, sectors such as steel, refining, fertilisers, and heavy transport cannot be easily electrified. A blast furnace requires intense, continuous heat that batteries cannot provide. A long haul truck cannot carry enough battery weight. Green hydrogen offers a solution: it can be produced when renewable electricity is abundant, stored for months in salt caverns or tanks, and then used in fuel cells or burned directly to provide high grade industrial heat. This makes hydrogen not a competitor to renewables, but their strategic

partner—a way to decarbonise the “hard to abate” sectors that renewable power alone cannot touch.

The Technology Behind Green Hydrogen: Splitting Water at Scale

Green hydrogen is produced through electrolysis – passing an electric current through water to split H_2O into hydrogen and oxygen. When the electricity comes from renewable energy, the resulting hydrogen is effectively carbon free. Four main electrolyser technologies are available today:

- **Alkaline electrolysis (AE)** – The most mature and cheapest upfront, but slower to respond to variable power.
- **Proton exchange membrane (PEM)** – More expensive but highly flexible, ideal for pairing with intermittent solar and wind.
- **Solid oxide electrolysis (SOE)** – Very efficient but operates at extremely high temperatures (700–850°C); still in early commercial stages.
- **Anion exchange membrane (AEM)** – An emerging technology that promises low cost and high flexibility.


Fig 2: Electrolyser Technologies

As of late 2025, the cost of green hydrogen production in India ranged between ₹350 and ₹450 per kg, while grey hydrogen (from natural gas) cost ₹160–200 per kg. The gap remains formidable. Former NITI Aayog CEO Amitabh Kant has set a target of reducing green hydrogen production costs to ₹89 per kg by 2030 – the point at which it would become competitive with grey hydrogen without subsidies.

Current Developments and Initiatives Under the Green Hydrogen Mission

The National Green Hydrogen Mission is structured around several pillars:

- **Production incentives** under the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme: 862,000 TPA of green hydrogen capacity awarded to 18 companies.
- **Electrolyser manufacturing:** 3,000 MW per annum allocated to 15 firms, with a focus on domestic production.
- **Demand creation:** Pilot projects for blending hydrogen into natural gas grids, fuel cell buses, and proposed green hydrogen purchase obligations for refineries and fertiliser plants.
- **Export ambitions:** Targeting a 10% share of the global green hydrogen market by 2030.
- **Infrastructure and standards:** Development of safety protocols, storage guidelines, and certification frameworks.

By March 2026, the government expanded the mission's scope, adding ₹100 crore for biomass based hydrogen pilots and announcing standards for green ammonia and green methanol to facilitate trade. The total investment envisaged under the mission exceeds ₹8 lakh crore (approximately

\$96 billion) and annual reduction of fossil fuel imports by more than ₹1 lakh crore.

Comparative Analysis: Green Hydrogen vs. Other Renewable Energy Sources

It is a common mistake to pit green hydrogen against solar, wind, or batteries. In reality, they are complementary.

- **Solar and Wind** provide the cheapest electricity in history, with levelized costs below ₹2.5–3.0 per kWh in many parts of India. Their limitation is intermittency.
- **Batteries** excel at short duration storage (4–6 hours) and fast response, but become prohibitively expensive for seasonal or long duration storage.
- **Green Hydrogen** is inefficient and expensive to produce (round trip efficiency of 30–40% versus 80–90% for batteries), but it can store energy for weeks or months and can replace fossil carbon directly in industrial processes.

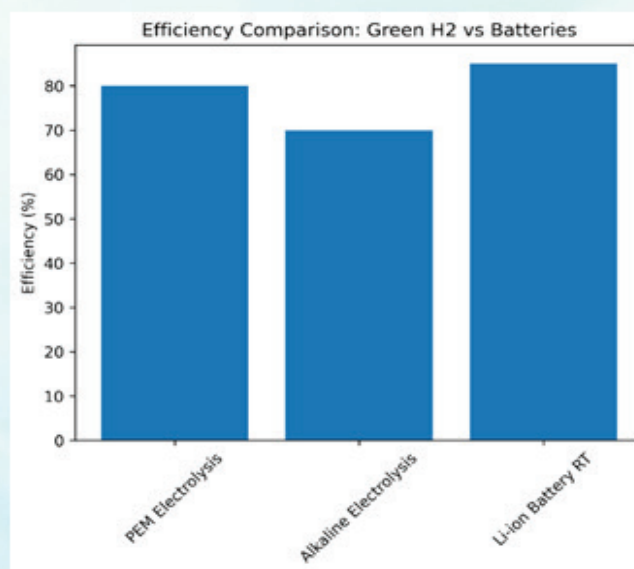


Fig 3: Comparison between Green H2 vs Batteries efficiencies

A 2024 study on offgrid hybrid renewable systems for remote Indian villages found that for autonomy periods exceeding

a few days, hydrogen storage became more cost effective than batteries. For industrial applications such as steel making (via direct reduced iron), refineries, and ammonia production, hydrogen has no viable alternative for deep decarbonisation. Thus, the near term role of green hydrogen is not to replace solar or batteries, but to cover the niches they cannot.

Policy Frameworks and Government Support

The Indian government has deployed a multi pronged policy arsenal to de-risk the green hydrogen sector:

- **Viability Gap Funding (VGF)** and production linked incentives under SIGHT (₹17,490 crore allocated).

- **Green hydrogen purchase obligations** proposed for refineries, fertiliser plants, and city gas distribution networks.

- **Waiver of interstate transmission charges** for renewable energy used in green hydrogen production.

- **Standards and certification** for green hydrogen, ammonia, and methanol, enabling domestic and international trade.

- **International collaboration:** Agreements with the EU, Japan, Australia, and the UK, including a recent India UK conference on hydrogen safety standards (February 2026).

Despite these measures, the policy framework has significant gaps. As of early 2026, there is still no binding mandate on industries to purchase green hydrogen. Without guaranteed off take, private investors remain hesitant. A November 2025 report by the Institute for Energy Economics and Financial Analysis (IEEFA) identified “unclear demand signals” as the single big-

gest barrier to project development. Additionally, the regulatory framework for hydrogen transport, storage, and retail is still being drafted, creating uncertainty for early movers.

Challenges and Barriers to Implementation

No energy transition is without roadblocks, and green hydrogen faces a particularly daunting set.

- **High production costs.** Green hydrogen remains two to three times more expensive than grey hydrogen. Even with aggressive targets, achieving cost parity by 2030 requires electrolyser capital costs to fall by half and renewable electricity prices to decline further. Current subsidies cover only a fraction of the gap.

- **Infrastructure deficits.** India has virtually no dedicated hydrogen pipelines. Transporting compressed hydrogen by truck is energy intensive and expensive. Salt cavern storage is being explored, but no large scale facilities exist. The lack of shared infrastructure forces each project to build its own, raising costs.

- **Unclear demand.** As of August 2025, India had 158 green hydrogen projects at various stages, but many lack committed buyers. Refineries and fertiliser plants continue to use grey hydrogen because it is cheaper and readily available. Without a carbon price or binding green hydrogen consumption mandates, demand will remain weak.

- **Electrolyser scale up.** The 3 GW of manufacturing capacity awarded is a fraction of the 25–30 GW needed. Moreover, domestic electrolyser technology is not yet globally competitive; most large projects still rely on imported stacks.

- **Water scarcity.** Electrolysis consumes about 9 litres of water per kg of hydrogen. In water stressed regions of western and southern India, this could become a constraint. Desalination or treated wastewater can mitigate the issue, but both add cost and energy.

- **Safety and public perception.** Hydrogen is highly flammable and has a low ignition energy. Building public trust and establishing rigorous safety standards for production, transport, and storage is essential. The India UK conference on safety protocols was a step in the right direction, but much work remains.

Case Studies: Successful Green Hydrogen Projects in India

Several projects demonstrate that green hydrogen is moving from policy to practice, albeit at a modest scale.

- **NTPC's Kawas Green Hydrogen Blending Project (Gujarat)**

In January 2023, NTPC commissioned India's first green hydrogen blending project in partnership with Gujarat Gas Limited. Green hydrogen produced via solar powered electrolysis is blended into the piped natural gas (PNG) network of NTPC's Kawas township in Surat. The Petroleum and Natural Gas Regulatory Board has allowed up to 5% blending. This pilot is generating crucial data on pipeline embrittlement and safety.

- **IOCL Panipat Refinery Green Hydrogen Plant (Haryana)**

In May 2025, L&T Energy Green Tech won a bid to construct a 10,000 TPA green hydrogen plant at Indian Oil Corporation's Panipat refinery. The plant, based on a build own operate model, will supply green hydrogen to replace grey hydrogen

used in refining processes. At 10,000 TPA, it is one of the largest green hydrogen projects awarded to date.

- **H2E Pvt Ltd Pilot Plant (Jorhat, Assam)**

H2E established a 30 kg/day green hydrogen plant at Jorhat, storing hydrogen at 200 bars. The facility also manufactures 1 GW stacks for electrolyzers and fuel cells at Jalgaon, Maharashtra, demonstrating end to end domestic capability. Though small, it proves that Indian firms can build and operate the full value chain.

- **GAIL's PEM Electrolyser (Vijaipur, Madhya Pradesh)**

GAIL (India) Limited awarded a contract for one of the country's largest PEM electrolyzers at Vijaipur. The project is designed to produce green hydrogen for blending into GAIL's natural gas pipeline network, serving as a model for blending in high pressure transmission systems.

- **Deendayal Port Green Hydrogen Storage (Kandla, Gujarat)**

In March 2026, Deendayal Port Authority invited bids for a metal hydride based green hydrogen storage system with a capacity of at least 3 kg and fuel cell based power generation of at least 4 kW. This small project is a testbed for solid state hydrogen storage, which offers safer and more compact storage compared to compressed or liquid hydrogen.

These projects are encouraging, but none yet represents the large scale, fully integrated industrial complex that the mission envisions. The gap between pilot scale and commercial scale remains wide.

Positioning India as a Global Leader

India's green hydrogen ambitions extend far beyond its borders. By leveraging some of the world's lowest solar and wind tariffs, a large domestic market, and a growing manufacturing base, India could become a global hub for both green hydrogen production and electrolyser manufacturing.

The global green hydrogen market is projected to reach \$100–120 billion by 2025, with a compound annual growth rate of 30–40% through 2030. However, the International Energy Agency (IEA) recently revised its 2030 forecast for low emissions hydrogen capacity downward to 37 million tonnes per annum, citing project delays and cancellations worldwide. This creates both an opportunity and a warning: the market is smaller than once hoped, but competition is also weaker.

If India succeeds in reducing green hydrogen production costs to \$1–1.5 per kg by 2030, it could outcompete natural gas based hydrogen in many markets. That would not only secure India's energy independence but also create a significant export opportunity, particularly to hydrogen importing nations such as Japan, South Korea, and Germany. Furthermore, the mission is expected to create over 600,000 jobs across manufacturing, installation, operations, and R&D, contributing to India's goal of becoming a \$5 trillion economy while decarbonising its industrial base.

Rewriting the Rules, One Molecule at a Time

The National Green Hydrogen Mission is audacious, timely, and fraught with challenges. The technology is mature enough, the policy framework is evolving,

and private capital is eager. Yet the gap between ambition and reality remains wide. High production costs, infrastructure deficits, unclear demand, and the sheer scale of the required scale up threaten to derail the mission before it truly takes off.

Nevertheless, there are reasons for optimism. India has a proven track record of disruptive clean energy scaling. Solar power costs fell by over 80% in a decade, driven by policy support and economies of scale. Green hydrogen could follow a similar trajectory, especially if the mission's focus on domestic electrolyser manufacturing, blended hydrogen pilots, and strategic international partnerships pays off.

The path forward requires urgent action on several fronts: accelerating demand creation through binding green hydrogen purchase obligations; investing in shared hydrogen infrastructure (pipelines, storage caverns, refuelling stations); strengthening international standards and certification; and ramping up R&D into next generation electrolyzers and advanced storage materials.

If India can navigate these challenges, it will not only achieve its own net zero goal by 2070 but also rewrite the rules of clean energy. The country could demonstrate that heavy industry can be decarbonised without sacrificing growth, that fossil fuel dependence can be broken not just in power generation but across entire economies, and that the Global South can lead in the next wave of energy innovation. The green hydrogen revolution is still in its early innings. But with the wind in its sails and the sun at its back, India stands poised to turn the molecule of hope into the fuel of the future.

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Photography by Hrishikesh Gupta, SM (Chemical)

Interview on Butterfly Conservation and Its Impact on Ecosystem Stability

Envicare team reached out two young environmentalist Lepidopterist Dr Monsoon Jyoti Gogoi and Dr. Roshan Upadhyay for their Butterfly conservation work in North East India. We hope their actions inspire us too.

Dr. Monsoon Jyoti Gogoi is a renowned Indian lepidopterist and wildlife scientist from Kaziranga, Assam, widely recognized for his groundbreaking contributions to butterfly research and conservation in Northeast India. He has spent nearly two decades documenting the region's rich biodiversity. His work has established several monumental milestones for Indian entomology. His extensive, years-long research established Kaziranga National Park as India's second-highest hub for butterfly diversity, documenting 446 species in the park landscape. Dr. Gogoi has discovered and recorded 18 new butterfly records for India. Notable species include the Burmese Threering, Glassy Cerulean, Dark-bordered Hedge Blue, and Andaman Yellow Banded Flat. He successfully tracked and rediscovered rare Orange Flat butterflies (*Pintaburca* & *pinwilli*) after a 130-year gap in Northeast India.



Recently in the year 2025 while working on a community conservancy program with the Ashoka Trust for Research in Ecology and the Environment (ATREE), his team added six new butterfly species to the Indian fauna from the Upper Siang region of Arunachal Pradesh, including the Medog Tufted Ace. Further, Dr. Gogoi is the founder of the North-East India Butterfly Meet (NEBM), an initiative launched in 2014 to foster regular community-driven monitoring, habitat protection, and butterfly eco-tourism across Northeast India. Dr. Gogoi awarded as Young Naturalist Awards in the year 2010 by Sanctuary Nature Foundation.

Q :: What inspired you to follow the journey of becoming a Butterfly Expert? What struggles you have experienced in your journey?

A :: During my childhood, I was naturally quiet and did not easily mix with other children in playgroups and often preferred to sit alone at school. Growing up near Kaziranga National Park, however, gave me

a unique and enriching alternative form of companionship. Surrounded by rich landscapes and wildlife, I developed a deep connection with nature. That environment became my space for reflection, comfort, and learning, and it strongly influenced my perspective on life and my enduring bond with the natural world.

Q :: Why are butterflies considered key indicators of environmental health?

A :: Butterflies are most sensitive to any kind of environmental changes, being insects the change in temperature different effects the larval stage lifecycle including the adults. If there is any change in the environment, butterflies are the first one to indicate, from pollution in the environment to change in the surrounding temperature. If the place is unsuitable for human habitation, butterflies are the first group to indicate such, so the concept of butterfly parks/gardens are very much in urban township plannings.

Q :: How are Butterflies connected to Ecosystem stability?

A :: Butterflies and moths form very important part of food chain by supplying food cycle to birds, lizards, spiders etc. They are also the best pollinators in tropical and subtropical conditions of India, the ecosystem services they provide is immense.

Q :: What are the biggest threats which may endanger butterfly populations?

A :: Anthropogenic changes such as habitat degradation and global climate change are biggest threat to butterfly populations. Change in temperature effects butterfly phenology as well as phenology of flowers. The flowers may emerge earlier due to climate change, but butterflies may not be there to pollinate or vice versa.

Q :: What conservation strategies have proven most effective in protecting butterflies?

A :: Conserving woodlands and creating riparian habitats have proven most effective for butterfly protection. Butterflies are host plant dependent and primary natural forest are therefore prime habitat for most butterfly species, except for few which have succeeded to be adapted to urban dominated

landscapes. Creating riparian habitats create cool environment in the forest, allow the riparian nectar and hostplants to grow and also provide mud puddling beds for butterflies which are essential components for butterfly survivability.

Q :: Could you share an instance where conservation efforts made a real difference?

A :: Conservation efforts by Apatani community in Ziro valley landscape made a real difference. In Apatani landscape, Ngunu Ziro NGO initially established home stays back in 2006-07. The NGO also launched Ziro butterfly meet since 2014 and works for conservation of Bhutan Glory and Apatani Glory. This is a successful eco-tourism model where people are earning and at the same time nature/traditional land is conserved.

Q :: Are traditional practices or indigenous knowledge helpful in butterfly conservation?

A :: Yes, traditional practices are helpful although not directly targeted for butterfly conservation. In most part of Arunachal Pradesh, the communities conserve the surrounding forest area which provide immense ecosystem services to the surroundings, however in states like Assam, the village woodlands are being converted to tea gardens which has severely impacted the horticulture crops or fruits. For e.g. when we were small, oranges grew in the villages of Brahmaputra floodplains, but now they do not grow. So, although not directed towards butterfly conservation, the forest dwelling communities understand the role of forest in their life.

Q :: How people who are not connected or unaware can contribute to butterfly conservation?

A :: People not connected or unaware can contribute by creating their own but-

terfly gardens in home by planting native medicinal valued plant species, good nectar sourced plants for butterflies and by creating artificial streams at their home.

Q :: What lessons can humans learn from butterflies?

A :: Humans can actually learn lots of lessons from butterflies. Human can learn to be happy 'happiness is butterflies'.

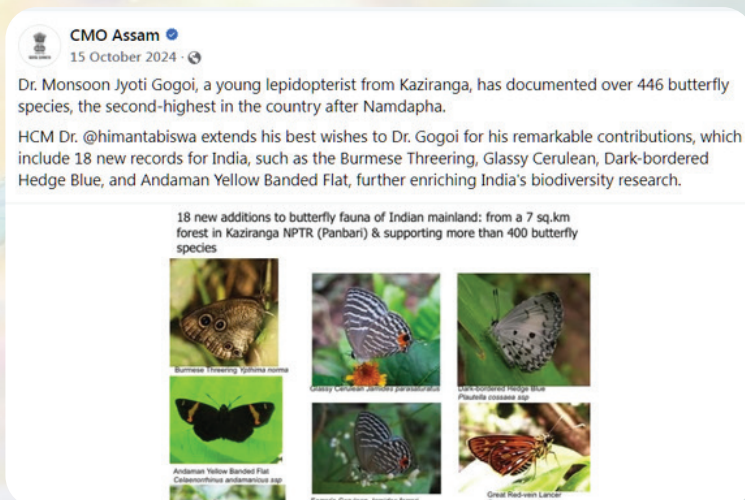
Q :: Do you think current environmental policies are sufficient to protect butterflies and their habitats? Do you feel of any requirement in the policy or institu-

tional level to support conservation efforts?

A :: Current environmental policies are not sufficient. With the construction of flyovers, there is direct collision of vehicles with butterflies without any notice. Policies such as butterfly safe corridors are never considered for India.

Q :: What is your future planning in the journey of conservation of butterflies.

A :: Prepare regional database on butterflies for entire NE India and filling the gap areas. Also, promote conservation friendly livelihood associated with nature-based tourism such as butterflies.



Various Butterfly species documented by Dr. Monsoon Jyoti Gogoi

Interview on Butterfly Conservation and Its Impact on Ecosystem Stability

Roshan Upadhyay (also spelled Upadhaya) is widely known as the "Butterfly Man of Arunachal Pradesh". He is a state police commando and a passionate lepidopterist (butterfly expert) who has gained nationwide recognition for documenting over 600 butterfly species and discovering multiple species new to the India Book of Records (2020) for safely carrying the highest number of live butterflies on his person at one time. He has received numerous environmental honors, including the prestigious Young Naturalist Award by the Balipara North East Young Achiever (2023) and the award by Dalmia Cement Himadri Acharyya, he uses his platform to conduct nature camps, butterfly walks, programs for school children. In May 2025, he and researcher Taslima Sheikh recorded the first-ever confirmed sighting of the rare butterfly species *Euthalia malaccana* in India, of Arunachal Pradesh. In March 2026, Roshan Upadhyay, along with researcher Kalesh Sadasivan, discovered a completely new species of butterfly in the semi-evergreen forests of Basar, Leparada district. They scientifically named it *Euthalia (Limbusa) Zubeengargi* in honor of Assamese cultural and music icon Zubeen Garg. It features distinct olive-brown wings with white markings and a vibrant turquoise-green underside.



Q :: What inspired you to follow the journey of becoming a Butterfly Expert? What struggles you have experienced in your journey?

A :: Mother Nature itself is an inspiration for me. I have joined police department in the year 2012 and in 2016 I got some serious health issue, and that time I chose nature to heal myself and during that process I have started observing butterfly and the journey began. Also, I had attended Pasighat Butterfly meet in 2017 and was fortunate to

meet some experts Dr Monsoon Jyoti Gogoi, Mr Nawangla Bhutia, Dr. Joram Kopey, Rajiv Rudra Tariang Sir who inspired me to work on butterfly conservations.

Being a policeman it's always difficult to spare time, 24 x 7 duty and no particular timetable and the nature of service we have to perform is known to all.

Q :: Why are butterflies considered key indicators of environmental health?

A :: Because of their extreme sensitivity to environment changes and also particularly

butterflies have their specific hostplant for life cycle. Their health and population trends reflect the overall health of their environment

Q :: How are Butterflies connected to Eco-system stability?

A :: Butterflies contribute to ecosystem stability by acting as pollinator for vast array of plants including many food crops, contributing directly to global food security, very important part of food chain and also act as bioindicators.

Q :: What are the biggest threats which may endanger butterfly populations?

A :: Deforestation, habitat loss, climate change, fertilizers and chemical usage have become threat not only for human population, but it has seriously affected butterflies.

Q :: What conservation strategies have proven most effective in protecting butterflies?

A :: Creating awareness programs like photo Exhibition, formation of nature club in every school, Eco tourism, campaigning in social media. Involving younger kids and students through regular nature walks.

Q :: Are traditional practices or indigenous knowledge helpful in butterfly conservation?

A :: In Arunachal Pradesh, the agriculture time is decided by the migration of butterfly (indirectly). Preserving Natural Habitats and planting native tree species can be helpful for sustenance of indigenous butterflies.

And also Butterfly is considered as lucky charm in many indigenous tribes, like butterfly dance(form of Bagurumba dance) in Boro Tribe.

Q :: What lessons can humans learn from butterflies?

A :: Butterfly's Life-cycle is a powerful metaphor about personal growth and transformation. The Metamorphosis of Cocoon to Butterfly especially which involves Caterpillar shedding of skin to become butterfly, teaches us -

- One must let go of old habits which have no place in our life.
- Change in life is necessary and can be painful but is essential for progress

Q :: Do you think current environmental policies are sufficient to protect butterflies and their habitats? Do you feel of any requirement in the policy or institutional level to support conservation efforts?

A :: Current environmental policies are not sufficient to protect butterflies and their habitats. As stated earlier that Butterfly being a bioindicator its sustenance is very much important for Eco cycle. It should start from every human being following the traditional ways, raising awareness in every institution from Primary level to Higher Studies. Consciousness of our surrounding environment and practical knowledge is much more effective when it's come to conserve nature

Q :: What is your future planning in the journey of conservation of butterflies?

A :: I am currently pursuing PhD in this particular topic butterfly conservation and impact on climate change and also working as an independent researcher. I am hopeful that my study and my knowledge I can contribute to butterfly conservation.



Indian Physiography – A Go Through



R.B. Shashank
SM (Chemical)

India stands as one of the world's oldest and most advanced civilizations, boasting a unique cultural identity. India is situated north of the equator between 8°4' north to 37°6' north latitude and 68°7' east to 97°25' east longitude. It is the seventh Largest Country in the World.

What is Physiography?

Physiography refers to physical geography or the natural features and characteristics of a land or region. Physiography provides insight into the natural landscape and how it has been shaped over time by geological, hydrological, and atmospheric processes.

Indian Physiographic Regions

India can be divided into six physiographic regions. They are:

- Northern and North Eastern Mountains
- Peninsular Plateau
- Indo-Gangetic Plain or The Northern Plains
- Thar Desert
- Coastal Plains
- Islands

Northern and North- Eastern Mountains

An arc of mountains consisting of the Himalayas, Hindu Kush, and Patkai ranges define the northern frontiers of the Indian subcontinent. These mountains form the boundary between two biogeographic realms : the temperate Palearctic realm that covers most of Eurasia, and the tropical and subtropical Indomalayan realm which includes South Asia, Southeast Asia and Indonesia. Rivers originating in these mountains flow through the fertile Indo–Gangetic Plain. The Himalayas in India extend from Ladakh in the north to the state of Arunachal Pradesh in the east.

Karakoram: The Karakoram Range runs through Ladakh. The range is about 500 km (310 mi) in length and the most heavily glaciated part of the world outside of the Polar Regions.

The Patkai, or Purvanchal, are situated near India's eastern border with Burma. The physical features of the Patkai Mountains are conical peaks, steep slopes and deep valleys and consists of three hill ranges that come under the Patkai: the Patkai–Bum, the Garo–Khasi–Jaintia and the Lushai hills.

The Peninsular Plateau

This is a large region of the Indian subcontinent located between the Western Ghats and the Eastern Ghats, and is loosely defined as the peninsular region between these ranges that is south of the Narmada River. It contains mountain ranges (Aravalli, Vindhayachal and Satpura ranges), ghats (Eastern Ghats and Western Ghats) and plateaus (Malwa Plateau, Chhota Nagpur Plateau, Southern Granulite terrain, Deccan Plateau and Kutch Kathiawar plateau).

Mountain ranges:

Aravali Range is the oldest mountain range in India, running across Rajasthan from northeast to southwest direction. The Aravali Range is the eroded stub of an ancient fold mountain system.

Vindhya range, lies north of Satpura range and east of Aravali range, runs across most of central India. They are believed to have been formed by the wastes created by the weathering of the ancient Aravali mountains.

Satpura Range, lies south of Vindhya range and east of Aravali range, begins in eastern Gujarat near the Arabian Sea coast and runs east across Maharashtra, Madhya Pradesh and Chhattisgarh. It is triangular in shape, with its apex at Ratnapuri and the two sides being parallel to the Tapti and Narmada rivers.

Plateaus

Malwa Plateau is spread across Rajasthan, Madhya Pradesh and Gujarat. Most of the region is drained by the Chambal River and its tributaries; the western part is drained by the upper reaches of the Mahi River.

Chhota Nagpur Plateau is situated in eastern India, covering much of Jharkhand and adjacent parts of Odisha, Bihar and Chhattisgarh is divided into three smaller plateaus: Ranchi, Hazaribagh and Kodarma plateaus. Much of the plateau is forested and vast reserves of metal ores and coal have been found in the Chota Nagpur plateau.

Southern Granulite terrain: Covers South India especially Tamil Nadu excluding western and eastern ghats. It represents the southernmost part of the Indian peninsula, situated south of the stable Dharwar Craton. Unlike the lower-grade metamorphic rocks found further north, the Southern Granulite Terrain is composed of high-grade metamorphic rocks (granulites) that were formed deep within the Earth's crust under extreme pressure and temperature.

Deccan Plateau, also called Deccan Trapps, is a large triangular plateau, bounded by the Vindhyas to the north and flanked by the Eastern and Western Ghats. It slopes gently from west to east and gives rise to several peninsular rivers such as the Godavari, the Krishna, the Kaveri and the Mahanadi which drain into the Bay of Bengal. Much of the Deccan is covered by thorn scrub forest scattered with small regions of deciduous broadleaf forest.

Kutch Kathiawar plateau is located in Gujarat state. The Kathiawar peninsula in western Gujarat is bounded by the Gulf of Kutch and the Gulf of Khambat. The natural vegetation in most of the peninsula is xeric scrub, part of the Northwestern thorn scrub forests ecoregion.

Ghats

Ghat is a term used to identify a difficult passage over a mountain.

Western Ghats also known as Sahyadri (Benevolent Mountains) run along the western edge of India's Deccan Plateau and separate it from a narrow coastal plain along the Arabian Sea. The range covers an area parallel to the western coast of the Indian peninsula from south of the Tapti river near the Gujarat-Maharashtra border and across Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat. to the southern tip of the Deccan peninsula. It is a UNESCO World Heritage Site and is one of the eight "hottest hot-spots" of biological diversity in the world. It is sometimes called the Great Escarpment of India. It is a biodiversity hot-spot that contains a large proportion of the country's flora and fauna; many of which are only found here and nowhere else in the world. According to UNESCO, Western Ghats are older than Himalayan mountains.

Eastern Ghats are a discontinuous range of mountains along India's eastern coast, which have been eroded and quadrisected by the four major rivers of southern India, the Mahanadi, Godavari, Krishna, and Kaveri. Parts of the coastal plains, including the Coromandel Coast region, lie between the Eastern Ghats and the Bay of Bengal. The structure of the Eastern Ghats includes thrusts and strike-slip faults all along its range.

Indo-Gangetic Plain

The Indo-Gangetic plains, also known as the Great Plains are large alluvial plains dominated by three main rivers, the Indus, Ganges, and Brahmaputra. They run par-

allel to the Himalayas, from Jammu and Kashmir in the west to Assam in the east, drain most of northern and eastern India. The great plains are sometimes classified into four divisions: The Bhabar Belt, Tarai Belt, Bangar Belt and Khadar Belt. The Indo-Gangetic belt is the world's most extensive expanse of uninterrupted alluvium formed by the deposition of silt by the numerous rivers. The plains are flat making it conducive for irrigation through canals. The plains are one of the world's most intensely farmed areas.

Thar Desert

The Thar Desert forms a significant portion of western India. About 10 percent of this region consists of sand dunes, and the remaining 90 percent consist of craggy rock forms, compacted salt-lake bottoms, and interdunal and fixed dune areas. The soils of the arid region are generally sandy to sandy-loam in texture. The consistency and depth vary as per the topographical features. The low-lying loams are heavier may have a hard pan of clay, calcium carbonate or gypsum.

Coastal Plains

The Eastern Coastal Plain is a wide stretch of land lying between the Eastern Ghats and the oceanic boundary of India. It stretches from Tamil Nadu in the south to West Bengal in the east. The Mahanadi, Godavari, Kaveri, and Krishna rivers drain these plains

The Western Coastal Plain is a narrow strip of land sandwiched between the Western Ghats and the Arabian Sea and it extends from Gujarat in the north and extends through Maharashtra, Goa, Karnata-

ka, and Kerala. The Western Coastal Plain can be divided into two parts, the Konkan and the Malabar Coast.

Islands

The Lakshadweep and the Andaman and Nicobar Islands are India's two major island formations and are classified as union territories.

The Lakshadweep Islands lie off the coast of Kerala in the Arabian sea. They consist of twelve atolls, three reefs, and five submerged banks, with a total of about 35 islands and islets.

The Andaman and Nicobar Islands consist of 572 islands lie in the Bay of Bengal. The Andaman group has 325 islands while the Nicobar group has only 247 islands to it.

India's only active volcano, Barren Island is situated here. It last erupted in 2017. The Narcondum is a dormant volcano and there is a mud volcano at Baratang.

Equation with Ecosystem

Ranging from Himalayas to plateaus, plains, islands, river systems etc. describe how remarkable, vast and diversified, physiography of Indian System is. The physiography of India, with its diverse range of

mountains, plains and deserts play a crucial role in maintaining ecosystem balance. The Himalayas for example act as a natural barrier, influencing climate and facilitating monsoon, which is essential for the growth of many plant species. The Northern Plains, with their flat terrain and fertile soil support agriculture and dense population, contributing to the overall balance of ecosystem. Deccan Plateau rich in minerals and forests provides essential minerals and habitats for various species. The Thar Desert while hot and dry has unique desert wildlife that contributes to the biodiversity of the region.

Indian physiography highlights the interplay between natural forces and human activity, emphasizing the importance of geography in everyday life. Understanding the features of Indian physiography helps in disaster management, sustainable development, and regional planning. It also explains the diverse natural environments that support a variety of ecosystems and human lifestyles. In summary, each feature contributes to India's geographical diversity, influencing climate, agriculture, settlements, and economic activities. Each region's unique features and its preservation will help in the conservation and sustainable use of natural resources, promoting ecological balance and resilience.



When we heal the Earth, We heal our selves.

शहर की हवा



देबजित तालुकदार

वरिष्ठ प्रबंधक (रसायन)

प्रदूषण का आलम कुछ ऐसा है
कि बाहर निकलना हो गया है मुश्किल
जहरीली हो गयी है शहर की हवा
न रहा सास लेने के काबिल।

सड़को पर रोज चलते गाड़ी मोटर
धुंएँ में छोड़े कार्बन मोनोऑक्साइड
और हवाको बनाये 'साइलेंट किलर'
जहरीली हो गयी है शहर की हवा
ख़तम कर रही है हम सबको भीतर-भीतर।

पेड़ों को काट कर बनाया है कारखाना
कारखानों से निकले बेहिसाब धुआँ
और धुआँ दूषित करे वातावरण
जहरीली हो गयी है शहर की हवा
सास लेते ही सीने में होती है जलन।

रास्ते के बगल में रोज फेंकने से कूड़ा
बन गया है कचरे का पहाड़
जिसके बदबू से है हर कोई परेशान
जहरीली होगयी है शहर की हवा
रूमाल से मुँह ढक कर कबतक चले इंसान।

वक्त रहते ही प्रदूषण को रोका नहीं अगर
अपने जिम्मेदारियों को निभाया नहीं अगर
अपनी की हुई गलतियों को सुधारकर
जहरीली हो गयी है शहर की हवा
किसी दिन सास लेना पड़ेगा
लगाकर ऑक्सीजन सिलिंडर।





জলবায়ু পৰিৱৰ্তন (শিশু নাট)



জেহেৰুল ইছলাম

সহকাৰী কাৰ্যবাহী অভিযন্তা

প্ৰদূষণ নিয়ন্ত্ৰণ পৰিষদ, ডিব্ৰুগড়

বৰ্ণনাকাৰী :

ধৰিত্ৰী মা কান্দি আছে। প্ৰতিদিনে হাবি-বন নাইকিয়া হৈ আছে। বিভিন্ন কাৰণত জলবায়ু পৰিৱৰ্তন হৈ আছে। ইয়াৰ বাবে দায়ী কোন? কোনে আমাক ৰক্ষা কৰিব।

নাগৰিক :

যতে-ততে প্লাষ্টিক পৰি আছে। মানুহবোৰ ব্যক্তিগত বাহন নহলে কতো যাবই নোৱাৰে। অমনোযোগিতাবে বিদ্যুত ব্যয় কৰে। জানে নে

সৰু সৰু ভুলবোৰৰ কাৰণে আজি অনিমিত ৰ'দ বৰষুণ, গৰম আদিৰ পৰা ভুগি আছে।

ধৰিত্ৰী মাঃ

(লাহে লাহে খোজ দি আহি আছে) মই আপোনালোকক বিশুদ্ধ বতাহ, পানী, হাবি-বন সকলো যোগান ধৰিছো। কিন্তু আপোনালোকৰ কিছুমান ভুল কৰ্ম আৰু লোভেই মোক ধংস কৰি আছে। ঘৰখন ধংস হলে, আপোনালোকে ক'ত বসবাস কৰিব?

উদ্যোগপতিঃ

উন্নয়ন হবলৈ আমাক উদ্যোগ, গাড়ী সকলো লাগিব। প্ৰয়োজনত ৰাস্তা বনাবলৈ গছ-গছনি কাটিব লাগিব।

ছাত্ৰঃ

কিন্তু উদ্যোগে বিষাক্ত গেছ এৰি দিছে, যাৰ ফলত প্ৰদূষণ হৈছে।

খেতিয়কঃ

এইবোৰ কাৰণত খেতি উৎপাদন কমি গৈছে। আমাৰ জীৱন বিপদাপন্ন হৈছে।

ধৰিত্ৰী মাঃ

বহনক্ষম (Sustainable Development) উন্নয়নৰ ধাৰণাৰে উদ্যোগ হলে, গছ কটিলে মোৰ ক্ষতি নহব। মানে প্ৰদূষণ নিয়ন্ত্ৰণৰ জৰিয়তে উদ্যোগ হ'লে, আমাৰ উন্নয়ন ও হব, আপোনালোকেও সুৰক্ষিত থাকিব।

বৰ্ণনাকাৰীঃ

গছ কাটিছে, কিন্তু নতুন এজোপা নোৰুৱাকৈ কিয়? জানে নে গছে বায়ুমণ্ডলৰ পৰা CO₂ শোষণ কৰে আৰু আমাক O₂ যোগান ধৰে।

নাগৰিকঃ

আপুনি সত্য কথা কৈছে। আমি কৰা ভুলৰ বাবে প্ৰদূষণ হলে, আমাৰ সকলোৰে ধংস অনিবাৰ্য।

ছাত্ৰঃ

তেন্তে আমি এতিয়াও আমাৰ ধৰিত্ৰী মাক সুৰক্ষিত কৰাৰ সময় আছে।

ধৰিত্ৰী মাঃ

হয়, আপোনালোকৰ প্ৰতিটো পৰিৱেশমুখী ভাল পদক্ষেপে সকলো সুৰক্ষিত ৰাখিব।

ছাত্ৰঃ

আমাক স্কুলত শিকাইছিল যে যাতায়ত হিচাবে আমি সকলোৱে চাইকলে, ৰাজহুৱা গাড়ী ব্যৱহাৰ কৰিব লাগে। ই প্ৰদূষণৰ পৰিমাণ কমাই দিয়ে।

নাগৰিকঃ

আমি ঘৰৰ ফেন, লাইট আদি প্ৰয়োজনত ব্যৱহাৰ কৰিলে বিদ্যুত সঞ্চয় হব আৰু যাৰ ফলত প্ৰদূষণ কম হব।

খেতিয়কঃ

সকলোৱে গছ ৰুই হাবি-বন সুৰক্ষিত ৰাখিব পাৰিম। পৰিবেশ প্ৰতিকূল নহ'লে, খেতি উৎপাদন বেছি হব।

ছাত্ৰঃ

প্লাষ্টিকৰ ব্যৱহাৰ কমাব লাগিব। আৱৰ্জনা য'তে ত'তে পেলাব নালাগে। পৌৰনিগমৰ সহায়ত আৱৰ্জনা নিষ্কাশন পদক্ষেপত সহযোগ কৰিব লাগিব।

ধৰিত্ৰীঃ

প্ৰকৃতিক সুৰক্ষিত ৰাখিলে, প্ৰকৃতিয়ে আপোনাক সুৰক্ষা দিব।

বৰ্ণনাকাৰীঃ

জলবায়ু পৰিৱৰ্তন ভবিষ্যতৰ সমস্যা নহয়, বৰ্তমানৰ সমস্যা। সেয়ে আমি আজিৰ পৰা সজাগ হওঁ, আহক।



The Cost of Delay in a Changing Climate



Debajit Das
SM (Chemical)

The morning air no longer feels the same!

There was a time—not too long ago—when dawn arrived gently. Cool winds would pass through open windows, trees would whisper in unison, and the rhythm of nature felt predictable—almost comforting.

That predictability is fading.

Summers arrive earlier, linger longer, and burn harsher. Rains come either as a whisper or a warning. Winters hesitate, as if unsure of their own place in the calendar. What once felt balanced now shows signs of drift.

Something subtle has shifted. And we can feel it.

Climate change is no longer a distant theory confined to conferences or printed in dense scientific reports. It has entered our homes, altered our routines, and quietly rewritten the rules of the world we live in.

World Environment Day is not a call to observe. It demands that we respond.

“Climate Change: Accelerating Action to Combat Its Impacts” is a reminder that the challenge today is not understanding—it

is timing.

We know the causes. We understand the consequences. What remains uncertain is whether we are willing to act fast enough.

In any engineered system, delay has consequences.

A minor deviation, if left unattended, does not remain minor. It accumulates. It amplifies. What begins as variation evolves into failure.

The climate system is no different.

It is not collapsing in an instant—it is shifting, gradually but persistently, away from equilibrium. Glaciers retreat like memories fading from the earth’s surface. Forests, once dense and thriving, stand thinner each year, bearing the scars of fire and neglect. Coastal regions live with a quiet anxiety as sea levels rise, inch by inch, wave by wave. And in cities, where concrete replaces soil, heat settles like an unwelcome guest that refuses to leave.

These are not isolated failures. They are connected signals.

Which brings us to a question often framed as a dilemma:

Can development and environmental responsibility coexist?

The answer is not only yes— it must.

Development cannot pause. The demand for infrastructure, energy, and industry will continue to grow. But what must evolve is how we define progress.

It can no longer be measured only by speed, scale, or output. It must also account for efficiency, sustainability, and long-term stability. Because a system that performs well today but fails tomorrow is not well designed.

Responsible growth is not a constraint on development—it is its refinement.

When environmental awareness is integrated into design, progress does not slow down. It becomes more precise, more efficient, and more durable.

The real choice is not between growth and conservation. It is between careless expansion and engineered progress.

The solutions are already within reach. Cleaner energy systems, efficient processes, sustainable materials, circular resource flows—these are not ideas waiting to be discovered. They are tools waiting to be deployed at scale.

What is required now is acceleration.

Not acceleration driven by panic—but by clarity.

It is the shift from discussion to implementation. From knowing to doing. From delay to decision.

Because time, in this system, is not passive.

Delay increases load. It reduces margin. It narrows the space within which correction remains effective.

And the system we are dealing with is not abstract.

It is economic. It is social. It is human. It shapes livelihoods, infrastructure, health, and stability. Its effects may vary in intensity, but its presence is universal.

And yet, there is reason for measured optimism.

Every system redesigned for efficiency restores balance. Every structure built with awareness reduces impact. Every decision that prioritizes long-term performance over short-term gain moves the system closer to stability.

The path forward does not demand perfection. It demands direction.

Because the future is not something we inherit.

It is something we shape—through the balance we maintain, the systems we improve, and the actions we choose to accelerate today.



The greatest threat to our planet is the belief that someone else will save it.

- Robert Swan

Events & Awareness

Tree Plantation drive at BCPL Plant, Lepetkata on World Environment Day 2025



Events & Awareness

Tree Plantation drive at BCPL Plant, Duliajan on World Environment Day 2025



Tree Plantation drive at BCPL Plant, Lakwa and BCPL Township, Sivsagar on World Environment Day 2025



Events & Awareness

Awareness program organised for Children of BCPL / GAIL employees at BCPL Township, Barbaruah on the occasion of World Environment Day - 2025



Events & Awareness

Awareness program organised for Spouses of BCPL / GAIL employees at BCPL Township, Barbaruah on the occasion of World Environment Day - 2025



Events & Awareness

Awareness program at Sanmilita Janata High School, Kalakhowa,
on the occasion of World Environment Day - 2025



Events & Awareness

Inauguration of Envicare 'Vol. VI' on World Environment Day - 2025



Events & Awareness

Closing Ceremony and Prize Distribution on World Environment Day - 2025



Events & Awareness

Closing Ceremony and Prize Distribution on World Environment Day - 2025



Participation

BCPL Participate in India Energy Week 2026



BCPL Participate in Technical Meet on Design, Operational, Strategies for Waste Water Treatment and Zero Liquid Discharge (ZLD) systems organised by FICCI, New Delhi



Visits

Shri Deepak Gupta, Chairman, BCPL and Smt. Anjana Sanjeeva, Director BCPL visit BCPL, Lepetkata



Visits



Shri Sandeep Kumar Gupta Ex. Chairman, BCPL
visits BCPL, Lepetkata



Shri Vedveer Arya, Additional Secretary
and Shri Inderjeet, Dy. Secretary, MoPNG visit BCPL, Lepetkata

Acknowledgement

It is our mammoth pleasure to accomplish this awareness deed of publishing the Souvenir “**Envicare Vol. VII**” in the shortest possible time, and this could not be possible without the constant support and motivation of BCPL Management, its employees and stakeholders. We would like to express our gratitude to all those who were a part of this journey and munificently helped in coloring the backbone of this Souvenir with their valuable messages, knowledge, expertise and excellent contributions.

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To all the contributors, whose amalgamation made this Souvenir a Kaleidoscope of Environment Consciousness.

And most importantly, you our reader, who will propagate the message of conservation of environment and our ecosystem, contained in this Souvenir.

Let us all join together for creating a better environment.

Disclaimer :*The opinions, facts, beliefs, and view points expressed by the various authors and contributors on this souvenir do not necessarily reflect the opinions, beliefs and view points of BCPL and its Environment Team. Further some of the pictures used in the souvenir are taken from different sources of internet. Any inadvertent mistake may also please be excused.*

Event Calender

MONTH	DATE	IMPORTANT DAYS
FEBRUARY	2	World Wetland Day
	28	National Science Day
MARCH	3	World Wildlife Day
	21	International Day of Forests
	22	World Water Day
	Last Saturday of March	Earth Hour Day
APRIL	18	World Heritage Day
	22	International Mother Earth Day
MAY	22	International Day for Biological Diversity
JUNE	5	World Environment Day
	17	World Day to Combat Desertification
JULY	1 st Week of July	Van Mahotsav
	28	World Nature Conservation Day
	29	International Tiger Day
AUGUST	10	International Biodiesel Day
	12	World Elephant Day
SEPTEMBER	16	International Ozone Day
	18	International Coastal Clean up Day
	28	Green Consumer Day
OCTOBER	1 to 7	Wildlife Week
	4	World Animal Welfare Day
	1 st Monday of October	World Habitat Day
	13	International Day for Natural Disaster Reduction
DECEMBER	2	National Pollution Control Day
	3	Bhopal Gas Tragedy Day
	5	World Soil Day
	11	International Mountain Day
	14	National Energy Conservation Day

Some of the pictures used in this souvenir are taken from different sources in internet



Asian elephant
IUCN: Endangered
Loc: Kaziranga
PC: Arindam Bordoloi



One Horned Rhinoceros
IUCN: Vulnerable
Loc: Kaziranga
PC: Arindam Bordoloi



Asian Wild Water Buffalo
IUCN: Endangered
Loc: Kaziranga
PC: Arindam Bordoloi



Royal Bengal Tiger
IUCN: Endangered
Loc: Kaziranga
PC: Arindam Bordoloi



Hog Deer
IUCN: Endangered
Loc: Kaziranga
PC: Arindam Bordoloi



Arindam Bordoloi
photography

