

BIOGAZETTE



Pioneering the next era of biotechnology

SUSTAINOVATE

INNOVATING TODAY, SUSTAINING TOMORROW



BIOTECH CORNER

M. G. SCIENCE INSTITUTE

Insights of BioGazette

BioGazette is the first official magazine of the Biotechnology Department, a student-initiated vision that took shape through determination and ownership, born not overnight, but through a month's long journey of ideas, effort, and collective commitment. What began as a simple thought gradually evolved into a structured platform through countless discussions, revisions, late hours, teamwork, and perseverance by both students and faculty.

This inaugural edition represents more than printed pages. It reflects the creativity of students, the guidance of teachers, and the determination to build something meaningful from scratch. From conceptualizing themes to curating content, designing layouts, editing manuscripts, and meeting deadlines, every step demanded patience, collaboration, and consistency. As first-time creators of a departmental magazine, the learning curve was steep, but it was precisely this challenge that shaped BioGazette into what it is today.

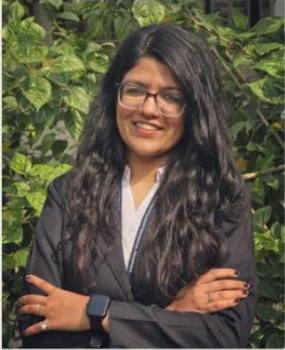
Under the leadership and constant support of Dr. Shivani Raval, Head of the Biotechnology Department, and with the dedicated involvement of students, BioGazette has emerged as a space where scientific knowledge meets creativity. It serves as a platform for biotechnology students to express their ideas, research interests, academic insights, and innovative thinking beyond the classroom.

More importantly, BioGazette is envisioned as a legacy, one that will continue to grow with each passing year. Future editions aim to provide upcoming batches of biotechnology students an opportunity to showcase their work, voice their perspectives, and contribute to a culture of scientific curiosity and creative expression.

As we release this first edition, we look forward to many more stronger, richer, and more diverse, each carrying forward the spirit with which BioGazette was first created.

THE EDITORIAL BOARD

CORE MEMBERS



HIMANI THAKKAR
BIOTECH (SY)



DIYA SHAH
BIOTECH (SY)



HIMANSHI GOHIL
BIOTECH (FY)



PARAS GODSE
BIOTECH (SY)

TECHNICAL TEAM



MANN PRAJAPATI
DSA (SY)



AARYAN PATEL
DSA (SY)



ABHAY SOLANKI
DSA (SY)



RUSHI THAKKAR
DSA (SY)



KRISH KAROVA
BIOTECH (SY)



DARSHIL VAGHASIYA
BIOTECH (FY)

MEMBERS



KAVYA SHAH
BIOTECH(SY)



DRASHTI DARJI
BIOTECH(SY)



PEARL RAO
BIOTECH(SY)



HEER SHAH
BIOTECH(SY)



AAYUSHI GOHIL
BIOTECH(SY)



DEVANGI MALVI
BIOTECH(FY)



PRIYANSHI DAMANI
BIOTECH(FY)



VISHWA BAROT
BIOTECH(FY)



SHRINI JAIN
BIOTECH(FY)



RENY PATEL
BIOTECH(FY)



RIDDHI VORA
BIOTECH(FY)



KRUTI VALA
BIOTECH(FY)



ANVEE PATEL
BIOTECH(FY)



DIYA PATEL
BIOTECH(FY)

Table of Contents

- From Principal's Desk 8.
- From Vice Principal's Desk 9.
- From The Department's Desk 10.
- Shaping Biotechnology: The Legacy of Jennifer Doudna. 11.
- How Biotechnology is Rewiring the Packaging Industry? 12.

~Dr. Jemi Gandhi

01. Ethnobotany

- From Folk Remedies to Future Medicines : How Ethnobotany Supports Sustainable Healthcare. 16.
~Diya Shah
- Ethnobotany : Bridging Tradition and Sustainability 20.
~Hardi Parmar
- Ethnobotany in modern sustainability 23.
~Prisha Mistry
- Ethnobotany: Nature's Solution to Modern Problems 25.
~Krish Karova

02. Circular Bioeconomy

- Rethinking Waste: How the Circular Bioeconomy Redesigns Value 29.
~Drashti Darji
- Circular Bioeconomy—Paradigm for the Future 32.
~Paras Godse
- Industrial Biotechnology as a Driver of Circular Bioeconomy : Innovations for Sustainable Future 35.
~Himanshi Gohil
- The Circular Bioeconomy: Bridging Nature, Technology, and Prosperity 39.
~Dhriti Brahmaniya
- Closing the loop: Future of a Circular Bioeconomy 42.
~Devangi Malvi & Riddhi Vora

03. Sustainable Mining

- Sustainable Mining: Balancing Development And The Environment 45.
~Hitarth Damor & Diya Shah
- Reimagining Mining for a Sustainable Future: Turning Waste into Opportunity 49.
~Himani Thakkar
- Biotechnological Approaches for Sustainable Mining: An Eco-friendly Perspective 53.
~Vishwa Barot
- From Quantum Biology to Physics: The New Era of Sustainable Mining ! 56.
~Shaikh Masuma Mohammed Yunus & Bhakhar Freya Nilesh

04. Biofuels & Bioenergy

- Biofuels from Biowaste: A Sustainable Pathway for Energy Generation **59.**
~*Pearl Rao*
- India & Bioenergy at its Crossroads **62.**
~*Kavya Patel*
- Power from nature : A Sustainable in transit to renewable energy **65.**
~*Ziya Mansuri, Italiya Khushi and Jinal Borad*

05. Biopolymers

- Biopolymers: Building a Circular Bioeconomy for a Sustainable Future **68.**
~*Divyesh Patni & Diya Shah*
- Biopolymers in Medical Implants: Building a Sustainable Future for Healthcare **71.**
~*Himani Thakkar & Kavya Shah*
- Biopolymers: “Shaping a Sustainable Future” **74.**
~*Shrini Jain & Reny Patel*
- Engineering Biopolymer-based Food Packaging For Sustainability **78.**
~*Jheel Patel*

06. Bioremediation

- Bioremediation : A Sustainable Biotechnological Solution For Environmental Pollution **82.**
~*Vala Kruti*
- Integrating Computational Tools and Molecular Docking for Sustainable Bioremediation: A Student-Led Case Study. **85.**
~*Shaikh Masuma Mohammed Yunus*
- Bioremediation : When Nature Becomes The Healer Of Our Planet **88.**
~*Niki Kansara*
- Healing the earth naturally : the power of Bioremediation **90.**
~*Sanskriti Bhimani & Madhavi Pandya*

07. Green Pharmaceuticals

- Tiny Titans: How Nanoparticles are Shaping the Future **93.**
~*Mahek Satasiya & Heer Gandhi*
- Green Pharmaceuticals: Rethinking Healthcare for a Sustainable Future **96.**
~*Kavya Shah*
- Sustainable Healthcare: Antimicrobial Stewardship To Reduce Antibiotic Resistance **99.**
~*Heer Shah*
- Prescribing Sustainability: The Green Evolution Of Healthcare **102.**
~*Priyanshi R Patel*

- Creative Corner **106.**
- Fun Facts **108.**
- Gallery of Achievements and Activities **109.**
- Note of Thanks **113.**

From Principal's Desk



*Dear Students,
Biotechnology Department,
M. G. Science Institute (Autonomous)*

I feel proud that the students-driven magazine 'BioGazette' of Biotechnology department is going to be launched on 24th February 2026.

This magazine is a wonderful example of how learning goes beyond textbooks and classrooms. 'BioGazette' gives students a creative space to share ideas, explore scientific thoughts, and express their passion for biotechnology. As our Institute firmly believes in the holistic development of students through cultural, creative, and co-curricular activities, initiatives like this help build confidence, teamwork, curiosity, and a deeper understanding of the subject.

The enthusiasm and hard work of the students who have taken the lead in creating this magazine is quite commendable. I also appreciate the constant support and guidance of all the faculty members and all staff members of Biotechnology department. Their efforts reflect creativity, dedication, and a strong spirit of collaboration.

I can ensure that 'BioGazette' will continue to grow into an inspiring platform that encourages innovation, critical thinking, and scientific curiosity among students.

My good wishes and blessings are with the editorial team and contributors' great success and look forward to many more exciting editions in the future.

Best wishes,

A handwritten signature in black ink, appearing to read 'Dr. Jatin Parikh', written over a horizontal line.

Dr. Jatin Parikh
Offg. Principal

From Vice Principal's Desk



It is wonderful to see the Department of Biotechnology present its departmental publication, 'BioGazette'.

Bringing out a magazine like these calls for vision, coordination, and sustained effort. From selecting themes to refining content and designing each page, it is a journey that reflects commitment and pride in one's discipline. BioGazette captures the innovative outlook and academic vibrancy that the department consistently promotes.

*I sincerely commend all the **student and faculty contributors** for their thoughtful work and perseverance. Their behind-the-scenes dedication has shaped this publication into a meaningful platform for ideas, learning, and creative expression.*

This initiative goes beyond academics—it strengthens collaboration, builds confidence, and celebrates the spirit of biotechnology in a unique way.

My heartfelt congratulations to the Head of the Department, faculty and everyone involved in this endeavour. I am confident that BioGazette will grow into a valued and inspiring tradition for the department.

With best wishes,

Warm regards,

Dr. Noopur Goyal

Vice Principal

M.G. Science Institute, Ahmedabad

From The Department's Desk

It is with great pride and enthusiasm that the Department of Biotechnology presents the inaugural issue of "BioGazette" magazine. The department stands as a dynamic platform dedicated to the holistic enhancement of students at all scientific, technical, and curricular levels. Our core objective is to nurture young minds by integrating strong theoretical foundations with hands-on laboratory exposure, interdisciplinary learning, and research-oriented thinking. Alongside academic rigor, equal emphasis is placed on co-curricular and extracurricular activities that foster leadership, innovation, teamwork, and communication skills.

This magazine serves as a creative and intellectual forum where students and faculty can showcase their scientific insights, research ideas, achievements, and perspectives on emerging trends in biotechnology. We hope this initiative inspires curiosity, collaboration, and a lifelong passion for learning, while strengthening the department's commitment to excellence and student empowerment.

As 2026 marks the second year since the establishment of our department and the inaugural year of BioGazette, I extend my sincere congratulations to all team members, students, and faculty for their dedicated and commendable contributions. We express our heartfelt gratitude to M. G. Science Institution for being the backbone of such creative initiatives. Their unwavering support, guidance, and trust made this endeavour possible. Such encouragement not only nurtures innovation but also plays a vital role in shaping students' academic and personal journeys, truly upholding the motto, "for the student, by the student."

Shaping Biotechnology: The Legacy of Jennifer Doudna.

S Jennifer Doudna: Architect of the Genetic Revolution

Biochemist Jennifer Doudna is a visionary whose work has fundamentally altered our relationship with the "code of life." A Professor at UC Berkeley and a founder of the Innovative Genomics Institute, she is most famous for co-developing a technology that was once the stuff of science fiction: the ability to edit the DNA of any living organism with surgical precision.

The Road to the Nobel Prize

In 2020, Jennifer Doudna and her collaborator, Emmanuelle Charpentier, were awarded the Nobel Prize in Chemistry "for the development of a method for genome editing." The recognition was historic, marking the first time the Chemistry prize was shared by an all-female team. Perhaps more remarkably, the award came less than a decade after their initial discovery, a testament to how rapidly their work transformed the global scientific landscape and opened new frontiers in medicine and agriculture.

The Breakthrough: CRISPR-Cas9

Before Doudna's work, gene editing was slow, expensive, and notoriously inaccurate—like trying to fix a single typo in a library by throwing a handful of ink at a wall. Doudna and Charpentier looked to nature for a better way, specifically studying the immune system of bacteria which uses a mechanism called CRISPR to "remember" and slice up invading viruses. In 2012, they published a landmark study showing that this bacterial defense could be repurposed into "genetic scissors." By pairing the protein Cas9 (the scissors) with a custom-made guide RNA (the GPS), they created a tool that could find a specific spot in a genome and snip it, allowing scientists to silence harmful genes, repair mutations, or insert new genetic material with unprecedented ease.

Key Contributions & Legacy

Beyond the invention of these "scissors," Doudna has established herself as a world leader in structural biology, spending decades mapping the complex 3D shapes of RNA molecules to understand their functional secrets. Recognizing the immense power of her discovery, she has also become a leading moral compass for the scientific community, spearheading global conversations on the ethics of gene editing and advocating for strict regulations regarding "designer babies." Today, her legacy continues through the Innovative Genomics Institute, where her research fuels breakthroughs in drought-resistant crops and life-saving treatments for diseases like sickle cell anemia and various forms of cancer.

How Biotechnology is Rewiring the Packaging Industry?

Author: Dr. Jemi Gandhi,

Assistant Professor, Biotechnology

jemi.gandhi@mgscience.ac.in

The Crisis of Persistence

Plastic production worldwide is more than 380 million tonnes a year, and about 40% of that is for single use packaging. Polyethylene, polypropylene, and polystyrene are all types of plastic polymers that are made to last forever. Yet, single use plastic packaging is only used for short duration. This leads to environmental crisis - microplastics infiltrating marine ecosystems, landfill saturation, and a reliance on fossil fuels that accelerates climate change.

Although, recycling mechanisms exist statistically, recycling rates remain very low i.e., below 9% globally. Multi-layer packaging which is essential for food safety is nearly impossible to recycle. Owing to this, it becomes clear that we need durable, affordable packaging solutions that do not persist in the environment for centuries. This is where biopolymers are emerging as a promising solution. Traditionally viewed as materials derived from renewable plant sources such as corn starch, the field of biopolymers is rapidly evolving due to biotechnological interventions. We are transitioning from merely processing crops to harnessing the power of cellular machinery. Through advanced biotechnology, we are not only producing bioplastic through fermentation by micro-organism but are also digested by enzymes, creating a closed-loop system that minimizes environmental impact,

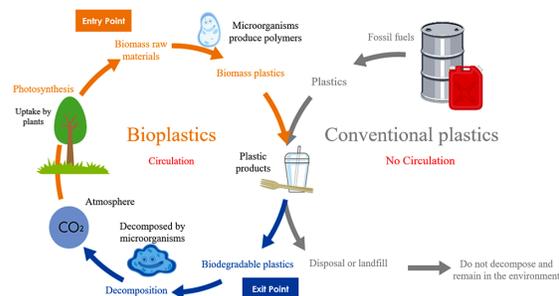


Figure 1: Schematic representation of life cycle of conventional plastic and bioplastic.

Courtesy:

https://link.springer.com/chapter/10.1007/978-981-96-4492-6_12

Biotechnology: Rewiring Metabolic Pathways

To begin with, **polylactic acid (PLA)** is the first generation of biotech plastic. Herein, microorganisms (often *Lactobacillus*) are used to ferment plant sugars (corn or sugarcane) into lactic acid. However, to turn lactic acid into usable plastic, the acid must be chemically processed through polymerization, which uses metal catalysts and requires high energy. It is a hybrid of biology and chemistry. While successful and widely used, PLA relies on food crops and lacks the ability to degrade in natural environments.

The deepest scientific shift in this sector is the move from chemical synthesis to biological synthesis. This involves treating cells (bacteria, yeast, algae) as

microscopic factories. One the most promising biotech advancement involves production Polyhydroxyalkanoates (PHAs)/Poly(3-hydroxybutyrates) (PHBs) by microorganisms. Unlike PLA (Polylactic Acid), which requires plants for feedstock and chemical processing, PHAs/PHBs are produced directly by bacteria (such as *Ralstonia eutropha*) as energy reserves, similar to how humans store fat.

Using metabolic engineering, DNA of these bacteria are modified to turn them into hyper-efficient production units where they make PHAs/PHBs. In addition, instead of feeding the bacteria pure sugar, researchers are engineering strains to consume waste streams such as methane from landfills, wastewater sludge, or carbon dioxide. Through fermentation, the bacteria produce polymers inside their cells, which are then harvested. This creates a truly carbon-negative plastic cycle, Figure 2.

From wastewater to PHA bioplastic



Figure 2: Production of PHAs by bacterial fermentation from wastewater. Courtesy: <https://www.eawag.ch/en/info/portal/news/news-detail/producing-bioplastics-from-wastewater/>

A challenge with standard bioplastics is that of poor thermal and barrier properties. This problem is solved by engineering yeast strains (*Saccharomyces cerevisiae*) to produce novel monomers that have good thermal and barrier properties. For example,

scientists are bio-engineering yeast to produce FDCA (2,5-furandicarboxylic acid). When polymerized, FDCA creates PEF (polyethylene furanoate), a plant-based bottle that rivals polyethylene terephthalate (PET) in strength, higher thermal stability and is also superior barrier against oxygen, keeping drinks or beverages fresher for longer time period.

Companies are using fungal mycelium (the root structure of mushrooms) as a binding agent for bioplastic production. By inoculating agricultural waste with mushroom spores, the mycelium grows through the substrate in a mold, forming a dense, foam-like material. This "grown packaging" is currently being used as a direct replacement for Styrofoam (expanded polystyrene) in protective packaging.

The Breakthrough: Enzymatic Recycling

A major breakthrough in recent years in the field of plastic degradation has been the discovery and engineering of plastic eating enzymes.

In 2016, scientists discovered a bacterium, *Ideonella sakaiensis*, that had evolved to eat PET. Researchers have since used protein engineering to stabilize the "PETase," – an enzyme produced by *I. sakaiensis*. This process, known as biological depolymerisation, allows us to break plastic waste back down into its original monomers, Figure 3. These monomers can then be repolymerized into virgin-quality plastic—a form of infinite recycling that mechanical methods cannot achieve.

(SRISTI), Ahmedabad is working on documenting and scaling grassroots innovations, often bridging traditional knowledge with modern biotech.

Startups Leading the Charge

- **Phool.co** uses a flower-cycling technology, they employ a "flower-cycling" process (a form of microbial composting) to turn temple floral waste into Fleather, a vegan leather alternative.
- **Ecoware** uses natural polymer cellulose from agricultural waste (bagasse and straw), bypassing the need for synthetic biotechnology.
- **Banyan Nation** is creating a "formalized" circular economy for recycled plastic by working toward integrating biological recycling methods.

The Plastic Waste Management Amendment Rules (2021) and the Extended Producer Responsibility (EPR) framework create a regulatory environment where high-value biopolymers can compete. The Government of India's "National Policy on Biofuels" and support for "Waste to Energy" projects under the Ministry of New and Renewable Energy (MNRE) provide grants and subsidies that indirectly aid the bioplastic sector.

Conclusion

Biotechnology provides the tools necessary to complete the carbon cycle, from the bacteria that make the polymers to the enzymes that break them down. Although there are challenges with respect to scale and cost the combination of synthetic biology, metabolic engineering, and waste management—particularly in biomass-rich nations like India—suggests that the plastic era is

evolving into the bioplastic era. The transition will not happen overnight, but with continued research and policy support, the "green wrap" is set to become the standard of a sustainable civilization.

References

1. Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, 3(7), e1700782.
2. Tournier, V., Topham, C. M., Gilles, A., et al. (2020). An engineered PET depolymerase to break down and recycle plastic bottles. *Nature*, 580, 216–219.
3. Rosenboom, J. G., Hohl, D. K., Fleckenstein, P., Storti, G., & Morbidelli, M. (2022). Sustainable polymers in the circular economy. *Nature Reviews Chemistry*, 6, 750–764.
4. Kourmentza, C., Placido, J., Venetsaneas, N., et al. (2017). Recent advances and challenges towards sustainable polyhydroxyalkanoate (PHA) production. *Bioengineering*, 4(2), 55.
5. Sharma, V., & Mudhoo, A. (2011). Bioplastics: A sustainable alternative to the petroleum-based plastics. In *Handbook of Bioplastics and Biocomposites Engineering Applications*. Wiley-Scrivener.
6. Central Pollution Control Board (CPCB). (2022). Guidelines on Extended Producer Responsibility (EPR) on Plastic Packaging. Ministry of Environment, Forest and Climate Change, Government of India.
7. Kumar, S., & Haridas, N. (2021). Valorization of agricultural waste for production of Polyhydroxyalkanoates (PHA): An Indian perspective. *Journal of Cleaner Production*, 284, 124776.
8. European Bioplastics (2022). *Bioplastics Market Data 2022*.

From Folk Remedies to Future Medicines: How Ethnobotany Supports Sustainable Healthcare

Author: Diya Shah

Semester 4, Second Year

B.S. Biotechnology, Department of Biotechnology

Introduction

For thousands of years, plants have served as the primary source of medicine for human societies. Long before laboratories and synthetic drugs existed, indigenous communities relied on local flora to treat illnesses, prevent infections, and maintain overall well-being. This traditional knowledge, developed through careful observation and experience, has been passed down through generations and continues to influence modern medicine in subtle yet powerful ways.

In today's world, healthcare systems face increasing challenges such as rising treatment costs, environmental pollution caused by pharmaceutical waste, and the overexploitation of natural resources. In this context, ethnobotany—the study of the relationship between people and plants—offers valuable insights for building a more sustainable healthcare system. By scientifically validating traditional plant-based remedies and integrating them with modern biotechnology, ethnobotany bridges the gap between ancient wisdom and future medicine.

Understanding Ethnobotany and Its Relevance Today

Ethnobotany is a scientific discipline that explores how different cultures use plants for medicinal, nutritional, and cultural purposes. It focuses on documenting traditional knowledge related to plant usage, particularly in indigenous and rural communities, where reliance on natural resources is deeply rooted. This knowledge often includes information about plant identification, preparation methods, dosage, and therapeutic effects.

In the modern era, ethnobotany has gained renewed importance due to the growing demand for sustainable and eco-friendly healthcare solutions. Many traditional remedies are derived from locally available plants, making them cost-effective and environmentally sustainable. Moreover, ethnobotanical studies serve as a foundation for drug discovery by guiding researchers toward biologically active compounds that might otherwise remain unexplored. As concerns about biodiversity loss and climate change intensify, preserving ethnobotanical knowledge becomes essential not only for healthcare advancement but also for cultural and ecological sustainability.

Ethnobotany and Modern Drug Discovery

Ethnobotanical knowledge has played a significant role in shaping modern drug discovery. Many widely used medicines have their origins in traditional plant-based remedies identified through centuries of human experimentation. For instance, aspirin was developed from salicin, a compound found in willow bark that was traditionally used to relieve pain and fever. Similarly, quinine, derived from the bark of the cinchona tree, became one of the earliest effective treatments for malaria, while artemisinin, now a cornerstone in malaria therapy, was discovered through traditional Chinese medicinal practices.

What makes ethnobotany particularly valuable in drug discovery is its ability to reduce the time, cost, and uncertainty associated with pharmaceutical research. Instead of screening thousands of random compounds, researchers can focus on plants that already exhibit therapeutic potential based on traditional usage. Modern biotechnology techniques such as phytochemical analysis, molecular characterization, and bioassays allow scientists to isolate, test, and validate these compounds under controlled conditions.

In addition to improving efficiency, ethnobotany supports sustainability in drug development. Plant-based medicines often rely on renewable biological resources, and when cultivated responsibly, they can offer environmentally friendly alternatives to synthetic drugs. By combining traditional knowledge with scientific validation, ethnobotany not only accelerates medical innovation but also promotes a more sustainable and inclusive approach to healthcare.

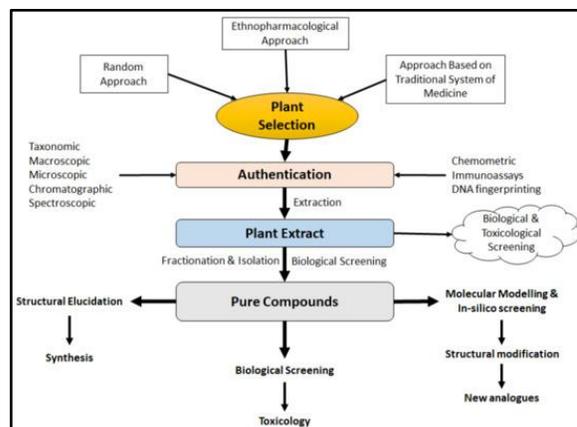


Figure 1: Overview of plant-based drug discovery integrating traditional knowledge with modern scientific validation.

Courtesy: Open-access academic source

Sustainability Challenges in Modern Healthcare

Despite remarkable advancements, modern healthcare systems face several sustainability challenges. The large-scale production of synthetic pharmaceuticals often involves extensive energy consumption, chemical waste generation, and environmental contamination. Improper disposal of medical and pharmaceutical waste can pollute soil and water bodies, posing risks to both ecosystems and human health. Additionally, high treatment costs make quality healthcare inaccessible to a significant portion of the global population.

Ethnobotany offers an alternative perspective by promoting the use of natural, locally sourced medicinal plants. When integrated responsibly, plant-based therapies can reduce dependency on resource-intensive pharmaceutical manufacturing processes. Traditional medicine systems emphasize prevention, holistic well-being, and the use of

potential. By combining traditional knowledge with scientific innovation, researchers can develop safer, more effective, and environmentally sustainable medicines.

Ethnobotany also has an important role to play in strengthening primary healthcare systems, especially in developing regions. Community-based medicinal plant cultivation, supported by scientific training and regulatory oversight, can improve healthcare accessibility while promoting environmental conservation. Furthermore, digital documentation of traditional plant knowledge can help preserve cultural heritage and guide future research efforts.

As the global focus shifts toward sustainability, ethnobotany offers a holistic approach that balances human health, ecological protection, and cultural respect. Its interdisciplinary nature makes it a valuable contributor to sustainable healthcare models that prioritize long-term well-being over short-term solutions.

Conclusion

Ethnobotany represents a vital link between traditional wisdom and modern medicine. By exploring and validating plant-based knowledge developed over generations, it provides valuable insights for creating healthcare systems that are both effective and sustainable. In a world facing environmental degradation and rising healthcare demands, ethnobotany

offers solutions that are rooted in nature, culture, and scientific innovation.

Embracing ethnobotany does not mean rejecting modern medicine; rather, it encourages a balanced approach that respects traditional knowledge while applying rigorous scientific standards. As we move toward a future where sustainability is essential, ethnobotany stands as a promising foundation for healthcare systems that heal both people and the planet.

References

Fabricant, D. S., & Farnsworth, N. R. (2001). The value of plants used in traditional medicine for drug discovery. *Environmental Health Perspectives*, 109(1), 69–75. <https://doi.org/10.1289/ehp.01109s169>

Newman, D. J., & Cragg, G. M. (2020). Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. *Journal of Natural Products*, 83(3), 770–803. <https://doi.org/10.1021/acs.jnatprod.9b01285>

World Health Organization. (2013). *WHO traditional medicine strategy 2014–2023*. <https://www.who.int/publications/i/item/WHO-HIS-HSR-13.1>

Convention on Biological Diversity. (2011). *Nagoya Protocol on access to genetic resources and the fair and equitable sharing of benefits*.

Ethnobotany: Bridging tradition and sustainability

*Author: Hardi Parmar
Semester 4, Second Year
Department of Biotechnology*

Introduction of Ethnobotany

Ethnobotany in modern sustainability involves using the traditional knowledge that indigenous and local communities have about plants. This knowledge helps support practices that are good for the environment, protect a wide variety of plant life, encourage farming that can last for the long term, and improve healthcare. It also helps meet current needs without harming the ability of future generations to meet theirs. In recent years, sustainability has become a major global issue because of many reasons like fast industrial growth, climate change, loss of forests, decline in biodiversity, and overuse of natural resources. While science and technology offer various ways to tackle this issue, they often fail to consider traditional knowledge systems which have supported human communities for many centuries. Ethnobotany, which studies how people interact with plants, gives important knowledge for modern sustainability efforts. By combining indigenous wisdom with current scientific methods, it helps create development layouts and plans which are good for the environment, helpful to society, and economically sustainable.

Role of ethnobotany in environmental sustainability

Ethnobotany looks at how Indigenous and local communities use plants for food, medicine, farming, shelter, and cultural activities. This knowledge grows over time through close interaction with the environment, careful observation, and learning through experience. Usually, traditional ways of using plants focus on renewal, respect, and also on balance for nature rather than taking resources directly. Because of this reason, ethnobotany is now becoming more valued as a way to address current environmental and sustainability issues. Ethnobotany plays a key role in helping out modern sustainability by giving protection to the environment and preserving biodiversity. Many indigenous groups use better ways to harvest plants, like taking only certain parts, collecting at specific times like season wise, and letting plants grow back on their own. They also use things like protected forest areas, shared community forests, and cultural rules that discourage harm to certain plants. These traditional methods help keep ecosystems healthy and support a wide variety of plant life, all without needing costly technology or modern tools.

Importance in healthcare and agriculture

Ethnobotany also plays a substantial role in sustainable healthcare systems. A large ratio of modern medicines is derived from plants that were first identified through traditional knowledge. Medicinal systems for example Ayurveda, Siddha, Unani, and folk medicine rely heavily on plant-based remedies that are natural, renewable, and environmentally safe. Ethnobotanical studies help identify medicinal plants with therapeutic potential, which can then be scientifically validated using biotechnology and pharmaceutical research. Sustainable cultivation of medicinal plants reduces pressure on wild populations and ensures long-term availability of natural resources.

In agriculture, ethnobotany helps to create farming methods that are both sustainable and able to handle climate challenges. Traditional farming approaches often include growing a variety of crops, planting different crops together, rotating crops, using natural fertilizer like manure, and controlling pests without chemicals. Indigenous farmers usually grow types of crops that are native to their area, which are suited to local conditions and can resist pests and diseases. These farming techniques help the soil to stay clean, use water more efficiently, and cut down on the need for chemical fertilizers and pesticides. Because of this, it supports farming which is sustainable and less harmful to the environment. Ethnobotany also plays a major role in ensuring food security and good nutrition, which are important for long-term sustainability. Traditional knowledge includes using wild plants, fruits, seeds, and roots that are

nutritious. Many of these plants can survive in tough environments and can grow in less favorable land. Encouraging the use of these lesser-known plants can help make diets more varied, reduce cases of malnutrition, and boost local food systems, especially in rural and tribal communities.

Economic and social significance

Ethnobotanical knowledge, which is crucial for understanding how people use plants, is under threat today. Factors like urban growth, cutting down forests, industrial progress, and changes in cultural traditions are causing traditional knowledge to fade away. Many younger people are moving away from their ancestors' ways, leading to the slow loss of important plant-related knowledge. Also, when traditional knowledge is taken without permission or proper benefit-sharing, it can be misused and not benefit the original communities. To prevent this, it's important to properly record this knowledge, protect it through legal means, and ensure that benefits are shared fairly with the communities that hold it. Integrating ethnobotany into modern sustainability efforts needs teamwork between scientists, government officials, and local people. Schools and universities should teach about ethnobotany so students learn about its value. Advances in biotechnology can help by checking the effectiveness of traditional plant uses and creating eco-friendly products from plants. Government policies should support local involvement in protecting nature and managing resources responsibly.

Conclusion

In conclusion, ethnobotany connects traditional knowledge with modern sustainability goals. It provides affordable, eco-friendly solutions for health, farming, and economic growth. By valuing and protecting this knowledge, we can work towards a sustainable future that also keeps biodiversity and cultural traditions alive. Ethnobotany isn't just about studying how plants are used—it's a way to guide us toward a more balanced and sustainable world.

References

- Cotton, C. M. (1996). *Ethnobotany: Principles and Applications*. John Wiley & Sons, UK.
- Jain, S. K. (1987). *A Manual of Ethnobotany*. Scientific Publishers, Jodhpur, India.
- Balick, M. J., & Cox, P. A. (1996). *Plants, People, and Culture: The Science of Ethnobotany*. Scientific American Library.
- Posey, D. A. (1999). *Cultural and Spiritual Values of Biodiversity*. UNEP, Nairobi.
- WHO (World Health Organization). *Traditional Medicine Strategy reports (for medicinal plant sustainability)*

Ethnobotany in modern sustainability

*Author: Prisha Mistry
Semester 2, First year
Department of biotechnology.*

Abstract

Ethnobotany, the study of interactions between plants and human cultures, has emerged as a cornerstone of modern sustainability science. This article explores how ethnobotany functions as a bridge between traditional knowledge and modern sustainability goals. It highlights ethnobotany's role in drug discovery, environmental stewardship (conservation) and alignment with global sustainability frameworks. The article also examines contemporary methodological innovations, ethical challenges and future directions.

Introduction

Sustainability in the 21st century demands unifying approaches that integrates ecological integrity, social equity, and economic viability. Historically viewed as a descriptive discipline, ethnobotany has evolved into a dynamic field addressing global challenges such as healthcare inequity, biodiversity loss, climate change, and cultural erosion.

Ethnobotany as a pillar of sustainable healthcare.

Traditional medicinal knowledge has been instrumental in shaping modern pharmacology. A significant proportion of contemporary drugs originate from ethnobotanical leads, demonstrating the sustainability value of plant based knowledge systems. Classic examples include:

Vinblastine and vincristine from Catharanthus roseus for cancer treatment.

Taxol (paclitaxel) from Taxus species also used to treat breast cancer, ovarian cancer etc.

Artemisinin from Artemisia annua for malaria.

What sustainable perspective do they provide?

1. Affordable and locally accessible healthcare.
2. Reduced dependence on synthetic drugs.
3. Preservation of medicinal plant diversity.

Ethnobotany, biodiversity conservation, and environmental sustainability.

Ethnobotanical knowledge systems are deeply intertwined with ecosystem management. Indigenous communities often practice sustainable harvesting, seasonal resource use etc. rooted in cultural ethics. Such practices align closely with SDG 15 (Life on land) and biodiversity conservation goals. Such plant knowledge contributes directly to:

- Agroecological resilience (ability of farming systems, using ecological principles to withstand shocks.)
- Restoration of degraded lands and climate change adaptation strategies.

Social sustainability, cultural heritage and knowledge equity.

Ethnobotany plays a crucial role in safeguarding intangible cultural heritage. Traditional plant knowledge is often transmitted orally and is increasingly threatened by urbanization, globalization and cultural homogenization. Modern ethnobotany highlights:

- Recognition of indigenous intellectual property
- Ethical benefit – sharing under frameworks such as NAGOYA PROTOCOL.

Challenges in ethnobotany-driven sustainability.

- Biopiracy and exploitation of traditional knowledge.
- Loss of orally transmitted plant knowledge.
- Limited integration into formal healthcare and policy systems.

Future directions

Ethnobotany's role in sustainability will continue to expand through:

- Alignment with the UN sustainable development goals

- Integration with climate science, public health, and biotechnology.
- Development of standardized, sustainable herbal products.
- Promotion of urban and migrant ethnobotany.
- Community – led conservation and cultivation programs.

Conclusion

Ethnobotany stands at the intersection of traditional wisdom and modern sustainability science. It contributes to sustainable healthcare, biodiversity conservation etc. By embracing ethical engagement and interdisciplinary innovation, ethnobotany offers a powerful pathway towards inclusive and resilient socio-ecological futures. As global sustainability challenges intensify, ethnobotany's integrative vision becomes not only relevant but essential.

References

1. Recent trends in ethnobotany by Dr. Deosthale S. M. March - April 2025

Chapter 9 (Ethnobotany: a bridge between traditional knowledge and modern pharmacy) of ethnobotany in India, volume 1 by Kadambini Das, Sonali D Suple, Emdad Hossain, Sanjeet kumar and Rajeev Kumar Singh

Ethnobotany: Nature's Solution to Modern Problems

Author: Krish Karova,
Semester-4, 2nd year

Department of Biotechnology

Abstract

Sustaining our environment especially in the modern age is a topic of concern and requires valiant efforts combining knowledge, skills and technology.

Ethnobotany explores the vision of environmental sustenance through nature's lens and the relationship between plants and humans can be the key component the world requires.

This article projects light on the Ethnobotanical ways for environmental sustenance.

Natural cooling agents to combat Global Warming

Dimethyl Sulfide (C₂H₆S) also known as DMS is a sulfur compound emitted mainly by marine phytoplanktons and also by a select few trees and plants.

Swietenia Macrophylla a species of big-leaf Mahogany trees is observed to emit DMS gas into the atmosphere that forms aerosols which are solid or liquid particles formed in the atmosphere when DMS in gaseous form is released into the air.

These aerosols act as the nucleus for water droplets to stick around and initiate cloud formation.

These clouds reflect a part of the solar radiation back into space thereby having a cooling effect on the planet [Figure(1)]

Therefore controlled cultivation of species such as Mahogany trees and marine phytoplanktons can help reverse the damage caused by the green house gases.

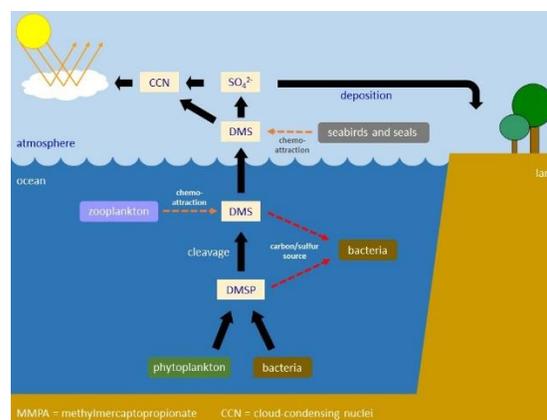


Figure 1: Synthesis of DMS for cloud formation.

Courtesy: Springer nature

Cleansing Agents for Air Pollution Reduction

Experts at the Royal Horticultural Society (RHS) in the UK have declared air pollution as a major issue.

It seems like the scientists have finally made a breakthrough and found a solution for the problem.

The Gray Cotoneaster plant {Figure(2)} or specifically *Cotoneaster glaucophyllus* is also known as a 'super plant' due to its pollution absorption abilities, it is the perfect anti-polluting agent

According to the experts at the RHS the Gray Cotoneaster can absorb at least 20% more pollution than regular plants at the roadside of traffic packed areas.

To put thing into perspective the researchers say that a 1 meter long well-managed dense hedge of Gray Cotoneaster will wop up the same amount of pollution that a car emits over a 500-mile drive (800 kms) and that too in a span of just 7 days

Due to its simple leaf structure the Gray Cotoneaster makes an ideal anti-polluting agent in pollution hotspots.

Another species of plants that can help regulate the climate contaminants is the Silver maple (*Acer saccharinum*), it is a rapidly growing deciduous tree, capable of reaching annual height increments of 1–1.5 meters, which contributes to its high carbon sequestration capacity. According to data referenced by the USDA Forest Service, fast-growing urban trees like silver maple can absorb several kilograms of CO₂ per year through extensive leaf area and high photosynthetic rates. Its broad canopy improves air quality, moderates urban temperatures, and enhances soil moisture retention. In ethnobotany, silver maple supports sustainable human–ecosystem interactions by providing shade, habitat, and ecological services vital to community-based environmental management

Biofuel Production

Biofuels are the source of energy in the new age.

They can be defined as the renewable energy sources obtained from biological compounds like plants, algae and animal waste.

Biofuels are divided into 4 generations and most of the 1st generation biofuels were obtained through Plants. Figure(4).

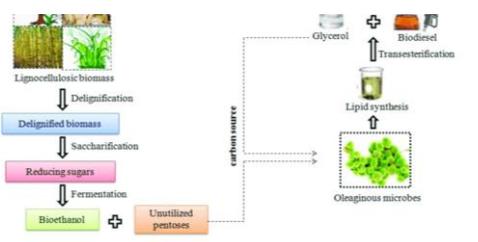


Figure 4: Biofuel Production using biomass

Courtesy: Researchgate

The feedstock i.e. the biomass which is to be used for biofuel production is primarily converted into liquid or gas fuel depending on the contents of the feedstock.

The crude fuel is then cleaned and concentrated to meet fuel standards.

These fuels are not suited to be used on their own and therefore are generally mixed with petroleum fuels before sale.

Cosmopolitan Plants

Acacia nilotica is a highly resilient multipurpose tree adapted to extreme climatic variability. It survives prolonged drought through a deep taproot exceeding 10 m, efficient stomatal control, and osmotic adjustment, while

also tolerating seasonal flooding and temporary waterlogging. The Food and Agriculture Organization (FAO) reports its successful growth in regions receiving less than 400 mm of annual rainfall across Africa and South Asia. *Acacia nilotica* improves soil fertility via nitrogen fixation, reduces erosion, and stabilizes degraded lands. Ethnobotanically, its bark, pods, and gum are used in traditional medicine, fodder systems, fuelwood production, and climate-resilient agroforestry, supporting rural livelihoods and sustainable land management under changing environmental conditions globally.

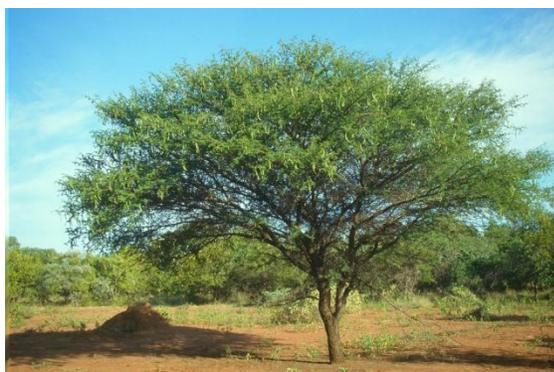


Figure 5: *Acacia Nilotica*

Courtesy: Random Harvest Nursery

Multipurpose Climate Regulators

Paulownia tomentosa is an exceptionally fast-growing deciduous tree recognized for its high carbon sequestration potential. Under favourable conditions, it can grow 2–4 meters annually and develop large leaves exceeding 40 cm in diameter, significantly increasing photosynthetic efficiency. According to reports cited by the Food and Agriculture

Organization (FAO) and research supported by the European Forest Institute, Paulownia plantations can absorb up to 30–40 kg of CO₂ per tree per year. Its deep root system improves soil structure and prevents erosion. In ethnobotany, Paulownia is valued for lightweight timber, agroforestry integration, land restoration, and sustainable human–environment interactions in climate-smart forestry systems.



Figure 6: *Paulownia tomentosa*

Courtesy: Ninaseeds

Conclusion

Ethnobotany studies the relationship between plants and animals and the benefits of plants in our day to day life if the resources are used correctly.

Plants can be used as cooling agents for atmosphere, anti-polluting agents and also for biofuels productions.

Ethnobotany has much more potential for growth and many other aspects of it are yet to be explored.

References

1. Charlson, R. J., Lovelock, J. E., Andreae, M. O., & Warren, S. G. (1987). Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate. *Nature*, **326**, 655–661.
2. Simó, R. (2001). Production of atmospheric sulfur by oceanic plankton. *Trends in Ecology & Evolution*, **16**(6), 287–294.
3. Mallick, I., et al. (2016). Biogenic sulfur emissions from terrestrial vegetation and their role in climate regulation. *Environmental Science & Pollution Research*, **23**, 22445–22454.
4. Royal Horticultural Society (RHS). (2021). Hedge your bets with ‘super plant’ to fight air pollution. *RHS Science*.
5. Popek, R., et al. (2013). Particulate matter accumulation on leaves of woody plants. *Environmental Science and Pollution Research*, **20**, 1–10.
6. United States Department of Agriculture (USDA) Forest Service. (2018). *Urban tree carbon sequestration and air quality benefits*. USDA Reports.
7. Demirbas, A. (2009). Biofuels securing the planet’s future energy needs. *Energy Conversion and Management*, **50**, 2239–2249.
8. Naik, S. N., et al. (2010). Production of first-generation biofuels: A review. *Renewable and Sustainable Energy Reviews*, **14**, 578–597.
9. Food and Agriculture Organization (FAO). (2017). *Acacia nilotica: Ecological adaptability and uses*. FAO Forestry Paper.
10. European Forest Institute (EFI). (2019). *Fast-growing tree species and carbon sequestration potential*. EFI Technical Report.
11. FAO. (2020). *Paulownia species in climate-smart forestry*. FAO Forestry Working Paper

Rethinking Waste: How the Circular Bioeconomy Redesigns Value

Author: Drashti Darji

Semester 4, Second Year

B.S. Biotechnology, Department of Biotechnology

Nature has never known the concept of waste. In ecosystems, every output seamlessly becomes an input for something new. Human systems, however, have followed a different path resources are extracted, transformed, and ultimately discarded, creating fragility as waste accumulates faster than nature can absorb it.

Sustainability is often treated as repair work, when its real power lies in redesigning systems. Every day, valuable resources from agricultural residues to pharmaceutical by-products, slip through economic cracks, not because they lack value, but because our systems fail to retain it. Sustainability must move beyond limiting harm, shifting from disposal to design, and reimagining how value flows at the heart of the circular bioeconomy.

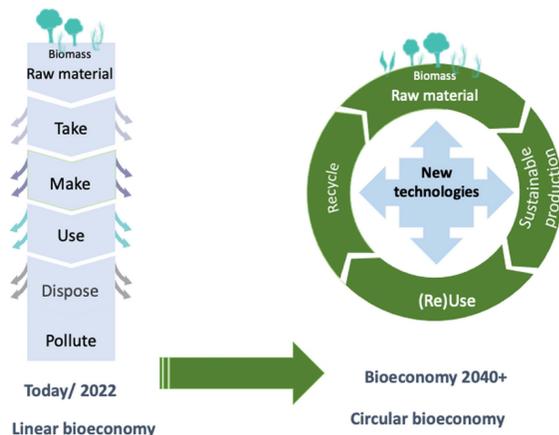


Figure 1. "Redesigning the Flow: Shifting from a linear 'Take-Make-Waste' system to a regenerative Circular Bioeconomy."

Courtesy: Adapted from ResearchGate, linear vs circular bioeconomy.

From Disposal to Design

The circular bioeconomy is often framed through policies and targets, but, it is a mindset, a new way of thinking about resources, value, and waste. It challenges the assumption that waste is inevitable.

Sustainability goes beyond reducing harm. It rethinks product design, and material flows so resources remain in circulation rather than being prematurely lost. Biotechnology enables this shift: enzymes, microbes, and bioprocesses convert residues, by-products, and discarded materials into valuable inputs. In doing so, the circular bioeconomy reframes sustainability not as a limit, but as an opportunity to regenerate value while restoring balance between industry, healthcare, and the environment.

Biotechnology: Closing the Loop

The circular bioeconomy relies on visible transformations in materials and waste, but biotechnology is the real engine. At the molecular level, it enables systems to retain and regenerate value rather than lose it.

Nature operates in loops: microorganisms and enzymes break down and rebuild materials without creating waste. Biotechnology extends

this logic into industry, healthcare, and energy, transforming discarded materials into bio-based products through fermentation, enzymatic reactions, and bioprocessing.

At the heart of this shift is biological renewal. Enzymes deconstruct complex compounds into reusable components, while microbes reconstruct them into new forms, ensuring materials remain active. This regenerative capacity reshapes sectors: cleaner synthesis in pharmaceuticals, microbial conversion of residues in agriculture, and circular bio-industrial production reconnect human systems with natural cycles. By enabling regeneration instead of disposal, biotechnology turns the circular bioeconomy from vision into reality.

Healing Without Harming

Healthcare exists to restore health, yet modern pharmaceutical processes often burden the environment. Conventional drug manufacturing relies on resource-intensive steps, large volumes of solvents, and complex reactions, hiding the environmental cost of healing.

Green pharmaceuticals rethink production using biotechnology, particularly enzyme-based synthesis and biocatalysis. Enzymes catalyze reactions with precision, reduce by-products, operate under mild conditions, and minimize solvent use, shifting production from waste management to prevention.

Continuous enzyme-driven manufacturing improves material recovery, reduces process footprints and replaces toxic reagents, showing how healthcare can heal without harming within the circular bioeconomy.

When Waste Becomes Wealth

Waste is often seen as the end of a process, a sign that value has been exhausted. In a circular bioeconomy, it is understood differently, not as a burden, but as untapped potential.

Microbes and enzymes drive this transformation. Biological systems break down complex residues and rebuild them into useful forms, converting agricultural, food, and industrial waste into bio-based materials, chemicals, and energy. What was once discarded becomes a valuable input for new cycles.

Bio-based industries emerge, relying on renewable processes where enzymes replace harsh chemicals and microbes convert residues into inputs, delivering environmental and economic gains. These processes already turn food waste into biogas and agro-industrial residues into bioplastics, proving that value does not disappear, it changes form. Circular bioeconomy turns waste into innovation, showing sustainability and growth can advance together through intelligent design.

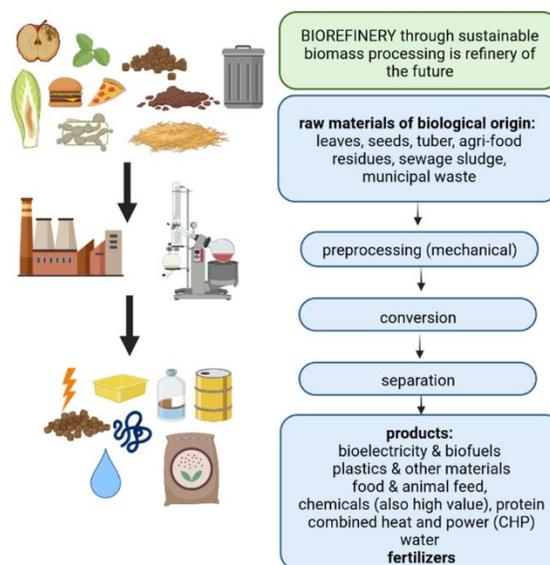


Figure 2. Biorefinery conversion of biowaste and agricultural residues into value-added products under the circular bioeconomy.

Courtesy: ResearchGate, adapted from Arias et al.

India's Circular Moment

The circular bioeconomy is gaining global momentum, but its success depends on local realities. India stands out with abundant biological resources, a growing industrial base, and urgent sustainability needs. It is not merely participating in the transition; it is positioned to shape it.

Globally, circular bioeconomy thinking has shifted from environmental ideal to economic necessity, driven by rising waste, and finite resources. Systems integrating resilience, scalability, and sustainability are no longer optional they define future-ready growth.

India's strength lies in biological abundance. Agricultural residues, food processing by-products, and organic waste can become feedstocks, converted via biotechnology into fuels, materials, chemicals, and health related inputs, linking rural biomass with modern bio-based industries. Circular models operate across communities and industrial platforms, aligning sustainability with livelihoods and positioning India as a potential leader in regenerative progress.

Redefining Our Relationship with Resources

For centuries, progress was measured by how much we extract, use, and discard. Waste was treated as inevitable; sustainability meant slowing damage. But waste is not a failure of resources, it is a failure of design.

The circular bioeconomy begins with a shift in perspective. Materials are carriers of ongoing value. Even what we label as "waste" can be transformed: coffee pulp, for example, becomes fertilizers or bioplastics, proving value waits for redesign. Biotechnology regenerates what linear systems abandon, enabling cycles of renewal guided by biological logic. This shift redefines sustainability, moving from damage control to intelligent design.

Viewed this way, growth is continuous value creation within natural limits. Biotechnology quietly powers this change, transforming residues and by-products into materials, energy, and health solutions. Waste signals incomplete design; aligned systems restore purpose and reintegrate materials into cycles.

What if the next time we call something waste, we ask: How can this live again? In that question lies the heart of the circular bioeconomy and the future we are invited to co-create

References

1. Ubando, A. T., Felix, C. B., & Chen, W. H. (2020). Biorefineries in circular bioeconomy: A comprehensive review. *Bioresource Technology*, 299, 122585.
2. Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768.
3. Department of Biotechnology (DBT), Government of India. (2022). *India Bioeconomy Report*. Ministry of Science and Technology, New Delhi

Circular Bioeconomy—Paradigm for the Future

*Author: Paras Kedar Godse
Semester 4, Second year
Department of Biotechnology*

The Promise—and the Problem

The global shift toward a bio-based economy is often framed as a straightforward solution to environmental crises. Replace fossil fuels with crops, convert waste into useful products, and sustainability will naturally follow. Yet this optimistic narrative conceals a deeper issue: biological resources are not automatically sustainable simply because they are renewable.

When poorly managed, a bioeconomy can reproduce the same extractive patterns that define fossil-fuel systems. Land is overused, ecosystems are degraded, and demand continues to rise. The materials may change, but the logic remains linear—take, make, consume, discard.

To avoid repeating past mistakes, sustainability must move beyond substitution. It requires a systemic rethinking of how biological resources are produced, used, and returned to nature.

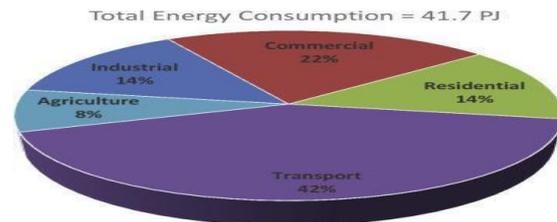


Fig-1: Biomass Consumption.

Courtesy: [ScienceDirect.com]

Why “Bio” Is Not Always Green

The label “bio-based” often carries an assumption of renewability. Plants regrow, forests regenerate, and organic materials decompose. But renewability depends on ecological limits. When soils erode, water is depleted, or biodiversity declines, biological resources lose their capacity to recover.

Early bioeconomy efforts largely focused on efficiency—producing more with fewer inputs. While this improves performance per unit, it does not necessarily reduce overall environmental impact. As demand grows, total pressure on ecosystems can increase rather than decline.

Nature is more than a source of raw materials. Ecosystems regulate climate, maintain food systems, and support human well-being. These services are rarely accounted for in economic

decision-making, yet their loss carries long-term consequences that no technological fix can easily reverse.

materials and minimizing losses at every stage.

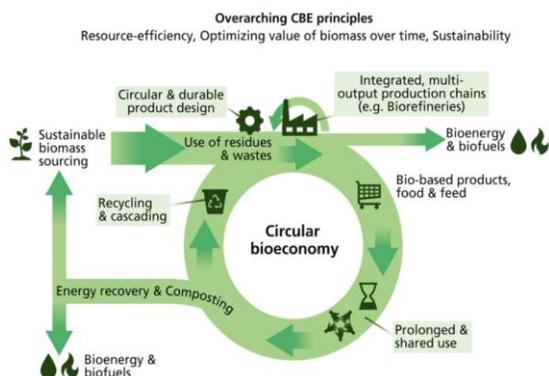


Fig-2: Circular Bioeconomy.

Courtesy: [MDPI Journals]

What Biocircularity Changes

Biocircularity offers a more disciplined framework for sustainability. Instead of asking whether a product is bio-based, it asks whether the entire system operates within ecological boundaries. The goal is to keep biological materials circulating at their highest value for as long as possible—without degrading the natural systems that produce them.

This approach emphasizes responsible sourcing. Biological materials must come from recent living systems, not hidden carbon reserves, and their extraction should not damage soils, water, or biodiversity. Ideally, production should restore ecosystems rather than exhaust them.

Design plays a crucial role. Materials must be durable, and products should be easy to repair, reuse, and dismantle. Circularity depends not just on recycling, but on extending the useful life of

The Road Ahead

Implementing biocircularity is not without challenges. Measuring sustainability across complex global supply chains is difficult, especially when impacts vary across regions and timeframes. Valuing ecosystems also raises ethical questions about responsibility, equity, and long-term stewardship.

Energy use is another constraint. Recycling and remanufacturing often require more energy than producing new materials, meaning biocircular systems rely heavily on renewable energy transitions. Without clean energy, circular processes risk becoming inefficient.

Food systems sit at the center of the debate. Land used for bio-materials competes with land needed to feed people. A truly sustainable bioeconomy must prioritize food security, reduce waste, and align consumption patterns with ecological limits.

Biocircularity matters because it replaces vague green claims with clear principles. It reframes progress—not as producing more “eco-friendly” goods, but as designing economies that operate within nature’s boundaries. Only by closing the loop with nature at the center can the bioeconomy deliver on its promise.

References:

1. Journal Article (Holden et al., 2023)
Holden, N. M., Neill, A. M., Stout, J.
<https://doi.org/10.1007/s43615-022-00180-y>
2. Journal Homepage (Springer Journal)
Circular Economy and Sustainability. (n.d.). Springer.
<https://link.springer.com/journal/43615>
3. ScienceDirect Article (example reference; limited metadata available)
Harper, G., & Smith, A. (2014). A biomass energy flow chart for Fiji.
C., O'Brien, D., & Morris, M. A. (2023). Biocircularity: A framework to define sustainable, circular bioeconomy. *Circular Economy and Sustainability*, 3(1), 77–91.
Renewable and Sustainable Energy Reviews, ??(?), Article S0961953414004978.
<https://www.sciencedirect.com/science/article/abs/pii/S0961953414004978>
4. MDPI Journal Article
Author(s). (2022). Biowaste valorization using hydrothermal carbonization for wastewater treatment: A review. *Water*, 14(15), Article 2344.
<https://www.mdpi.com/2073-4441/14/15/2344>

“Industrial Biotechnology as a Driver of Circular Bioeconomy: Innovations for Sustainable Future”

*Author: Himanshi Gohil
Semester 2, First Year*

B.S. Biotechnology, Department of Biotechnology

Introduction

In recent years, rapid industrial growth and increasing population demands have placed significant pressure on natural resources and the environment. Conventional industrial systems often follow a linear model of production, where resources are extracted, used, and discarded. This approach has contributed to environmental pollution, resource depletion, and ecological imbalance, creating an urgent need for more sustainable development models.

The concept of a circular bioeconomy has come up as a promising solution to these challenges. It emphasizes sustainable use of biological resources by promoting reuse, recycling, and regeneration within industrial systems. Unlike traditional linear approaches, a circular bioeconomy aims to minimize waste while maximizing resource efficiency, thereby supporting long-term environmental and economic sustainability. Industrial biotechnology plays a crucial role. By utilizing microorganisms, enzymes, and biological processes, it supports environmentally friendly and resource-efficient production methods.

From a biotechnological perspective, the circular bioeconomy demonstrates how biological systems can be strategically used to develop sustainable industrial

solutions. Understanding these approaches allows biotechnology to contribute meaningfully toward building resilient and sustainable industrial systems for the future.

Circular Bioeconomy: A Shift Towards Sustainable System

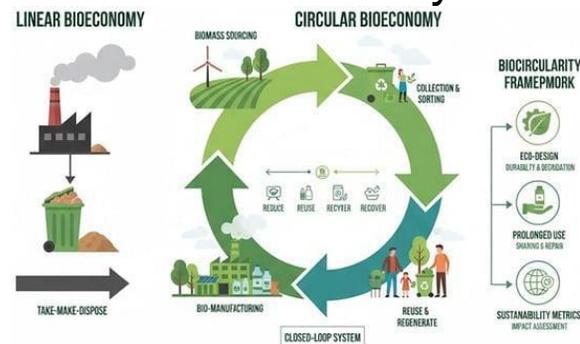


Fig 1: Circular economy model
Courtesy: MDPI open access journal

The circular bioeconomy represents a transformative approach that shifts away from the traditional linear model of extraction, consumption, and disposal. Instead, it promotes a continuous reuse, recycling, and regeneration of biological resources to create long-term environmental and economic value. This shift is essential in addressing global challenges such as resource depletion, pollution, and climate change.

Unlike conventional industrial systems that often generate large amounts of waste, a circular bioeconomy focuses on

closing material loops by utilizing renewable biological resources. It encourages the conversion of biological waste into valuable products, reducing dependence on non-renewable resources and minimizing environmental impact. By combining biological processes with industrial practices, the circular bioeconomy supports responsible resource use, reduces waste generation, and cleaner production methods. As a result, it plays a key role in shaping sustainable and future-ready industrial systems.

Industrial Biotechnology as A Key Driver of Circular Bioeconomy

Industrial biotechnology supports the circular bioeconomy by using microorganisms, enzymes, and biological processes to develop sustainable industrial solutions. Instead of resource-intensive chemical methods, it enables efficient conversion of renewable biological materials into valuable products while minimizing waste and environmental impact. By promoting resource efficiency, cleaner production methods, industrial biotechnology strengthens the transition from linear to circular systems.

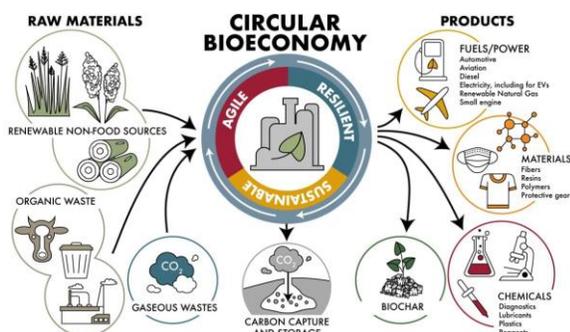


Fig 2 : Applications of industrial biotechnology in a circular bioeconomy, including food, energy, materials, and chemical production. Courtesy: American society for microbiology (ASM)

A) Microbial and Enzyme-Based Production Systems

Microbial and enzyme-based production systems form an essential part of industrial biotechnology within a circular bioeconomy. Microorganisms such as bacteria, fungi, and yeast act as biological factories that convert renewable raw materials into valuable products like enzymes, organic acids, and bio-based compounds. These systems require fewer chemical inputs and operate under controlled conditions, making them environmentally friendly.

Advancements in microbial strain improvement have significantly enhanced production efficiency. Yeast strains such as *Saccharomyces cerevisiae* are widely used in fermentation industries and have been optimized to produce higher yields. Similarly, *Escherichia coli* is commonly used as host organisms for producing industrial enzymes and biomolecules. These improvements help industries achieve higher productivity while reducing waste and resource consumption.

B) Sustainable Food and Fermentation Technologies

Sustainable food and fermentation technologies play an important role in supporting a circular bioeconomy by promoting efficient food production while minimizing environmental impact. Fermentation is traditional biotechnological processes, where microorganisms transform raw materials into valuable food products such as yogurt, cheese, bread, and fermented beverages. These processes enhance food quality and shelf life while reducing the need for chemical preservatives.

With advancements in biotechnology, fermentation processes have become more efficient and sustainable. Improved microbial strains allow better utilization of raw materials and reduced food waste. Lactic acid bacteria are widely used to improve nutritional value and food safety, supporting sustainable production practices aligned with circular bioeconomy principles.

C) Eco-friendly Textile and Material Processing

The textile industry contributes significantly to environmental pollution due to high water, chemicals and energy usage. Industrial biotechnology provides sustainable alternatives by replacing harmful chemical treatments with enzyme-based and microbial processes. Enzymes such as cellulases, proteases, and lipases are used to improve efficiency while minimizing waste and pollution.

A major example is enzymatic biostoning in denim processing, which replaces traditional stone-washing methods and reduces toxic wastewater. Biotechnology has also enabled the development of artificial or lab-grown leather using microbial or plant-based sources, reducing dependence on animal-derived materials and toxic tanning chemicals. These innovations highlight how biotechnological approaches support eco-friendly material production.

D) Biotechnology in Healthcare and Vaccines

Biotechnology plays a crucial role in healthcare by enabling safe and efficient production of medicines and vaccines. Microorganisms such as bacteria and yeast are used as biological factories to

produce essential medical products in a controlled and sustainable manner.

A well-known example is the production of the hepatitis B vaccine using genetically modified *Saccharomyces cerevisiae*. The yeast produces the hepatitis B surface antigen, which is purified and used in vaccine formulation. This method allows large-scale production with minimal environmental impact while supporting circular bioeconomy principles.

Challenges and Ethical Considerations

Despite its benefits, industrial biotechnology faces challenges such as high initial investment costs, the need for skilled expertise, and strict regulatory requirements. The use of genetically modified organisms also raises ethical concerns related to biosafety, environmental impact, and public acceptance.

These challenges can be addressed through responsible innovation, strong regulatory frameworks, and public awareness. Continuous research and ethical practices are essential to ensure safe and sustainable implementation of industrial biotechnology.

Future Prospects

The future of industrial biotechnology within a circular bioeconomy is promising. Continued technological advancements can further reduce waste, improve resource efficiency, and promote sustainable industrial practices. Increased awareness and support for sustainability are expected to strengthen the role of biotechnology in future industrial systems.

Conclusion

Industrial biotechnology plays a vital role in advancing a circular bioeconomy by promoting sustainable use of biological resources. Through microbial systems, enzyme-based processes, and innovative approaches, industries can reduce waste, conserve resources, and minimize environmental impact.

By integrating innovation with sustainability, industrial biotechnology offers practical solutions to modern industrial and environmental challenges. With continued research and ethical implementation, it holds strong potential for shaping a more sustainable future.

“Innovation is the ability to see change as an opportunity, not a threat.”

— **Steve Jobs**

References

- OECD. (2009). *The Bioeconomy to 2030: Designing a Policy Agenda*.
https://www.oecd.org/content/dam/oecd/en/publications/reports/2009/04/the-bioeconomy-to-2030_g1ghao7e/9789264056886-en.pdf
- Nielsen, J., & Keasling, J. D. (2016). *Engineering cellular metabolism*. *Cell*, 164(6), 1185–1197.
<https://www.sciencedirect.com/science/article/pii/S0092867416300708>
- Cavaco-Paulo, A. (1998). *Mechanism of cellulase action in denim finishing*. *Carbohydrate Polymers*, 37(3), 273–277.
<https://www.sciencedirect.com/science/article/abs/pii/S0144861798000708>
- Leroy, F., & De Vuyst, L. (2004). *Lactic acid bacteria as functional starter cultures for the food fermentation industry*. *Trends in Food Science & Technology*, 15(2), 67–78.
<https://www.sciencedirect.com/science/article/pii/S0924646004000708>
- Hilleman, M. R., McAleer, W. J., Buynak, E. B., & McLean, A. A. (1984). *Human hepatitis B virus vaccine prepared by recombinant DNA technology in yeast*. *Journal of Infectious Diseases*, 150(5), 610–614.
<https://pubmed.ncbi.nlm.nih.gov/631812>

The Circular Bioeconomy: Bridging Nature, Technology, and Prosperity

Author: Dhriti Brahmaniya

Semester 2, First Year

Department of Biotechnology

Abstract

As climate change, biodiversity loss, and resource scarcity intensify, the limitations of the linear economic model have become increasingly evident. The circular bioeconomy has emerged as a transformative framework that integrates renewable biological resources with principles of circularity to align economic development with ecological integrity. Moving beyond incremental efficiency improvements, it emphasizes system integration, resilience, and regeneration across food, material, and energy systems. This article examines the conceptual foundations of the circular bioeconomy, highlighting the role of biomass, multisectoral integration, and technological innovation in enabling sustainable transitions. Particular attention is given to forests as providers of renewable materials and ecosystem services, alongside the economic opportunities and equity challenges associated with bio-based development pathways.

Keywords: Circular bioeconomy; sustainability transitions; biomass; forests; regenerative development

1. Introduction

The accelerating crises of climate change, biodiversity loss, and resource depletion have exposed the fragility of the linear economic paradigm that has dominated industrial development for over a century. Built on extraction, consumption, and disposal, this model has generated material growth while eroding ecological stability and long-term resilience. In response, policymakers, researchers, and industries are increasingly turning toward an alternative framework: the circular bioeconomy.

At its core, the circular bioeconomy integrates renewable biological resources with circularity principles to sustain economic activity within planetary boundaries. Rather than focusing solely on reducing environmental harm, it proposes a systemic transformation of production and consumption patterns that prioritizes regeneration, adaptability, and long-term societal well-being.

2. From Linear Throughput to Circular Systems

The circular bioeconomy encompasses sectors reliant on biological resources, including agriculture, forestry, fisheries,

aquaculture, bio-based industries, and organic waste management. Its central objective is to retain biomass and bio-based materials at their highest functional value for as long as possible through cascading use, recycling, and recovery.

Unlike mineral resources, biomass is biodegradable, multifunctional, and time-sensitive. It simultaneously provides food, energy, materials, and cultural value, necessitating planning approaches that transcend traditional sectoral boundaries. Food, materials, energy, and waste streams must therefore be understood as interconnected systems rather than isolated domains optimized independently.

3. Technology as an Enabler

Technological innovation is fundamental to operationalizing the circular bioeconomy. Advanced biorefineries, integrated bioenergy systems, and flexible biomass conversion technologies enable diverse biological inputs to be transformed into multiple outputs, including food products, fuels, materials, and bio-based chemicals.

These technologies signal a shift away from narrow substitution strategies toward broader considerations of system flexibility and reliability. Long-term sustainability depends not only on efficiency gains, but also on rethinking consumption patterns and designing adaptive systems capable of responding

to environmental and economic uncertainty.

4. Forests and the Bioeconomic Transition

Forests occupy a pivotal position within the circular bioeconomy as the primary source of non-food renewable biological materials. They supply timber, fibers, and bio-based inputs capable of substituting carbon-intensive materials such as steel, cement, and synthetic textiles, resulting in substantial reductions in lifecycle greenhouse gas emissions.

Beyond material substitution, forests provide essential ecosystem services, including carbon sequestration, biodiversity conservation, and water regulation. Forest-based bioeconomy pathways are inherently context-specific. While industrialized regions often emphasize high-value engineered wood products, developing regions increasingly adopt decentralized solutions that convert agricultural and forest residues into energy or construction materials, supporting livelihoods while reducing environmental pressures.

5. Economic Potential and Equity

The circular bioeconomy is widely recognized as a driver of economic growth, innovation, and employment across multiple sectors. By improving resource efficiency and reducing dependence on fossil-based inputs, it can

enhance economic resilience and competitiveness.

However, without inclusive governance frameworks, bioeconomic development risks reinforcing existing inequalities. Issues related to land tenure, access to resources, and uneven distribution of benefits are particularly pronounced in developing regions. A socially just circular bioeconomy must therefore be grounded in transparency, participatory decision-making, and respect for local and Indigenous knowledge systems.

6. Urban Systems and Circular Futures

As global urbanization accelerates, cities will play a decisive role in shaping circular bioeconomy trajectories. Urban centers concentrate consumption and organic waste generation, creating opportunities for circular interventions such as urban agriculture, organic waste valorization, and bio-based construction materials.

Effective implementation requires integrated rural–urban planning and coherent policy frameworks. Collaboration among governments, research institutions, industry, and civil society is essential to scale circular bioeconomy solutions beyond isolated initiatives.

7. Conclusion

The circular bioeconomy represents a shift from extractive growth toward regenerative development. By embedding ecological processes within economic systems and prioritizing integration, resilience, and equity, it offers a viable pathway for addressing interconnected environmental and social challenges. Its success will depend not only on technological innovation, but also on collective willingness to redefine prosperity in alignment with planetary boundaries.

References

- Schipfer, F., Burli, P., Fritsche, U., Hennig, C., Stricker, F., Wirth, M., Proskurina, S., & Serna-Loaiza, S. (2024). The circular bioeconomy: A driver for system integration. Energy, Sustainability and Society, 14, 34.*
- CIFOR–ICRAF. (2023). Knowledge guide: The circular bioeconomy. Center for International Forestry Research and World Agroforestry.*
- Palahí, M., & Adams, J. (2020). Why the world needs a circular bioeconomy—for jobs, biodiversity and prosperity. World Economic Forum.*
- Raworth, K. (2017). Doughnut economics: Seven ways to think like a 21st-century economist. Random House.*

Closing the loop: Future of a circular bioeconomy

Author: *Malvi Devangi Sureshbhai, Vora Riddhi Shrenikkumar*
Semester 2, First Year
Department of Biotechnology

Introduction:

Everything has a deadline and expires with the increasing demands of society. Similarly, this linear economic model of take, make and break I.e dispose is no more sustainable in accordance with the great growing population.

In response to the extensive resource extraction which has made the natural resources increasingly limited, the circular bioeconomy- heroic savior of humanity serves to be an innovative and sustainably driven alternative to it.

Key Component

1. **Nature:** It is the primary source of the circular bio economy. It provides perfect biomass for example corn, sugarcane, soy etc. replaces oil while mycelium (fungi) is used in biodegradable packaging that replace Styrofoam. A natural process acts as a technical toolkit that transforms material via biological pathways for example photosynthesis, microbial action, bio mimicry etc.

2. **Renewable energy:** In a circular bio economy, renewable energy is like an engine that makes circularity possible. The two systems share a symbiotic relationship, renewable energy runs the factories of the bio economy, and the bio economy produces the fuels that keep our energy systems running when darkness limits direct sunlight. Here, value is added to residual waste that transforms into energy.

3. **Bio product:** Acts as link between ecological regeneration and manufacturing frameworks. For Example, producing biopolymers from corn starch to create compostable food packaging ensures that the "waste" from an industrial product can return to the soil as nutrients, completing a full biological loop. Bio products that play a crucial role in the circular bio economy are bio plastic, biochemical, bio textile, bioenergy etc.

4. **Society:** This economic framework improves societal well-being by creating eco-friendly employment opportunities, minimizing pollution, and enhancing health conditions.

5. **Ecosystem services:** Ecosystem services refer to the benefits provided by essential natural assets.

Interaction and Flows

Biomass and bioprocessing

This approach focuses on converting organic waste into useful products through biological processes such as bioenergy, biofuels, and bio products. Biodegradable waste becomes a valuable input instead of a harmful output.

Circularity:

1) **Reduce–Reuse–Recycle:** Minimizing resource use, extending product life, and recovering materials to reduce waste.

E.g.: - Using a cloth bag instead of plastic reduces waste. Reusing glass bottles for storage extends their life. Recycling aluminum cans turns waste into new products using less energy.

2) **Cascading use of biomass:** Using biomass sequentially for multiple purposes before final energy recovery.

E.g.: - Wood is first used to make furniture. Later, the leftover wood is used to make paper. Finally, the waste is used to produce energy through burning or biogas.

3) **Eco–design:** Designing products to be durable, repairable, recyclable, and resource-efficient.

E.g.: - A mobile phone designed with replaceable batteries and recyclable parts lasts longer and creates less electronic waste.

4) **Society at the center:** Circular systems prioritize social well-being, equity, and community participation.

E.g.: - Community-based waste segregation programs create local jobs, improve public health, and involve citizens in sustainable practices.

Ecosystem Services:

1) **Provisioning services:** Ecosystems provide tangible goods like food, water, fuel, and raw materials.

E.g.: - Forests provide timber, rivers supply fresh water, and farms produce food crops like wheat and rice.

2) **Regulating services:** Natural processes regulate climate, floods, diseases, and water quality.

E.g.: - Mangrove forests protect coastal areas by reducing flood damage, while trees help regulate climate by absorbing carbon dioxide.

3) **Cultural services:** Ecosystems offer non-material benefits such as recreation, aesthetics, spirituality, and education.

E.g.: - National parks offer spaces for recreation and tourism, while sacred forests provide spiritual and cultural value to local communities.

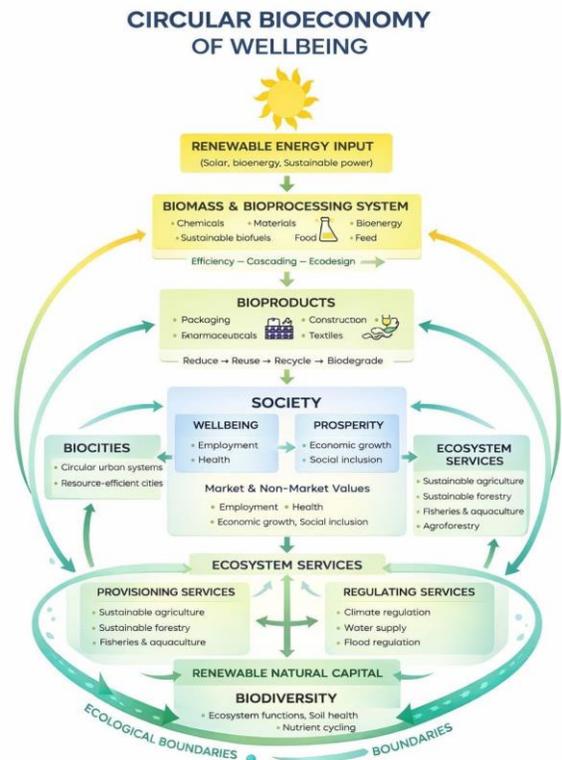


Figure: Workflow diagram representing the circular bioeconomy of wellbeing

Courtesy: Generated by AI

References

1. D'Amato, D., Droste, N., Allen, B., Kettunen, M., L\"{a}htinen, K., Korhonen, J., ... Toppinen, A. (2017).

Green, circular, bio economy: A comparative analysis of sustainability avenues.

Journal of Cleaner Production, 168, 716–734.

<https://doi.org/10.1016/j.jclepro.2017.09.053>

2. European Commission. (2018).

A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment.

<https://commission.europa.eu>

3. Kirchherr, J., Reike, D., & Hekkert, M. (2017).

Conceptualizing the circular economy: An analysis of 114 definitions.

Resources, Conservation and Recycling, 127, 221–232.

<https://doi.org/10.1016/j.resconrec.2017.09.005>

4. United Nations Environment Programme. (2019).

Global resources outlook 2019: Natural resources for the future we want.

<https://www.unep.org>

5. Carus, M., & Dammer, L. (2018).

The circular bioeconomy—Concepts, opportunities, and limitations.

Industrial Biotechnology, 14(2), 83–91.

<https://doi.org/10.1089/ind.2018.29121.mca>

Sustainable Mining: Balancing Development and The Environment

*Author: Hitarth Damor, Diya Shah
Semester 4, Second Year
Department of Biotechnology*

Introduction

From smartphones and electric vehicles to renewable energy infrastructure, modern life depends heavily on minerals extracted from the Earth. Mining has long been the backbone of industrial development, supplying essential raw materials for energy production, construction, and technological advancement. However, conventional mining practices have also contributed to severe environmental degradation, ecological imbalance, and social displacement. In response to these growing concerns, sustainable mining has emerged as a responsible approach that seeks to balance economic development with environmental protection and social well-being.

What Is Sustainable Mining?

Sustainable mining refers to mining practices that minimize environmental damage, optimize the use of natural resources, and ensure long-term benefits for local communities while remaining economically viable. It goes beyond mineral extraction to encompass responsible land use, waste management, energy efficiency, ethical governance, and post-mining land rehabilitation. By considering the entire mining life cycle, sustainable mining

aims to reduce negative impacts while meeting global resource demands.

Why Sustainable Mining Is Necessary

The need for sustainable mining has become increasingly urgent due to multiple interconnected factors. Traditional mining often results in deforestation, soil erosion, water contamination, and loss of biodiversity, causing long-term ecological harm. At the same time, the global transition toward clean energy technologies—such as electric vehicles, batteries, and solar panels—has sharply increased demand for minerals like lithium, cobalt, and copper.

Social accountability is another critical concern. Mining activities frequently affect indigenous and rural communities, making fair compensation, community participation, and social responsibility essential. Additionally, stricter environmental regulations and sustainability standards imposed by governments and international organizations have made responsible mining practices a necessity rather than a choice.

Key Principles of Sustainable Mining

One of the core principles of sustainable mining is efficient resource utilization. Advanced technologies such as automation, artificial intelligence-driven exploration, and precision mining reduce material waste and improve recovery from low-grade ores.

Another important principle is environmental management, which includes controlled water usage, reduced air emissions, safe tailings storage, and progressive land reclamation after mining operations. These measures help prevent long-term environmental damage.

The integration of renewable energy is also gaining importance. Mining companies are increasingly adopting solar, wind, and hybrid energy systems to reduce dependence on fossil fuels and lower carbon emissions.

Waste reduction and recycling play a crucial role in promoting sustainability. Reprocessing mine waste and recycling metals reduce the need for fresh extraction and support circular economy principles.

Finally, community engagement ensures that local populations benefit from mining activities through employment, healthcare, education, and fair compensation, fostering trust and long-term social sustainability.

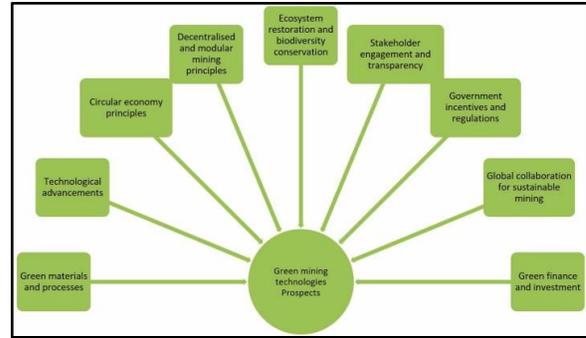


Figure 1. Key components and future prospects of green mining technologies, highlighting the integration of environmental, technological, economic, and governance aspects for sustainable mining.

Courtesy: Adapted from open-access sustainability and mining literature.

Role of Technology in Sustainable Mining

Technological innovation is transforming the mining industry and making sustainability achievable. Bioleaching uses microorganisms, such as extremophile bacteria, to extract metals through natural oxidation processes. This method reduces the need for toxic chemicals and high-temperature smelting and is particularly effective for copper, gold, and nickel recovery from low-grade ores.

Remote sensing and drones equipped with LiDAR and hyperspectral imaging enable low-impact mineral exploration by identifying deposits without disturbing land or biodiversity. These technologies significantly reduce environmental disruption during the exploration phase.

Digital twins, created using IoT sensors and real-time data, allow virtual simulation of mining operations. They help predict equipment stress, optimize

ventilation, enhance worker safety, and improve operational efficiency.

Another promising innovation is carbon capture and storage (CCS) through mineral carbonation, where carbon dioxide is permanently locked into mine tailings. This approach supports carbon-neutral or even carbon-negative mining operations.

Sustainable Mining in India

India is actively modernizing its mining sector through policy reforms and technological adoption. The Star Rating System for Mines ranks mining operations based on environmental, social, and operational performance, encouraging responsible practices. Stricter environmental clearance norms and periodic field verification ensure continuous compliance.

Mandatory mine closure and reclamation plans treat mining as a temporary land use, requiring ecological restoration after resource extraction ends. Additionally, policies promoting responsible sourcing and zero-waste mining align India's mining sector with global sustainability and safety standards.

Challenges Ahead

Despite its benefits, sustainable mining faces several challenges. High initial investment costs for green technologies can discourage small and medium-scale operators. Technological gaps and a lack of skilled manpower remain obstacles in developing regions. Weak law enforcement and limited monitoring capacity often result in regulatory non-compliance, particularly in remote mining areas. Illegal mining continues to

cause environmental damage while undermining responsible mining efforts.

The Road Ahead

The future of mining lies in innovation, transparency, and collaboration. Emerging technologies such as blockchain-based mineral traceability can ensure ethical sourcing, while stronger governance frameworks and active community participation will support long-term sustainability. Collective efforts from governments, industries, and local communities are essential to transform mining into a more responsible sector.

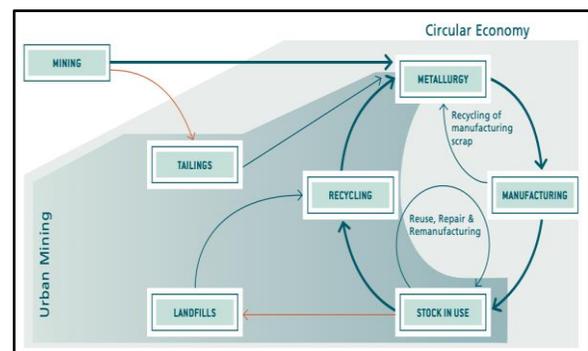


Figure 2. Circular economy framework in mining illustrating material flow from extraction to manufacturing, reuse, recycling, and reduced landfill dependency through urban mining practices.

Courtesy: Adapted from open-access circular economy literature.

Conclusion

Sustainable mining represents a paradigm shift—from exploiting the Earth to coexisting with it responsibly. By integrating eco-friendly technologies, ethical governance, and social inclusion, mining can evolve from an environmental burden into a powerful driver of sustainable development. Embracing sustainable mining today is

essential to protect natural ecosystems while securing resources for future generations.

References

Azapagic, A. (2004). Developing a framework for sustainable development indicators for the mining and minerals industry. *Journal of Cleaner Production*, 12(6), 639–662. [https://doi.org/10.1016/S0959-6526\(03\)00075-1](https://doi.org/10.1016/S0959-6526(03)00075-1)

International Council on Mining and Metals (ICMM). (2020). *Integrated mine closure:*

Good practice guide.
<https://www.icmm.com/en-gb/guidance/environmental-stewardship/integrated-mine-closure>

Lottermoser, B. G. (2010). *Mine wastes: Characterization, treatment and environmental impacts* (3rd ed.). Springer. <https://doi.org/10.1007/978-3-642-12419-8>

Ministry of Mines, Government of India. (2023). *Star rating of mines and sustainable mining practices.* <https://www.mines.gov.in>

Reimagining Mining for a Sustainable Future: Turning Waste into Opportunity

*Author: Himani Thakkar
Semester 4, Second Year
Department of Biotechnology*

Introduction

Mining is indispensable to modern society. From the minerals that power renewable energy systems to the metals used in electronics and infrastructure, mining supports nearly every aspect of contemporary life. Yet, despite its importance, mining has traditionally been associated with extensive environmental damage. Land degradation, massive waste generation, contamination of soil and water, and high carbon emissions have raised serious concerns about the long-term sustainability of this industry.

As global demand for minerals continues to rise—especially driven by green technologies—the mining sector faces growing pressure to evolve. Sustainable mining has therefore emerged as a forward-looking approach that seeks to meet present needs without compromising environmental and social well-being. Rather than viewing mining waste and degraded land as inevitable outcomes, recent research highlights how circular economy concepts, technological innovation, and nature-based solutions can transform mining into a more responsible and regenerative activity.

Moving Beyond the Linear Mining Model

Conventional mining follows a linear pathway: resources are extracted, processed, used, and ultimately discarded as waste. This model results in the accumulation of enormous quantities of tailings and residues, often stored in landfills or tailings dams that pose long-term environmental risks.

Sustainable mining challenges this approach by adopting circular economy principles, where waste materials are reintegrated into productive use. In this system, mining residues are no longer considered useless by-products but potential resources that can be reused, recycled, or repurposed. This shift not only reduces environmental stress but also improves overall resource efficiency and economic resilience within the mining sector.

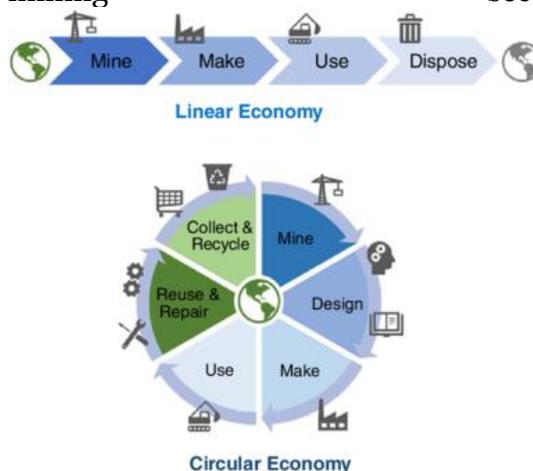




Figure 1: Diagram comparing traditional linear mining with circular mining. (extract–reuse–recycle–restore).

Courtesy: ResearchGate

Mining Waste as a Resource, Not a Liability

One of the most impactful ideas in sustainable mining is the valorization of mining waste. Mining operations generate vast amounts of waste materials that often contain residual minerals or chemically reactive components. When left unmanaged, these wastes can contaminate surrounding ecosystems. However, research demonstrates that with appropriate treatment, mining by-products can be transformed into useful materials.

Alkaline mineral wastes, for instance, can be used to improve degraded soils. When combined with organic matter such as compost, these materials help neutralize soil acidity, reduce the mobility of heavy metals, and enhance soil fertility. This approach simultaneously addresses two challenges: reducing waste accumulation and restoring damaged land. Such practices align closely with zero-waste

strategies and significantly lower the environmental footprint of mining activities.

Nature-Based Solutions for Land and Soil Restoration

Post-mining landscapes often struggle to recover naturally due to poor soil quality and contamination by toxic elements. Nature-based solutions (NBS) provide a sustainable alternative to conventional remediation techniques, which are often expensive and energy-intensive.

One effective NBS is phytoremediation, a process that uses plants to stabilize or immobilize contaminants in soil. Research shows that certain plant species can tolerate metal-contaminated soils and prevent pollutants from spreading further. When phytoremediation is combined with mineral and organic soil amendments derived from mining waste, the results are particularly promising. Improved soil structure, enhanced plant growth, and reduced metal bioavailability contribute to long-term ecosystem recovery.

Importantly, these methods allow land restoration to occur progressively during mining operations, rather than being postponed until closure, thereby reducing long-term environmental risk



Figure 2: Illustration of vegetation growth on reclaimed mining land using soil amendments.

Courtesy: Miu et al., Sustainability (MDPI)

Reducing Environmental and Carbon Impacts

Mining is a major consumer of energy and water, making it a significant contributor to greenhouse gas emissions. Sustainable mining strategies aim to reduce these impacts through process optimization and material reuse. Circular use of mining waste decreases the need for extracting fresh raw materials, which in turn reduces energy consumption and emissions.

Additionally, integrating renewable energy sources, improving process efficiency, and adopting cleaner technologies help lower the carbon intensity of mining operations. Together, these measures support global climate goals while making mining operations more environmentally responsible.

Role of Innovation, Policy, and Education

The transition to sustainable mining requires coordinated efforts across multiple sectors. Academic institutions play a crucial role in developing and testing innovative technologies, while governments provide regulatory frameworks and incentives that encourage sustainable practices. Collaboration between researchers, industry professionals, policymakers, and local communities is essential to ensure that solutions are both practical and socially acceptable.

Equally important is education and skill development. Implementing sustainable mining practices demands professionals who understand environmental science, circular economy principles, and modern technologies. Building this knowledge base is key to ensuring long-term success.

Conclusion

Sustainable mining represents a necessary evolution of an industry that is vital yet environmentally demanding. By rethinking waste as a resource, applying nature-based solutions, and embracing circular economy principles, mining can shift from being purely extractive to actively restorative.

The growing body of research demonstrates that environmentally responsible mining is not only achievable but also beneficial from an economic and social perspective. As the world moves toward sustainable development, mining must play its part by adopting practices that protect ecosystems, conserve resources, and support future generations.

References

1. Restrepo Baena, O. J. (2024). Exploring sustainable pathways in mining through circular economy practices. *Materials Science Research India*, 21(2), 72–73.
2. Salgado, L., Martínez, P., Gómez, R., & Silva, A. (2024). Valorization of mining waste for soil restoration and remediation. *Journal of Material Cycles and Waste Management*, 26, 2971–2979.
3. European Commission. (2014). *Towards a circular economy: A zero waste programme for Europ*

Biotechnological Approaches for Sustainable Mining: An Eco-friendly Perspective

Author: Vishwa Barot

Semester 2, First Year

Department of biotechnology

Introduction

Mining plays a crucial role in providing essential minerals and metals required for industrial growth and everyday applications. As industries and communities rely heavily on these resources, the need for responsible and sustainable practices has become increasingly important. In recent years, sustainable mining has gained attention as a solution that balances resource extraction with environmental protection, ensuring that mining can meet industrial demands without compromising the health of ecosystems and communities.

Conventional mining methods, however, often lead to severe environmental problems such as land degradation, water pollution, acid mine drainage, and loss of biodiversity, posing serious health risks to nearby populations. To address these challenges, biotechnology offers innovative and eco-friendly approaches that can reduce the negative impacts of mining activities and make sustainable resource extraction feasible and effective.

Why Traditional Mining Needs Change

Traditional mining methods involve extensive excavation and the use of chemical reagents, which result in large amounts of waste generation. One of the major concerns is acid mine drainage,

caused by the oxidation of sulfide minerals, leading to acidic water rich in heavy metals. This contaminated water can enter nearby rivers and soil systems, affecting aquatic life and agriculture. Additionally, deforestation and habitat destruction caused by mining disrupt ecological balance. These challenges highlight the urgent need for sustainable and environmentally responsible mining practices.

Role of Biotechnology in Sustainable Mining

1. Bioleaching

Biotechnology plays an important role in sustainable mining through bioleaching, a process that uses microorganisms such as *Acidithiobacillus ferrooxidans* to extract metals from low-grade ores. Unlike conventional mining methods that require high energy input and harsh chemicals, bioleaching is an eco-friendly and cost-effective alternative. It reduces energy consumption and minimizes environmental pollution while allowing efficient recovery of metals like copper, gold, and uranium.

2. Bioremediation of Mining Sites

Mining activities often generate toxic waste, including heavy metals and acid mine drainage. Bioremediation uses bacteria, fungi, and algae to detoxify polluted soil and water around mining areas. These microorganisms convert harmful

substances into less toxic or stable forms, helping restore contaminated ecosystems. This approach supports environmental sustainability and reduces long-term ecological damage caused by mining operations.

3. Treatment of Acid Mine Drainage (AMD)

Acid mine drainage is one of the most serious environmental problems associated with mining. Biotechnology helps manage AMD through sulfate-reducing bacteria, which neutralize acidity and precipitate heavy metals from wastewater. This biological treatment method is more sustainable than chemical neutralization and helps protect nearby water bodies and communities.

4. Use of Microorganisms for Metal Recovery from Waste

Biotechnology also enables recovery of valuable metals from mine tailings and industrial waste, supporting the concept of resource efficiency. Microbial processes help recycle metals that would otherwise be lost, reducing the need for new mining activities. This approach contributes to waste minimization and supports sustainable resource management.

5. Reduction of Environmental Footprint

By replacing energy-intensive and chemically aggressive mining techniques, biotechnological methods significantly reduce greenhouse gas emissions, water usage, and land degradation. Thus, biotechnology supports mining practices that are environmentally responsible and socially acceptable, aligning with global sustainability goals.

Advantages of Biotechnological Sustainable Mining

Implementing biotechnology in mining provides several important benefits. It helps preserve natural ecosystems by limiting land disruption and preventing chemical contamination of soil and water. Communities near mining sites experience better health outcomes due to reduced exposure to harmful substances. Efficient use of low-grade ores and mining waste reduces material loss, conserving valuable resources. Moreover, combining microbial processes with renewable energy and recycling initiatives promotes environmentally responsible operations while contributing to global sustainability targets, such as clean water, climate action, and responsible consumption.

Challenges and Future Prospects

Despite its benefits, biotechnological mining faces several challenges. Microbial processes can be slow and their efficiency is affected by environmental factors such as temperature, pH, and pollutant concentrations. The initial implementation cost of biotechnological methods is higher compared to conventional techniques, and large-scale operations require continuous monitoring and maintenance to maintain optimal conditions. Additionally, the use of genetically modified microorganisms demands strict regulatory compliance and environmental safety assessment.

However, these challenges can be effectively addressed. Microbial efficiency can be enhanced through genetic engineering and process optimization, while environmental sensitivity can be managed using controlled bioreactors and continuous monitoring systems. High initial costs are offset by long-term savings in energy and resource efficiency, and large-scale operations can be streamlined with automated monitoring and management systems, ensuring both feasibility and sustainability.

Looking forward, advances in genetic engineering, metagenomics, and process optimization are expected to further improve microbial efficiency and scalability in mining operations. Integrating biotechnology with renewable energy, automated monitoring systems, and circular resource management promises a future where mining is not only resource-efficient and eco-friendly but also socially responsible, contributing positively to both economic growth and environmental protection.

Conclusion

The future of mining lies in harmonizing industrial growth with environmental stewardship, and biotechnology provides the blueprint for this transformation. By leveraging innovative microbial and bio-

based strategies, the sector can maximize resource efficiency, reduce ecological footprint, and foster social responsibility. Combining these approaches with renewable energy, waste recycling, and smart monitoring not only safeguards natural ecosystems but also drives long-term economic resilience and global sustainability. Embracing biotechnological sustainable mining today ensures a legacy where progress and planet coexist, setting a benchmark for responsible industrial development worldwide.

References

- Johnson, D. B. (2014). Biomining – biotechnologies for extracting and recovering metals from ores and waste materials. *Current Opinion in Biotechnology*, 30, 24–31.
- Rawlings, D. E. (2002). Heavy metal mining using microbes. *Annual Review of Microbiology*, 56, 65–91
- Akcil, A., & Koldas, S. (2006). Acid mine drainage (AMD): causes, treatment and case studies. *Journal of Cleaner Production*, 14(12–13), 1139–1145. International Council on Mining and Metals (ICMM).
- United Nations Environment Programme (UNEP). Environmental management of mining operations.

From Quantum Biology to Physics: The New Era of Sustainable Mining!

*Author: Shaikh Masuma Mohammed Yunus.
BSc First Year Student,
Department of Biochemistry.*

*Co-author: Bhakhar Freya Nilesh.
BSc First Year Student,
Department of Physics*

Introduction.

Mining is the process of extracting valuable minerals, metals and other geochemical materials from Earth's crust. These natural resources are essential building blocks of modern civilization. Mining provides raw material for construction, technology, energy, healthcare and daily life. Despite its requisite, mining has many negative impacts on environment, human health, biodiversity and causes pollution and deforestation. As we cannot stop mining, we need to make it sustainable by using low impact techniques like in-situ leaching, implementing closed loop water systems and practising land rehabilitation once the mine closes. Along with these methods, Science is unveiling new ways to make mining more sustainable. One of the most remarkable and rarely discussed is 'Quantum Biology', a field that shows how nature uses quantum principles to achieve outstanding productivity and durability.

Beyond the Drill: From Sub-atomic to Sustainable. (A Q&A on How Quantum Biology is Redefining Mining)

What is Quantum Science?

It is the study of matter and energy at atomic and subatomic levels where laws of classical physics do not apply and matter behaves as both wave and particle, allowing phenomena like superposition, entanglement and quantum tunneling that defy our everyday logic.

What is Quantum Biology?

It is a modern field of research that studies how quantum effects can affect the chemical and biological processes in living systems.

Principles.

1. Superposition - particles exist in several states at once.
2. Tunneling - subatomic particles can pass through physical barriers.

3. Coherence - energy waves must be synchronized for effective transfer.
4. Entanglement - transfer of information takes place between interconnected particles.

How can this help in Sustainable Mining?

1. Quantum based sensors can help in finding ore deposits causing less harm to the environment.
2. Catalysts based on enzyme tunneling can reduce toxic chemical use in ore extraction.

Real-Life Proof.

To reduce both drilling and environmental harm, Fleet Space produced its Quantum Sensors for mineral exploitation in 2025 which can find ore deposits with extreme accuracy.

Biochemical Techniques for Sustainable Mining.

Biochemistry is notably impacting mining by replacing toxic chemicals with biological systems. The integration of biochemistry, biotechnology, microbiology and chemistry leads to successful resource management and environmental restoration. This molecular level innovation is proving that we can solve toughest industrial challenges by amalgamating different fields of Science .

Table: Key Biochemical Techniques for Sustainable Mining.

Technique.	Description.
Bioleaching	Uses microbes to reduce solid metals to liquid, which are then harvested.
Bio-oxidation	Employs microbes to break down unwanted rock layers, exposing valuable metals.
Bioremediation	Utilises microbes to clean and detoxify polluted mining soil and water.
Biosorption	Biological material like algae is used to absorb metals from liquid waste streams.
Phytomining	Genetically modified plants are used to extract minerals from soil.
Bioprecipitation	Microbes are used to transform dissolved metals into solid particles.

The Role of Physics in Sustainable Mining.

Physics is used to make mining sustainable by using principles and techniques from physics to improve sustainability. This involves using geophysical techniques to locate minerals accurately so that less land is disturbed, applying mechanics and rock physics to design mine structures to prevent collapses and protect workers, and applying thermodynamics and electrical physics to design energy-efficient machines and power mining operations with renewable energy. Fluid mechanics is able to conserve water by preventing waste and pollution of water sources. Radiation and particle physics help improve ore sorting technologies to minimize the amount of waste produced. Overall, physics helps with responsible resource extraction, environmental protection, and energy conservation for the future.

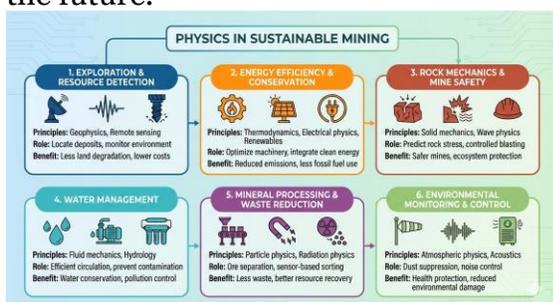


Figure 1. Physics-driven approaches advancing sustainability in mining across exploration, energy, safety, water, processing, and environment. Courtesy - Visual created by Gemini using data and design provided by the author.

Conclusion.

We cannot expect someone else to make mining sustainable. Thus, by integrating different scientific disciplines, we can discover new opportunities for mining as

quantum biology provides sensors and green catalysts, biochemistry and biotechnology help us in making genetically modified microbes and plants and through physics we can create safer, cleaner and smarter methods to make mining sustainable. Therefore the future depends on our willingness to act, because as Robert Swan said :

“ The greatest threat to our planet is the belief that someone else will save it ” - Robert Swan.

References.

1. Roberto, F. F., & Schippers, A. (2022). Progress in bioleaching: Part B, applications of microbial processes by the minerals industries. Applied Microbiology and Biotechnology.
2. Sharma, I. (2022). Bioleaching and biomining: Concept, applications and limitations
3. Nimbrana, S., Ranga, P., & Malik, A. (2023). Bioremediation of mining sites: Sustainable approach to restore a healthy ecosystem. In Heavy Metal Toxicity: Environmental Concerns, Remediation and Opportunities.
4. Alvarez, P. H., Gerhards, L., Solov'yov, I. A., & de Oliveira, M. C. (2024). Quantum phenomena in biological systems. Frontiers in Quantum Science and Technology.
5. Fleet Space. (2025, June 18). Fleet Space builds a quantum innovation pipeline for next-gen mineral exploration.
6. Pavloudakis, F. F., Roumpos, C., & Spanidis, P.-M. (2024). Sustainable mining and processing of mineral resources [Special issue]. Sustainability, 16(19), 8393. MDPI. Martens, E., Prommer, H., Sprocati, R., Sun, J., Dai, X., Crane, R., Jamieson, J., Ortega Tong, P., Rolle, M., & Fourie, A. (2021). Toward a more sustainable mining future with electrokinetic in situ leaching. *Science Advances*

Biofuels from Biowaste: A Sustainable Pathway for Energy Generation

*Author: Pearl Rao
Semester 4, Second year
Department of Biotechnology*

Abstract

The continuous generation of biowaste has made waste management a persistent daily challenge. Traditional waste management strategies mainly involve landfilling and incineration, both of which emit large volumes of greenhouse gases. These emissions significantly contribute to environmental pollution and accelerate global warming. Alongside this issue, rapid industrial development and increasing population levels have resulted in a steadily rising global demand for energy. To ensure sustainable development, it is essential to rely on energy sources that are affordable, clean, and socially acceptable. Hence, access to environmentally friendly and renewable energy sources has become a critical requirement to meet growing energy needs.

Biowaste as a renewable energy source

Biowaste offers a promising solution by serving as a renewable resource for clean energy production through bioenergy technologies. Sustainable energy industries are increasingly focusing on biomass fuels and waste-based resources. Waste-to-energy (WTE) approaches allow the transformation of waste materials into useful forms of

energy such as biogas, bioethanol, biodiesel, bioelectricity, and other bio-based fuels. Various biological processes including anaerobic digestion, fermentation, transesterification, and microbial fuel cells are employed to convert biowaste into energy while supporting sustainable development goals. In addition, several physicochemical conversion techniques such as pyrolysis, gasification, incineration, landfill processing, and hydrothermal carbonization have been developed for biowaste-to-bioenergy conversion. These methods demonstrate strong potential for producing diverse bio-resources efficiently.

Impact of climate change

Climate change and the exhaustion of conventional energy resources pose serious threats to global environmental and economic stability. The sharp rise in population is a major driver behind the depletion of fossil fuel reserves, which in turn is a primary cause of global warming. As population growth continues, daily energy consumption increases accordingly. Elevated concentrations of carbon dioxide (CO₂) in the atmosphere contribute to climate change and simultaneously increase the generation of solid and liquid waste. Utilizing waste materials for energy production while recovering valuable

nutrients supports sustainable development and strengthens economic growth.

Biowaste constitutes a substantial fraction of municipal solid waste and overall solid waste streams. Due to its biodegradable nature, biowaste holds significant promise as a renewable energy source and plays a crucial role in sustainable waste conversion. Numerous waste-generating sources, such as vegetable markets, municipal collection systems, and agricultural activities, produce large quantities of organic waste rich in biodegradable matter, making them suitable feedstocks for bioenergy production.

Energy recovery and value added products from biowaste

Several utilization pathways exist for biowaste, including the production of bio-based fine chemicals and high-value products. These include biofuels such as biomethane and biogas, as well as biocellulose, bioplastics, and other industrial chemicals. Anaerobic and aerobic digestion processes generate solid digestate and compost, which can further be used as soil conditioners. Many countries, including Germany, Canada, the United States, and Brazil, have made significant progress in commercial-scale production of biodiesel and biogas from biological waste. Microbial fuel cells (MFCs) have also emerged as innovative systems capable of producing bioelectricity and bioalcohols from diverse organic wastes, primarily through microbial metabolism and fermentation processes. Most of these applications aim to achieve low-cost energy production with efficient utilization of waste materials.

Economic Feasibility of Waste-to-Energy Technologies

Numerous studies report notable improvements in economic feasibility associated with biowaste-derived energy resources. For example, waste-to-hydrogen technologies based on fermentation and gasification processes have shown the ability to significantly reduce production costs. These techniques enable hydrogen generation from waste materials at approximate costs of 2 USD/g and 2.3 USD/g, respectively. Additionally, recent research by Devasan et al. demonstrated successful biodiesel production using biowaste-derived catalysts. Their study employed a microwave-assisted technique and further optimized the process through kinetic analysis, highlighting its cost-effectiveness and industrial potential.

Waste-to-Energy Technologies and Sustainable Development

This review highlights various energy production pathways, waste-to-energy technologies, and their relevance to sustainable development. Waste generated from diverse human activities poses a serious threat to the sustainable use of natural resources such as air, water, soil, and natural landscapes.

Waste-to-energy technologies enable the conversion of waste materials into different types of fuels that can be utilized for energy supply. Currently, nearly 780 WTE facilities operate worldwide, processing approximately 140 million tons of waste annually. Energy can be recovered from waste

processed into solid fuels, converted into biogas or syngas, or utilized as heat and steam through incineration. Technologies that generate fuels from waste are classified as waste-to-fuel systems. Advanced WTE methods can produce biogas (methane and CO₂), syngas (hydrogen and carbon monoxide), liquid biofuels such as ethanol and biodiesel, and even pure hydrogen, which can subsequently be converted into electricity. WTE technologies are broadly categorized into physical, thermal, and biological methods.

Biomass Potential as a Renewable Energy Source

Biowaste fuel sources include wood, short-rotation woody crops, agricultural residues, herbaceous crops, animal waste, and many other organic materials. Among these, biomass stands out as a highly promising renewable energy option due to its abundant availability and ability to meet future fuel demands. Biomass plays a vital role in both developed and developing nations. In developing countries, biomass accounts for approximately 35% of primary energy consumption, contributing to about 14% of global primary energy use.

Environmental Benefits of Biowaste-Based Fuels

The utilization of biowaste fuels provides considerable environmental advantages. Biomass absorbs CO₂ during its growth phase and releases it during combustion, resulting in a balanced carbon cycle. This characteristic allows biomass to recycle atmospheric CO₂ without increasing greenhouse gas concentrations. As a carbon-neutral fuel, biomass helps reduce overall CO₂ emissions and mitigates the adverse effects of climate change.

REFERENCE

1. Hasan, M. R., Anzar, N., Sharma, P., Malode, S. J., Shetti, N. P., Narang, J., & Kakarla, R. R. (2023). Converting biowaste into sustainable bioenergy through various processes. *Bioresource Technology Reports*, 23, 101542. <https://doi.org/10.1016/j.biteb.2023.101542>
2. Demirbaş, F. M., Balat, M., & Balat, H. (2011). Biowastes-to-biofuels. *Energy Conversion and Management*, 52(4), 1815–1828. <https://doi.org/10.1016/j.enconman.2010.11.030>

India & Bioenergy at its Crossroads

Author: Kavya Patel
Semester 4, 2nd year
Department of Biotechnology

Introduction to need of Energy

Since the dawn of time one law has been ruling & has been ruthless which is “LAW OF ENERGY”, from an ancient ordinary caveman [Homo neanderthalensis] to being the modern coffee slurping human beings [Homo sapiens], we all have been using & dependent on energy or its derivatives directly or indirectly. Prior to that we only used fire, i.e. a form of energy for warmth, or scaring off animals, then for cooking food, & slowly & quite steadily our usage of heat or any form of energy began to expand & we exploited it in ways our ancestors only could imagine doing so. We are popping rockets with liquid Hydrogen & oxygen to space, running motored vehicles, airplanes, generating electricity [by the help of which I'm writing this article :)], cook food, to keep us warm, make nuclear powered weapons & steamers & electricity plants & what not all where energy is being used & is helping us civilize our society, not just on this planet but also to slowly maybe proliferate to multiplanetary system.

Types of Energy

According to the Kardashev scale [made by astrophysicist Nikolai Kardashev in 1964, a hypothetical method to classify civilizations by their energy usage, originally with types I (planetary), II (stellar), and III (galactic)] & looking at the total energy generated by the world at

present, yearly being Around 600+ EJ (Exajoules) of energy which is of course still dominated by fossil fuels (oil, coal, gas) making up over 80% of it. Hence our need for energy is going to be ever increasing but it also must be sustainable, i.e., energy made with use of renewable energy consisting of the following sectors: -

Biomass energy: - A renewable energy that's converted into heat, electricity, or biofuels through burning, fermentation, or decomposition.

Wind energy: - Onshore & offshore turbines using winds kinetic energy to generate electricity.

Solar energy: - Usage of Photovoltaic panels to harness sunlight & generate electricity.

Hydropower energy: - A method to generate power by using the movement of flowing water at dams.

Ocean energy: - A method to utilize tidal energy [the movement of waves].

Green hydrogen: - Produced by using renewable electricity to split water [H₂O] into hydrogen and oxygen through electrolysis, being used as clean fuel.

*Nuclear energy isn't a renewable energy source which many of you think it might be, as the Uranium isotope U-235 is mined & is a finite fuel.

Indian POV on Energy

Modern India faces two major problems, which is air pollution & energy crisis both. On one side each year Delhi, Punjab ,north Uttar Pradesh , Himachal Pradesh & some parts of Jammu choke due to air pollution caused by stubble burning [practice of setting fire to leftover crop stalks (stubble) after harvesting grains like rice or wheat] & on the other hand we face power cuts & coal price surges which is used for running the greenhouse gas producing thermal power plants which use coal/non-renewable source of energy to produce electricity. This is not only an environmental issue but also a commercial issue from an economic standpoint of view.

The solution to this decades long standing problem is what literally personifies the idiom “Robin Hood”, i.e., hitting one arrow with another in the bullseye. Well, India is not newer to the concept of biogas plants or also known more often “Gobar-gas plants”. It was a scheme which gave farmers subsidies to build a biogas/Gobar-gas plants in their small communities, where the cattle’s dung is easily available & instead of waste or directly burning it which produces greenhouse gases it was thrown into a digester tank where the influent produces gases like Methane (CH₄) (55-60%) and Carbon Dioxide (CO₂) (35-40%), which was highly useful for fueling their daily requirements for cooking food, & in this way they not only got rid of never-ending cow-dung but also had a clean burning fuel with just a onetime fixed cost of building a biogas/gobar-gas plant.

The Modern Stand of Bioenergy

Well fellow readers, this was a story belonging to the past India where the energy requirements were less & there were few handful cars & not many homes which could afford or needed electricity , but today’s India with the mega factories & concretes city jungles where energy needed indifferent forms is the essential requirement by any citizen makes the past small-scale biogas plants quite insufficient even for the farmers who mainly used it. & with the Sustainable development goals the need for sustainable bioenergy is the requirement which can’t be ignored. Where comes the hero of our story, which is, “The Bioethanol”.

Bioethanol is produced by simple fermentation of sugars derived from wheat, corn, sugarcane, molasses & any sugar or starch sources that alcoholic beverages can be made from. Already with government incentives, subsidies, policies like BioE3, Initiatives the public & industry has shaken hands together & the usage of E20 [20% ethanol blended fuel] has picked up its momentum & several companies have gone in profit, farmers our happy & of course the amount of fossil fuel less consumed adds to the advantage of pumping less greenhouse gases into the atmosphere making probably the pollution crises & energy crises both fatal in the future.

Conclusion

If we favor only nature, we will make a fragile & weak economy; if we favor only the industries, civilization, & neglect nature then it will affect our health if not today than tomorrow. Hence it is necessary & the need of hour that we start

minding the “nature’s policy” too & achieve a sustainable growth.

References

Harnessing Artificial Intelligence for Sustainable Bioenergy: Revolutionizing Optimization, Waste Reduction, and Environmental Sustainability

Author links open overlay panelK. Anbarasu a, S. Thanigaivel b, K. Sathishkumar c,

Mohammed Mujahid Alam d, Abdullah G. Al-Sehemi d, Yuvarajan Devarajan

Book: -

Bioenergy research: advances & applications edited by Vijay K. Gupta , Maria G. Tuohy , Christian P. Kubicek, Jack Sedler, Feng Xu

https://link.springer.com/chapter/10.1007/978-981-97-2523-6_2

Power from Nature: A Sustainable in transit to renewable energy

Author: *Ziya Yusuf Mansuri, Italiya Khushi Pankajbhai, Jinal Rajeshbhai Borad*
Semester 2, First Year
Department of Biotechnology

Introduction

Even effortlessly smiling, blinking and raising your brows needs to be funded by energy. Knowingly, heartbeat powers your body as an engine does to a car; and fuel powers an engine as energy powers our body. A car and body work hand in hand for fuel and energy respectively as both energy is extracted from the living source leading to innovation of sustainable energy. Since the data of the last consecutive decade there is an increase in search of alternatives to nonrenewable energy that strengthen the demand of sustainable energy i.e. biofuels and bioenergy.

Bioenergy

Inside our body trillions of cells work as power hubs, every second converting the food we eat to energy. This fascinating energy is termed as bioenergy. Bioenergetics is the backbone of the life process as it answers to the mystery of this energy captured, converted and utilized by the living system.

Energy pertains to the basics of the laws of thermodynamics which conclude that life is the result of a constant balance of energy transformation. Also releasing some energy in the form of heat increases the disorderliness in the universe.

ATP-the energy currency is a high energy compound containing high-energy phosphate bonds that release energy that drive the life processes. ATP acts as a rechargeable battery, constantly charged and discharged to meet cellular energy demands.

The process of bioenergy production involves converting organic materials, known as biomass, into usable energy forms like heat, electricity, or liquid fuels through various conversion technologies.

Key Steps of Bioenergy Process

Biomass Sourcing: where organic materials or feed stocks are collected from various sources.

Conversion: The biomass is converted into solid, liquid, or gaseous fuels using different methods- Direct Combustion, thermochemical Conversion and biochemical Conversion.

Chemical Conversion: for instance transesterification converts vegetable oils and animal fats into biodiesel.

Energy Generation/Use: The resulting energy carriers (e.g., wood pellets, ethanol, biogas, electricity) are used for various applications.

Bioenergy is the umbrella concept of all energy derived from biological sources, in which biofuels are the specific solid, liquid, or gaseous energy carriers produced from biomass to meet various energy demands, particularly in transportation.

Biofuels

Biofuels are referred to as the liquid fuels and blending components produced from biomass materials called feedstocks.

E.g.: Ethanol and Biodiesel

Biofuels are categorized into 3 parts on the basis of types of feed stock used to produce them.

First generation: Biofuels produced from food crops.

For Ethanol = Feed stock includes sugarcane, corn and maize

For biodiesel= naturally occurring vegetable oils such as soybean and canola.

Second Generation: Biofuels are produced from cellulosic materials such as wood, grasses and inedible parts of plants to break down through fermentation and therefore require pre-treatment before it can be processed.

Third Generation: Biofuels are produced using the liquid production from algae.

Biofuels are currently the only viable replacement of petroleum transformation fuels because they can be used in existing combustion engines, this is an increasing advantage with growing concern about the environmental impacts of fossil fuels.

Around the globe biofuels can also help provide energy security in regions that do

not have hydrocarbons but do not have suitable agricultural condition while There is some dispute over just how renewable biofuels are.

Advantages

The advantages overshadows disadvantages proving to be an asset to humanity by serving with - renewable energy source; reducing Greenhouse gas emissions; Energy Security; Reduction in Sulfur Emissions; Improved Energy Efficiency; Potential for Carbon Neutrality;

Increased focus on biofuels promotes innovation in biotechnology and energy engineering.

Limitation And Current Challenges

Everything in the world possesses downfall, biogas and bioenergetics are no exception. Exploring its flaws, the cost of production is sky high that stands first as an economical hurdle. Secondly, Biomass availability ebbs and flows according to the season, this disrupts supply chain instability. Seeking for energy efficiency of biofuels, as the energy output of it is inferior to that of petrol and diesel. Controversy happens between land use and deforestation resulting in the rise of environmental impacts. Social and ethical concerns also hit hard.

Innovation And Future Prospect

Recent advancements include genetically edited microbes developed by scientists to increase fuel yield and AI-driven processes used to improve production efficiency. Additionally, advanced bio-

electrochemical systems and enhanced bio hydrogen production have been developed.

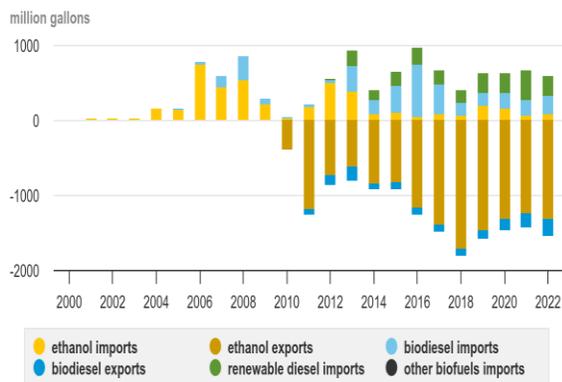
Moreover, in CO₂ Utilization by converting captured CO₂ into valuable products like algal oil (rich in Omega-3s) and acetic acid, creating a circular carbon economy; Bio refineries: produce multiple products from biomass; Utilizing algae, agricultural residues, food waste; Genetically Engineered Feed stocks and many more.

The future prospects include:

Bio-CNG & Bio hydrogen: Using organic waste for renewable natural gas and exploring hydrogen blending in transport.

Biochemical & Bio plastics create platform chemicals and biodegradable materials from biomass to replace petrochemicals.

Graphical representation of U.S. Biofuels imports and exports by major type (2000-2022)



(Image source: U.S. Energy Information Administration, *Petroleum Supply Annual, August 2023*, and *monthly Energy Review, September 2023*, preliminary data for 2022)

References

1. Demirbas, A. (2009). Biofuels: Securing the planet's future energy needs. *Energy Conversion and Management*, 50(9), 2239–2249. <https://doi.org/10.1016/j.enconman.2009.05.010>
2. Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101(6), 1570–1580. <https://doi.org/10.1016/j.biortech.2009.11.046>
3. International Energy Agency. (2023). *Bioenergy*. <https://www.iea.org/topics/bioenergy>
4. Singh, A., & Olsen, S. I. (2011). A critical review of biochemical conversion, sustainability and life cycle assessment of algal biofuels. *Applied Energy*, 88(10), 3548–3555. <https://doi.org/10.1016/j.apenergy.2010.12.012>
5. United Nations Food and Agriculture Organization. (2019). *Bioenergy and food security (BEFS)*. <https://www.fao.org/energy/befs>

Biopolymers: Building a Circular Bioeconomy for a Sustainable Future

*Author: Divyesh Kiran Patni, Diya Shah
Semester 4, Second Year
Department of Biotechnology*

Introduction

The growing global concern over climate change, plastic pollution, and depletion of fossil resources has accelerated the search for sustainable alternatives. In India alone, plastic waste generation exceeds 3.5 million tonnes annually, highlighting the urgent need for biodegradable alternatives such as biopolymers. Conventional petroleum-based polymers, although versatile and inexpensive, persist in the environment for centuries and contribute significantly to ecological damage. In this context, **biopolymers** have emerged as promising materials that align with the principles of sustainability and circular bioeconomy. Derived from renewable biological sources, biopolymers offer an eco-friendly solution by reducing environmental impact while maintaining functional efficiency.

What Are Biopolymers?

Biopolymers are naturally occurring or biologically synthesized polymers produced by living organisms or derived from renewable biomass. Common examples include polysaccharides such as cellulose and starch, proteins like gelatin and silk, and biodegradable polyesters such as polylactic acid (PLA) and polyhydroxyalkanoates (PHAs). Unlike synthetic plastics, many

biopolymers are biodegradable, compostable, and non-toxic, making them ideal materials for sustainable development.

Sources and Types of Biopolymers

Biopolymers can be broadly classified based on their origin:

- **Natural biopolymers:** Cellulose from plants, chitin from crustacean shells, and proteins from animal and plant sources.
- **Microbial biopolymers:** PHAs produced by bacteria as intracellular energy reserves.
- **Bio-based synthetic polymers:** PLA synthesized from lactic acid obtained through fermentation of sugars and starch.

These materials utilize agricultural waste, food industry by-products, and microbial fermentation, thus supporting resource efficiency and waste valorization.

Biopolymers and the Circular Bioeconomy

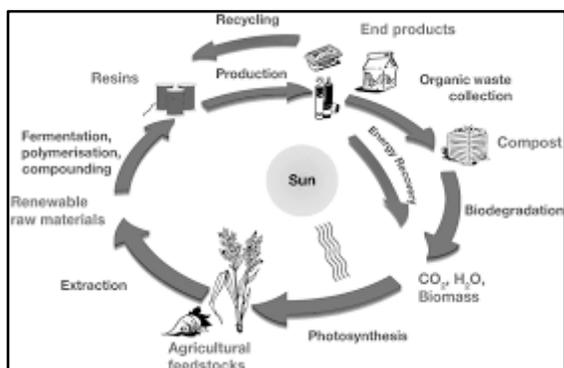


Figure 1. Circular bioeconomy model illustrating the lifecycle of biopolymers from renewable resources to biodegradation and recycling.

Courtesy: Open-access sustainability literature.

The concept of a circular bioeconomy focuses on minimizing waste, reusing biological resources, and regenerating natural systems. Biopolymers perfectly fit this model by enabling a closed-loop lifecycle—from biomass production to material use and eventual biodegradation. Agricultural residues, such as corn starch and sugarcane bagasse, can be transformed into bioplastics, reducing dependence on fossil fuels and lowering carbon emissions. At the end of their life cycle, biopolymers can decompose into harmless substances, enriching soil rather than polluting ecosystems.

Applications of Biopolymers

Biopolymers have found applications across multiple sectors:

- **Packaging industry:** Biodegradable films, carry bags, and food packaging materials reduce plastic waste.
- **Medical and pharmaceutical fields:** Biopolymers are used in drug delivery systems, sutures, tissue engineering scaffolds, and wound dressings due to their biocompatibility.
- **Agriculture:** Mulch films and controlled-release fertilizers made from biopolymers enhance soil health.
- **Textiles and consumer goods:** Sustainable fabrics and disposable products promote eco-conscious consumption.

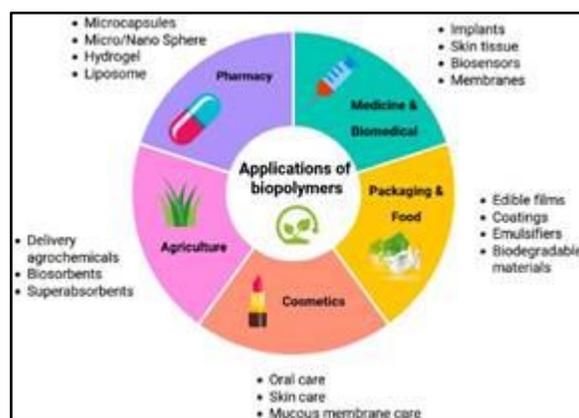


Figure 2. Applications of biopolymers across pharmaceutical, biomedical, agricultural, packaging, and cosmetic industries.

Courtesy: Adapted from open-source educational resources.

Their versatility demonstrates how innovation can meet sustainability goals.

Challenges and Future Prospects

Despite their advantages, biopolymers face challenges such as higher production costs, limited mechanical strength compared to conventional plastics, and scalability issues. However, advancements in biotechnology, genetic engineering, and industrial fermentation are addressing these limitations. Research into blending biopolymers, improving processing techniques, and utilizing low-cost biomass is paving the way for wider adoption.

With increasing environmental regulations and consumer awareness, the demand for sustainable materials is expected to rise. Biopolymers are poised to play a crucial role in shaping a greener future.

Conclusion

Biopolymers represent a powerful example of how scientific innovation can support environmental sustainability. By integrating renewable resources, reducing waste, and promoting biodegradability, biopolymers contribute significantly to the circular bioeconomy. As biotechnology continues to evolve, biopolymers will not only replace conventional plastics but also redefine how materials are produced and consumed. Embracing biopolymers today is a vital step toward sustaining tomorrow.

References

- Gross, R. A., & Kalra, B. (2002). *Biodegradable polymers for the environment*. *Science*, 297(5582), 803–807.
- Reddy, C. S. K., Ghai, R., Rashmi, & Kalia, V. C. (2003). *Polyhydroxyalkanoates: an overview*. *Bioresource Technology*, 87(2), 137–146.
- European Bioplastics. (2023). *Bioplastics – materials and applications*. <https://www.european-bioplastics.org>

Biopolymers in Medical Implants: Building a Sustainable Future for Healthcare

Authors: Himani Thakkar, Kavya Shah

Semester 4, Second Year

Department of Biotechnology

Introduction

Modern medicine relies heavily on implants to restore or replace damaged tissues and organs. From bone plates and vascular grafts to sutures and wound dressings, implants have transformed patient care and improved quality of life. Traditionally, these medical devices were made using metals, ceramics, and synthetic polymers. While effective, many of these materials pose challenges such as poor biodegradability, inflammation, long-term toxicity, and the need for secondary surgeries.

In recent years, biopolymers have emerged as a promising alternative. Derived from natural sources such as plants, animals, or microorganisms, biopolymers offer biocompatibility, biodegradability, and reduced immune reactions. Their ability to interact safely with biological tissues makes them especially attractive for medical implants and surgical applications. This article explores the role of biopolymers in medical implants, their applications, current limitations, and future potential.

What Are Biopolymers and Why Are They Important?

Biopolymers are naturally occurring macromolecules that resemble components of the human extracellular matrix. Common categories include

polysaccharides (such as chitosan, alginate, and hyaluronic acid) and proteins (such as collagen, gelatin, and silk fibroin). Unlike synthetic polymers, biopolymers are often recognized by the body as familiar materials, reducing the risk of rejection.

One of the biggest advantages of biopolymers is their biodegradability. Instead of remaining permanently in the body, many biopolymer-based implants gradually degrade into non-toxic by-products. This is particularly beneficial for temporary implants, as it eliminates the need for surgical removal and lowers patient discomfort.

Applications of Biopolymers in Medical Implants

Biopolymers are widely used in both surgical materials and implantable medical devices. In surgery, they are employed as sutures, wound dressings, sealants, and tissue adhesives. Materials such as chitosan and alginate help control bleeding, prevent infections, and promote faster wound healing.

In implant technology, biopolymers like polylactic acid (PLA), silk, and chitosan have shown great promise. PLA-based implants are commonly used in orthopedic applications such as screws, plates, and scaffolds. These implants

provide mechanical support initially and then safely degrade over time.

Silk fibroin, a protein-based biopolymer, is valued for its excellent mechanical strength and flexibility. It has been used in ligament repair, sutures, and tissue scaffolds. Chitosan, derived from chitin, stands out for its antibacterial properties and ability to promote cell adhesion and tissue regeneration. It is widely explored in wound healing, bone regeneration, and drug delivery systems.



Figure 1: Applications of biomaterials in implants.

Courtesy: Wiley Advanced Science.

Chitosan-Based Composites: Enhancing Implant Performance

Although biopolymers are biologically friendly, they often suffer from poor mechanical strength or limited stability. To overcome this, researchers combine chitosan with other biopolymers such as proteins or polysaccharides to form biopolymer composites.

Chitosan–biopolymer composites improve properties like strength, flexibility, antimicrobial activity, and cell

compatibility. These composites are used to create hydrogels, films, scaffolds, and coatings for implants. Such materials can support tissue growth, control drug release, and protect implants from bacterial infections.

Advanced chemical modifications and blending strategies have further expanded the functionality of these composites, making them suitable for applications such as tissue engineering, nerve repair, and 3D bioprinting.

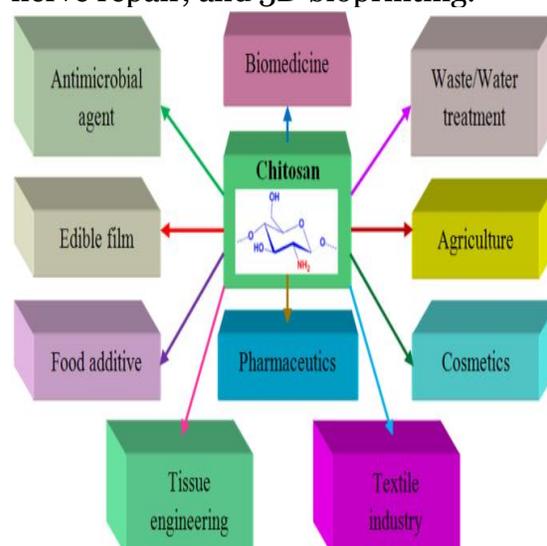


Figure 2: Chitosan-based composite materials and applications.

Courtesy: Springer Nature.

Challenges and What Needs to Be Changed

Despite their advantages, biopolymers are not without limitations. Natural variability in source materials can lead to inconsistent properties. Some biopolymers degrade too quickly or lack sufficient mechanical strength for load-bearing applications. Additionally, large-scale production and sterilization remain technical challenges.

To address these issues, more focus is needed on standardization, material modification, and composite development. Combining biopolymers with each other or with biodegradable synthetic polymers can help balance biological performance and mechanical stability. Stronger collaboration between researchers, clinicians, and industry is also essential to translate laboratory findings into reliable clinical products.

Future Prospects of Biopolymer-Based Implants

The future of biopolymers in medical implants is highly promising. Advances in material science, nanotechnology, and 3D printing are opening new possibilities for patient-specific implants. Smart biopolymer systems capable of responding to biological signals, releasing drugs on demand, or promoting targeted tissue regeneration are under active development.

As healthcare shifts toward sustainability, biopolymers align well with environmental goals by reducing dependence on petroleum-based plastics. Their renewable nature and eco-friendly degradation make them ideal materials for next-generation medical devices.

Conclusion

Biopolymers are redefining the landscape of medical implants and surgical materials. Their natural origin, biocompatibility, and biodegradability offer clear advantages over conventional materials. While challenges remain, ongoing research and innovation continue to improve their performance and reliability.

With further advancements, biopolymer-based implants have the potential to make healthcare safer, more sustainable, and more patient-friendly. For future biomedical scientists and healthcare professionals, biopolymers represent an exciting bridge between biology, materials science, and medicine.

References

1. Bibire, T., Yilmaz, O., Ghiciuc, C. M., Bibire, N., & Dănilă, R. (2022). Biopolymers for surgical applications. **Coatings, 12*(2)*, 211.
2. Rebelo, R., Fernandes, M., & Figueiro, R. (2017). Biopolymers in medical implants: A brief review. **Procedia Engineering, 200**, 236–243.
3. Guo, Y., Qiao, D., Zhao, S., Liu, P., Xie, F., & Zhang, B. (2024). Biofunctional chitosan–biopolymer composites for biomedical applications. **Materials Science & Engineering R, 159**, 100775.

BIOPOLYMERS: “Shaping a Sustainable Future”

Authors: Shrini Jain & Reny Patel
Semester 2, First year
Department of Biotechnology

Introduction

The most prevalent macromolecules are biopolymers, which comprise nucleic acids, proteins, carbohydrates, lipids, and giant non-polymeric molecules like lipid and macrocycles, the most frequent macromolecules

Plastics, synthetic fibers, and experimental materials, such as carbon nanotubes, are examples of synthetic macromolecules.

Definition

Biopolymers are the organic substances present in natural sources, basically they are the macromolecules found in living organisms made up of small repeating units or molecules- monomers.

Sustainable Development Goals

They are 17 global goals set by the United Nations (UN) in 2015, to be achieved by 2030, focusing on making the world better, fairer, and more sustainable.

Nurturing our Land (SDG 2): Farmers are increasingly using biopolymer-based tools, like biodegradable mulch films and smart hydrogels. Unlike traditional plastic that chokes the earth, these

materials dissolve naturally, keeping soil healthy and helping crops thrive with less water—a huge step toward food security.

Greener Habits (SDG 12): We are finally breaking our "take-make-waste" cycle. By choosing packaging made from plant waste instead of oil, we are creating a circular economy. These materials don't just replace plastic; they often keep our food fresh for longer, cutting down on the massive amount of food we throw away.

Breathing Easier (SDG 13): Every biopolymer product is a win for the climate. Because they are made from plants that absorb CO₂ while they grow, their carbon footprint is significantly lower than fossil-fuel plastics. It's a simple shift that helps us move away from oil and toward a cooler, more stable planet.

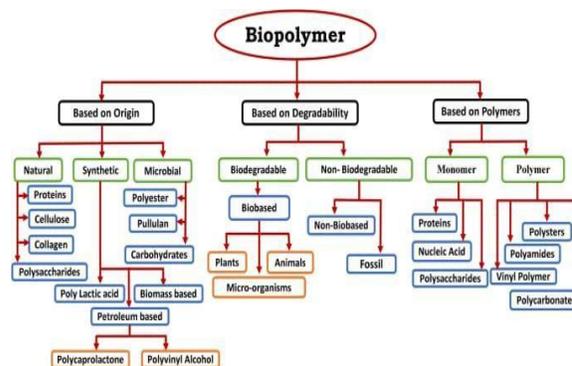


Figure 1: Classification of Biopolymers based on origin, degradability, and polymer structure.

Courtesy: Encyclopedia MDPI

Conflicts That Are Faced

Problem-weak machinal strength which makes them prone to cracking under stress

Solution-through nano bio-technology. This problem can be solved by transforming them into nano composites.

Problem- Weak moisture resistance which makes biopolymers unable to absorb water and water vapours.

Solution- It can be overcome through surface barriers like coating and sealants.

ASIA Syndrome

ASIA (Auto Immune or Inflammatory Syndrome Induced by Adjuvants)

The term was first introduced in 2011 by Dr. Yehuda Shoenfeld.

It is a medical condition proposed to describe a group of auto immune-like disorders that occur after exposure to adjuvants-substances that stimulate the immune system.

In cosmetic medicine, non-medical-grade biopolymers injected for body contouring (eg. Buttocks, face) have been linked to ASIA-like reaction:

- Chronic inflammation
- Granuloma formation
- Autoimmune complications
- Systemic symptoms

Uses of Biopolymers

Biopolymers are polymers derived from plants, microbes, or other biological sources rather than fossil fuels. They can be biodegradable, compostable, or bio-based, reducing dependence on

petroleum plastics, minimizing waste and pollution, and supporting a circular economy. Following are few uses of biopolymers:

1. Sustainable Packaging

Use: Replace traditional plastics in packaging materials such as bottles, films, bags, trays, and disposable products — often designed to biodegrade or compost after use.

Example Companies:

- *NatureWorks LLC*: Produces Ingeo™ PLA biopolymers used for compostable foodservice wares, packaging, and sustainable fibers — with significantly lower carbon footprint than conventional plastics.
- *BASF SE*: Offers ecovio® compostable bioplastics suitable for bags, agricultural films, and flexible packaging.

2. Agriculture & Horticulture

Use: Biopolymers make biodegradable mulch films, seed coatings, plant pots, and controlled-release fertilizer coating that reduce chemical pollution and improve soil quality

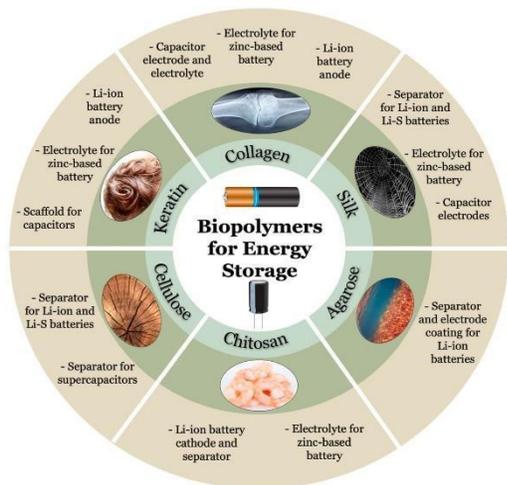


Figure 2: Biopolymer Materials | Courtesy: Encyclopedia MDPI

Example Companies:

- *Carapace (Netherlands)*: Offers bio-based coatings that enhance seed germination and soil health while being biodegradable.
- *Local innovators in India*: Use agro-waste to make biodegradable films and products tailored to composting systems.

3. Sustainable Textiles & Materials

Use: Biopolymers form fibers and fabrics that are biodegradable and lower impact than synthetic fibers — used in apparel, accessories, and composites.

Example Companies:

- *AMSilk (Germany)*: Produces Biosteel® synthetic spider silk, used in biodegradable textiles and footwear components with reduced waste.
- *von Holzhausen (USA)*: Creates plant-based biodegradable materials for fashion and other industries.

4. Biomedical & Healthcare Applications

Use: Biocompatible and biodegradable polymers are used in medical implants, drug delivery systems, wound dressings, and scaffolds for tissue engineering — reducing need for removal surgeries and long-term foreign materials in the body.

Example Focus Areas:

Collagen, chitosan, and polylactic acid (PLA) are common biopolymers in advanced medical products.

5. Corporate & Consumer Adoption

Use: Major brands adopt biopolymer materials to reduce carbon footprint and satisfy eco-consumer demand — in packaging, products, and design.

Industry Examples

- *IKEA* introduced PLA biodegradable cups and plates in their stores.
- *Patagonia* and other sustainable apparel brands incorporate plant-based polymers into textiles.

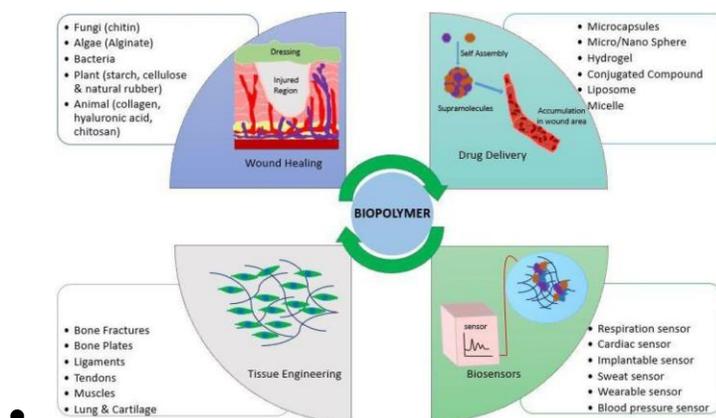


Figure 3: Recent Advancement of Biopolymers and Their Potential Biomedical
Courtesy: Encyclopedia MDPI

Disadvantages

1. High Production Rate:

Biopolymers are significantly more expensive than petroleum-based plastics.

- Raw Material Costs: The crops used (corn, sugarcane, potatoes) are more expensive to harvest and process than crude oil byproducts.
- Scale of Economy: Traditional plastic infrastructure has been refined for over 50 years. Biopolymer facilities are still scaling up, leading to higher price for the end consumer.

2. Low Thermal Resistance

Most biopolymers

- Soften or deform at high temperature
- Are unsuitable for hot food packaging or industrial use. Example- PLA melts at lower temperatures than polyethylene

3. Inferior Mechanical Strength

Compared to petroleum-based plastics, biopolymers often have:

- Lower tensile strength
- Poor impact resistance
- Brittleness under stress

This limits their use in heavy duty applications

References:

1. Siracusa, V., Rocculi, P., Romani, S., & Dalla Rosa, M. (2008). Biodegradable polymers for food packaging: A review. *Trends in Food Science & Technology*, 19(12), 634–643.
2. Narayan, R. (2011). Carbon footprint of bioplastics using biocarbon content analysis and life-cycle assessment. *MRS Bulletin*, 36(9), 716–721
3. NatureWorks LLC. (2023). Ingeo™ biopolymer for sustainable packaging. NatureWorks LLC. <https://www.natureworkslc.com>
4. Dober, E. (2020). Biopolymers in agriculture: Mulch films and controlled-release systems.
5. Perera, K. Y., Jaiswal, A. K., & Jaiswal, S. (2023). Biopolymer-based sustainable food packaging materials: Challenges, solutions, and applications. *Foods*, 12(12), 2422. <https://doi.org/10.3390/foods12122422>

Engineering Biopolymer-based Food Packaging for Sustainability

*Author: Jheel Patel
Semester 4, Second year
Department of Biotechnology*

Abstract

With the increase in environmental pollution due to petroleum-based plastics, the food industry has had to explore more sustainable packaging materials. This paper highlights the potential applications of biopolymer-based food packaging materials in implementing the concept of a circular economy. Biopolymers, which are derived from renewable biological sources such as plants, bacteria, and other organisms, are biodegradable and friendly to living organisms due to biopolymers such as PLA (polylactic acid) and chitosan, which are biodegradable and biologically friendly materials.

Though conventional plastics are favored due to their strength, the environmental impact caused by them is considerably lower compared to bioplastics. Yet, factors such as brittleness and water sensitivity are some limitations associated with bioplastics that restrict them from widespread applications. Innovations in the fields of material sciences, especially modifications in bioplastics, have opened new avenues in enhancing biopolymer materials, which currently illustrate the potential use in protecting food materials while being environmentally sustainable.

Introduction

Petro-based plastics continue to dominate the food packaging industry because of their low cost, flexibility, and high strength. These properties make them suitable for various applications.

Unfortunately, their high presence in landfills and oceans has resulted in serious environmental problems. Conventional plastics have shelf lives of hundreds of years in the natural environment. However, as sustainability has emerged as a growing concern for people all around the world, there has been increased emphasis on sustainable food packaging products. In this context, food packaging products based on biopolymers have shown great potential in addressing this concern.

Common Bioplastics and Biopolymer Packaging Materials

Of the many biopolymers investigated for food packaging applications, chitosan and polylactic acid (PLA) are relatively promising. Chitosan is derived from chitin, a biopolymer found in the shells of crustaceans, such as shrimp and crabs. Chitosan is biodegradable, non-toxic, and has high antimicrobial activity. When used for

food packaging, chitosan films and coatings can inhibit the growth of both bacterial and fungi organisms, and therefore extend the shelf life of food items such as fruits, veggies, meat, and seafood.

Polylactic acid – this biodegradable biopolymer has synthetic properties and is made from lactic acid, which is obtained from the fermentation process of renewable resources such as corn starch or sugarcane. It has good mechanical properties, clarity, and thermal processability, properties that make PLA very suitable for the packaging of foods such as containers, trays, cups, and packaging film. In fact, PLA is the commonly used biopolymer in packaging applications.

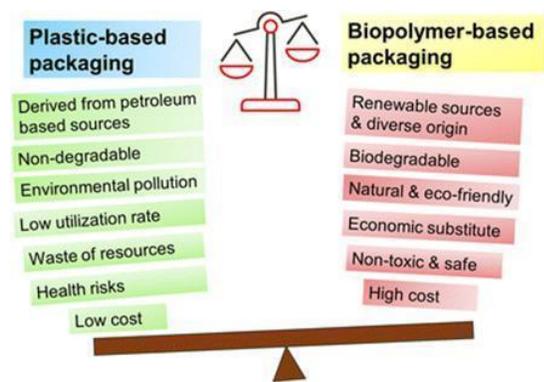


Figure 1 : Comparative analysis of plastic packaging and biopolymer-based packaging.

Courtesy:Royal Society Of Chemistry.

Production and Processing of Biopolymer Packaging

Methods of producing biopolymer packaging materials include sustainable technologies. In the case of chitosan,

there is extraction of chitin from seafood waste, then deacetylation, thereby converting waste to a material that can be packaged.

In the case of PLA, there is the production of lactic acid from microbes, then its polymerization to produce the final form of the biopolymer material. Finally, the biopolymer is converted to packaging products through various processing technologies, such as film casting, extrusion, injection molding, and coating, to produce various packaging products for foodstuff.

Biotechnologies Utilized in Packaging Sustainability

Biotechnology applications are crucial in upgrading the quality and sustainability of biopolymer-based food packaging. For instance, microbial fermentation can be applied in the synthesis of the starting materials of biopolymers. Enzymatic and genetic approaches are also vital for upgrading the flexibility, strength, and barriers offered by these materials. Biotechnology also facilitates the conversion of agricultural and food industry wastes into raw materials, which will reduce the generation of total wastes.

Benefits of Biopolymer-Based Food Packaging

All Biopolymer-based packaging materials have many advantages over traditional plastic packaging materials. The biodegradability of biopolymer-based materials contributes to the reduction of environmental pollution. The use of biopolymer-based materials reduces the dependence on fossil fuels

and minimizes carbon emissions. Moreover, biopolymer-based materials have antimicrobial properties due to the use of components like chitosan, which increases the safety of food and minimizes spoilage. Using biopolymer-based packaging materials facilitates sustainable Development.

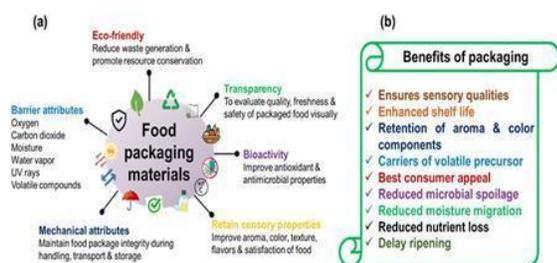


Figure 2: {a} Major properties of food packaging materials.

{b} Benefits of food packaging

Courtesy: Royal Society Of Chemistry.

Challenge and Limitations

Despite these advantages associated with their roles in improving the environment, there are challenges associated with biopolymer-based packaging materials. For instance, high production costs and diminished mechanical strength are factors associated with these types of materials and may prevent them from being widely used. Biopolymer-based packaging may also have a shorter shelf life. To overcome these challenges, research is currently ongoing to enhance these types of packaging.

Future Prospects

With the increasing awareness about environmental issues and the stringent regulations regarding the use of plastic materials, there is a potential rise in the requirement for sustainable packaging materials. Improvements in the field of biotechnology and materials science would enhance the strength and feasibility of using biopolymers in packaging materials. Biopolymers will play an important role in developing a sustainable and eco-friendly food packaging sector in the coming years.

Conclusion

Biopolymer packaging of food provides a convenient and environmentally friendly alternative to traditional packaging made of plastic. The utilization of renewable and biodegradable components such as chitosan and PLA makes it possible to significantly diminish the negative effects of the food industry on the environment. Despite certain restrictions, current scientific research and advancements in technology make possible the increased usage of such packaging components.

Biopolymer packaging of food is not only improving the safety of culinary items but is also facilitating effective protection of the environment and, hence, sustainability.

Moto: Preservation of food. Preservation of the planet.

References

1.O. Olawore, M. Ogunmola and S. Desai, Engineered nanomaterial , design,manufacturing, regulatory, and sustainability implications, *Micromachines*, 2024, 15(2), 245 CrossRef PubMed

2. T. Fadiji, M. Rashvand, M. O. Daramola and S. A. Iwarere, A review on antimicrobial packaging for extending the shelf life of food, *Processes*, 2023, 11(2), 590 CrossRef CAS.

3.R. Lev, P. Tanninen, J. Lyytikäinen and V. Leminen, Converting and its effects on barrier properties of coated packaging materials: A Review, *BioResources*, 2023, **18**(4), 8707

4.R. Nithya, K. Mohanrasu and A. Arun, Agro-Based Bioplastic Production and Its Application, *InBiodegradable Polymers, Blends and Biocomposites*, Taylor & Francis, 2025

Bioremediation: A Sustainable Biotechnological Solution for Environmental Pollution

Author: Vala Kruti
Semester 2, 1st Year
Biotechnology Department

Abstract

Environmental pollution caused by industrial activities poses serious ecological challenges. Bioremediation provides a sustainable solution by using microorganisms and plants to degrade or immobilize environmental pollutants. This article briefly discusses the principles, major approaches, eco-friendly nature, and potential for long-term environmental restoration.

What is Bioremediation?

Bioremediation has been effectively applied in various environmental settings to reduce pollution and restore ecological balance. In oil spill scenarios, hydrocarbon-degrading microorganisms accelerate clean up in marine and coastal environments by converting toxic petroleum compounds into less harmful substances. Heavy metal-contaminated soils near industrial and mining sites are treated using microbes and plants that extract or immobilize metals, providing a sustainable alternative to costly physical removal. In developing regions, its low cost and minimal infrastructure requirements make bioremediation particularly valuable for sustainable environmental management.

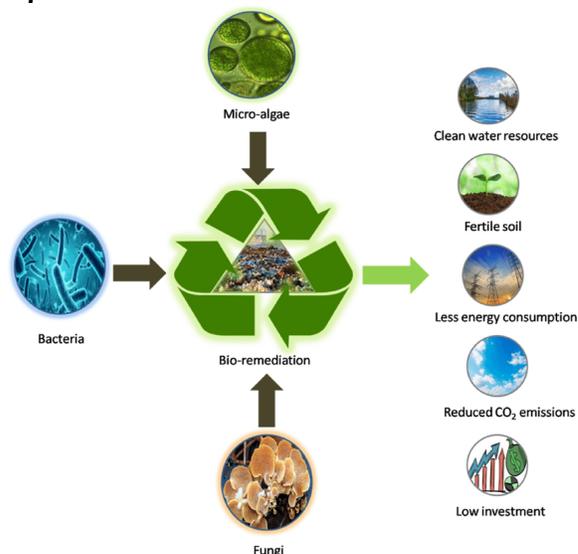


Figure 1: Diagram illustrating how microorganisms (bacteria, fungi, algae) and plants participate in bioremediation to transform or remove environmental pollutants.

Courtesy: ResearchGate

Major Bioremediation Approaches

Microbial Bioremediation

Microbial bioremediation employs bacteria and fungi to degrade or detoxify pollutants such as petroleum hydrocarbons, pesticides, and organic wastes by using them as energy or nutrient sources. Native microbial populations can naturally reduce contamination, but their efficiency

depends on environmental factors. When required, the process can be enhanced through the introduction of selected or engineered microbial strains.

Phytoremediation

Phytoremediation uses plants and their root-associated microorganisms to remediate contaminated soil and water. Plants remove or stabilize pollutants through processes such as phytoextraction, phytostabilization, and rhizodegradation. This low-cost approach is particularly effective for large, shallow contamination sites and offers additional benefits such as soil stabilization and improved landscape aesthetics.

Bioaugmentation and Biostimulation

Biostimulation enhances bioremediation by adding nutrients or electron acceptors to stimulate native pollutant-degrading microbes. Bioaugmentation involves introducing specialized microbial strains with high degradation efficiency. Both methods accelerate natural biodegradation and are often combined when native microbial activity is insufficient.

Real World Applications of Bioremediation

Bioremediation is widely used to reduce pollution and restore ecosystems. In oil spills, hydrocarbon-degrading microbes accelerate cleanup in marine environments. Contaminated soils near industrial and mining sites are treated using microbes and plants that extract or immobilize heavy metals. It is also applied in industrial and municipal wastewater treatment, where microbial

consortia break down organic pollutants. Owing to its low cost and minimal infrastructure needs, bioremediation is especially valuable for sustainable cleanup in developing regions.

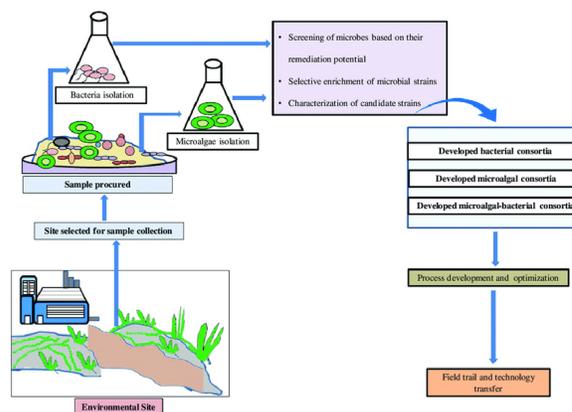


Figure 2: Bioremediation process in waste water treatment using microbial communities

Courtesy: ResearchGate

Bioremediation and Sustainability

Bioremediation is a sustainable environmental management strategy that relies on microorganisms and plants to clean polluted environments with low energy input and minimal chemical use. By reducing secondary pollution and preserving ecological balance, it offers an eco-friendly alternative to conventional remediation methods. Bioremediation also supports the circular bioeconomy by converting waste into less harmful substances and promoting resource regeneration. Through gradual ecosystem recovery, it enhances soil health, water quality, and biodiversity, aligning biotechnology with long-term environmental sustainability.

Limitations and Challenges of Bioremediation

Despite its sustainability benefits, bioremediation has several limitations. The process is often slow, as pollutant degradation depends on microbial growth and favorable environmental conditions. Its effectiveness is highly site-specific, influenced by factors such as temperature, pH, oxygen levels, and soil composition. Incomplete degradation may generate toxic intermediate compounds, posing additional risks. Regulatory, biosafety, and economic constraints—including long treatment durations and monitoring costs—further limit its use in large-scale or urgent remediation projects.[6]

Conclusion

Bioremediation represents a promising intersection of biotechnology and sustainability, offering environmentally friendly solutions to growing pollution challenges. While limitations such as slow remediation rates and site-specific constraints remain, continued research and technological innovation can enhance its efficiency and reliability. With responsible application, bioremediation can play a vital role in achieving long-term environmental restoration and sustainable development.

References

[1]Ayilara, M. S., Adeeyo, O., & Adeleke, R. A. (2023). Bioremediation of environmental wastes: the role of microbes and plants in pollutant removal. *Frontiers in Agronomy*. <https://doi.org/10.3389/fagro.2023.118369>
1

[2]Joutey, N. T., Bahafid, W., Sayel, H., & El Ghachtouli, N. (2013). Mechanisms of microbial bioremediation. *Environmental Chemistry Letters*, 11, 1–16. <https://doi.org/10.1007/s10311-012-0392-0>

[3]Azubuike, C. C., Chikere, C. B., & Okpokwasili, G. C. (2016). Bioremediation techniques—classification based on site of application: Principles, advantages, limitations and prospects. *World Journal of Microbiology & Biotechnology*, 32, 180.

[4]Ayilara, M. S., et al. (2023). Bioremediation of environmental wastes: the role of microbes and plants in pollutant removal. *Frontiers in Agronomy*. <https://doi.org/10.3389/fagro.2023.118369>
1

[5]Azubuike, C. C., Chikere, C. B., & Okpokwasili, G. C. (2016). Bioremediation techniques—classification based on site of application: Principles, advantages, limitations and prospects. *World Journal of Microbiology and Biotechnology*, 32, 180. <https://doi.org/10.1007/s11274-016-2137-x>

[6]Azubuike, C. C., Chikere, C. B., & Okpokwasili, G. C. (2016). Bioremediation techniques—classification based on site of application: Principles, advantages, limitations and prospects. *World Journal of Microbiology and Biotechnology*, 32, 180. <https://doi.org/10.1007/s11274-016-2137-x>

[7]Vidali, M. (2001). Bioremediation: An overview. *Pure and Applied Chemistry*, 73(7), 1163–1172. <https://doi.org/10.1351/pac200173071163>

[8]Vaid, N., Sudan, J., Dave, S., Pathak, H., & co-authors (2022). Insight into microbes and plants ability for bioremediation of heavy metals. *Current Microbiology*. (Figures depict bioremediation processes using microbes and plants.)

Integrating Computational Tools and Molecular Docking for Sustainable Bioremediation: A Student-Led Case Study.

*Author: Shaikh Masuma Mohammed Yunus
BSc First Year Student,
Department of Biochemistry*

Introduction.

Pollution from factories and cities is filling our biosphere with harmful chemicals, making life harder for human beings and other living organisms. We need safe ways to clean up this mess, and that's where bioremediation comes in. Bioremediation is defined as making use of plants, enzymes or microbes to break down pollutants and make our environment healthy. It is very helpful but it is also expensive because it needs special labs, trained people and certain equipment. To make it sustainable, scientists are looking for cheaper and smarter ways, for example using microbes, enzymes or making use of computational techniques (Bioinformatics and Molecular Docking) to test ideas before spending money in the lab.

Computational Tools Driving Sustainable Bioremediation.

Bioinformatics, Computational Biology and molecular docking are transforming bioremediation by making it more efficient and sustainable. Computational biology uses models and simulations to predict how microbes and enzymes interact with pollutants, while bioinformatics analyzes genomic data to discover new pollutant-degrading

enzymes and Molecular docking further helps by virtually testing how pollutants fit into enzyme active sites, saving time and resources before wet lab experiments. These approaches collectively lower expenses, provide clearer direction, and accelerate the creation of enzyme-powered solutions for pollution control.

Recent Research in Sustainable Bioremediation.

- Laccase Docking for pharmaceuticals. (1)
- Ai-driven Bioinformatics for heavy metals. (2)
- Natural compounds enhancing pollutant-binding proteins. (4)

Their approaches helped to design enzyme based cleanup strategies, and suggested eco-friendly compounds that can be used for pollutant degradation. Together these approaches showed how computational tools can make bioremediation more affordable and innovative. Based on this foundation, I designed a case study to illustrate the application of Molecular Docking in Bioremediation.

Student-Led Simulation : Phenol-Laccase Docking Study.

To reveal the usefulness of dry lab research on bioremediation, I performed a Molecular Docking Simulation using AutoDock4 to analyse the interaction between Phenol (PubChem CID:996), a common industrial pollutant, and Laccase (PDB ID: 1KYA), which is a multicopper oxidase enzyme known for disintegrating phenolic compounds.

- Phenol was chosen because of its toxicity.
- Laccase was selected for its catalytic adaptability.

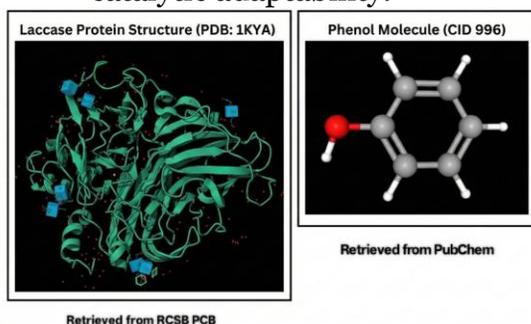


Figure 1 . Laccase 3D Structure and Phenol 3D Structure retrieved from PDB and PubChem respectively.

The docking showed a complementary binding pose of phenol near the enzyme's active site, exposing Molecular Docking as a predictive tool for sustainable bioremediation.

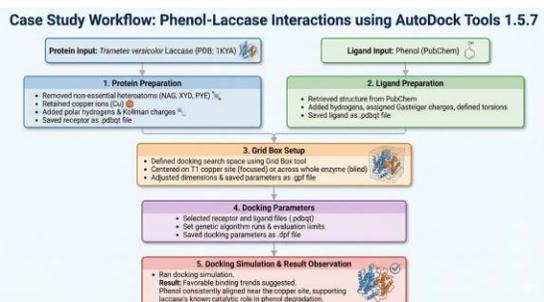


Figure 2 . Case study workflow diagram, designed by the author, summarizing the detailed AutoDock4 docking process to enhance clarity and accessibility.

Implications.

This simulation demonstrates how Molecular Docking can predict enzyme-pollutant interactions, making bioremediation viable and enduring. Dry Lab is making research more accessible and innovative but they can't stand alone. To establish reliable and real impact, computational predictions must be followed by Wet Lab validation.

[To further display the outcomes and skills gained from this project, the following image shows a key visualisation from the docking study. It also serves as a proof of the computational work undertaken by the author]

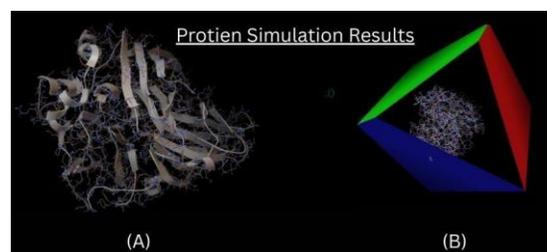


Figure 3 . (A) Shows Trametes versicolor laccase (PDB: 1KYA) with ligand Phenol (CID 996) in Autodock4. (B) Displays Grid Box Configuration.

Conclusion.

Thus, research across biotechnology, biochemistry, microbiology, bioinformatics , computational biology and molecular docking shows the transformative power of integrating wet and dry lab approaches. By bridging digital simulations with laboratory experimentation, Science is moving towards giving practical and scalable solutions for a cleaner and sustainable future.

Author's Reflection.

As a 1st year BSc Biochemistry Student, this project and article was both a challenge and a discovery. The application of computational tools, bioinformatics and molecular docking allowed me to move beyond theory and apply science into practice. Along the way, I enhanced my skills in writing, research, figure design and reading scientific papers. This experience showed me how dry and wet lab approaches complement each other, and it has inspired me to keep learning.

⇒ Further Reading

For readers interested in a detailed account of my experience and step-by-step methods of molecular docking, they can scan the QR code below to access my detailed blog on Google Blogger.



References.

1. Choudhary, A., Tiwari, A., & Bansal, H. (2025). Molecular docking analysis of laccase mediated bioremediation of pharmaceutical compounds from wastewater. *Systems Microbiology and Biomanufacturing*, 5(854–864). <https://doi.org/10.1007/s43393-024-00323-2>
2. RSC Editorial Board. (2025). Artificial intelligence driven bioinformatics for sustainable microbial bioremediation of heavy metals. *Environmental Science: Advances*. <https://doi.org/10.1039/D5VA00240K>
3. Subhashree, D. K., & Venugopal, S. (2024). Molecular docking and molecular dynamic simulation studies to identify potential terpenes against pollutant-binding proteins. *Frontiers in Bioinformatics*, 4. <https://doi.org/10.3389/fbinf.2024.1463750>
4. Joshi, M. (2022). Laccase mediated bioremediation of pharmaceutical pollutants: Molecular docking study (Master's thesis). Indian Institute of Technology Roorkee. Retrieved from <http://14.139.251.106:8080/jspui/bitstream/repository/20812/1/Monica%20Joshi%20M.Tech..pdf>
5. Giardina, P., Faraco, V., Pezzella, C., Piscitelli, A., Vanhulle, S., & Sannia, G. (2010). Laccases: A never-ending story. *Cellular and Molecular Life Sciences*, 67(3), 369–385. <https://doi.org/10.1007/s00018-009-0169-1>

BIOREMEDIATION: When Nature Becomes the Healer of Our Planet

*Author: Niki Kansara
Semester-2, First Year
Department of Biotechnology*

What Exactly Is Bioremediation?

Bioremediation is a process where living organisms such as bacteria, fungi, and plants are used to remove or break down harmful pollutants from soil, water, and air. These organisms convert toxic substances into harmless products like water, carbon dioxide, and simple organic compounds. Scientists call it an “ecofriendly technology” because it reduces pollution without adding any new chemicals to the environment. As pollution is the biggest environmental challenge of all time. According to global environmental reports, nearly 40% of the world’s land and water ecosystems are affected by industrial waste, oil spills, pesticides, plastics, and toxic chemicals. Cleaning this massive damage using machines and chemicals is not only expensive but can sometimes create new pollution problems. This is where bioremediation – Nature's own healing technique – steps in.

How Does It Work?

Microorganisms naturally feed on pollutants as a source of energy.

For example: *Bacteria can digest oil and petroleum compounds.

*Fungi can break down pesticides and industrial chemicals.

*Plants (in a process called *phytoremediation*) absorb heavy metals like lead, mercury, and arsenic from soil.

Sometimes, scientists even enhance these microbes by providing nutrients or oxygen to speed up the cleaning process. This makes bioremediation powerful, natural, and scientifically controlled.

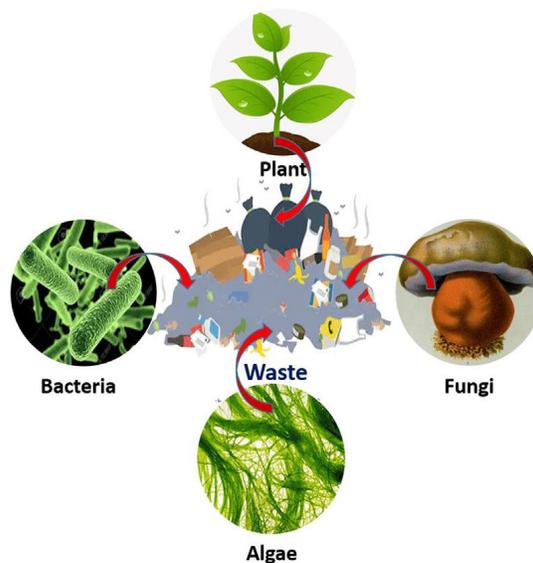


Figure 1: Diagram of microorganisms that feed on pollutants

Courtesy: Bob Barret., WUWF

Real-Life Success Stories

Bioremediation is not just theory – it has already helped solve major environmental disasters.

*After the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, naturally occurring bacteria broke down millions of barrels of spilled oil in seawater.

*In Ukraine and the United States, plants like sunflowers have been used to absorb radioactive contaminants and heavy metals from polluted soils.

*In India, bioremediation is being used to treat polluted rivers and industrial wastewater, helping restore ecosystems at lower cost compared to traditional methods.



Figure 2: Image of Oil spillage in the ocean of Gulf of Mexico
Courtesy : Naveen Kumar.,
Researchgate.net

Why Is Bioremediation Important?

*Eco-friendly: Does not harm the environment

*Cost-effective: Much cheaper than chemical cleanup

*Natural and sustainable: Uses organisms already present in nature

*Restores ecosystems: Helps bring life back to damaged soil and water

But It Has Challenges Too

Bioremediation is not a magic instant solution. It:

*Takes time, sometimes month or even years

*Need suitable temperature, oxygen, and nutrients

*Can not work on every type of chemical pollutant

Scientists are continuously researching to improve efficiency and expand its applications.

The Future Of Bioremediation

With increasing pollution and environmental awareness, bioremediation is becoming one of the most promising green technologies. Researchers are developing genetically improved microbes and smarter techniques to make the process faster and more effective. If supported widely, bioremediation could play a major role in building a cleaner, healthier planet.

Bioremediation teaches us that nature has the power to heal itself – if we allow it. Instead of always fighting pollution with chemicals, using nature's own tool may be the most intelligent and sustainable solution for our future.

References:

Atlas, R.M., & Hazen, T.C. (2011). Oil biodegradation and bioremediation: A tale of Deep water Horizon spill. Environmental Science & Technology.

Garbisu, C., & Alkorta, I. (2003). Basic concepts on heavy metal soil bioremediation. The European Journal of Mineral Processing and Environmental Protection.

National Oceanic and Atmospheric Administration. (2016). Deepwater Horizon oil spill – Restoration and progress report. Ministry of Environment, Forest and Climate Change, Government of India . (2020). Environmental sustainability and pollution management in India

Healing the earth naturally : the power of Bioremediation

*Author: Sanskruti Bhimani , Madhavi Pandya
Semester 2, First Year
Department of Biotechnology*

Biotechnology is an eco-friendly and cost effective technology that employs microorganisms such as bacteria , a fungi, and plants to degrade, detoxify and remove toxic substances from the environment. Common applications include treating industrial effluent, oil spills and contaminated sediments , making it a vital tool for addressing pollution from human activities. There are many techniques like in-situ and ex-situ treatments, biostimulation , bioaugmentation and many more. About 10 million tons of the toxic chemicals are released into air, land and water each year, meaning 310kg of toxic chemicals are released every second.

Microbes in Bioremediation

There are various microbes such as bacteria, fungi and algae that are used for bioremediation techniques. They detoxify heavy metals, paper and pulp effluent, polyaromatic hydrocarbons.

1. Bioremediation of paper and pulp effluent

The paper and pulp industry plays a vital role in releasing a toxic substance . Its effluent contains higher BOD[Biological oxygen demand] and COD[Chemical oxygen demand]. Bacteria *Enterobacter sp.* was isolated from tannic acid enriched soil reduced colour up to 82% and lignin up to 73%.

Another bacterial stain *Pseudochrobactrum glaciale* , *Providencia rettgeri*, and *Pantoea sp.* which reduce colour, COD and BOD by 96.02% , 91% and 92.59% . Bacteria *planococcus sp.* reduce concentration of phenol, lignin, colour and COD by 96%, 74%, 81% and 85% with 60 hours of incubation. Sonkar *et al.* reported *Bacillus sp.* degrading 82.22%, 89.50%, 93.33% and 73.01% TOC, COD, BOD and colour after 72 hours of treatment. Thermophilic ligninolytic *Serratia sp.* helps in reducing colour, lignin, phenol, BOD and COD up to 80%, 60%, 95%, 80% and 80% respectively.

2. Bioremediation of heavy metals

The metals that have high density such as chromium[Cr], Arsenic[As], Copper[Cu], etc are considered as heavy metals. The cadmium metal toxicity induces DNA breakage. They denature protein, disrupt cellular membrane, inhibit cell division. Joshi *et al.* reported that some fungi namely *Aspergillus awamori*, *A. flavus*, *Phanerochate chrysosporium* and *Trichoderma viride* are bioremediating lead, cadmium, chromium and nickel. Fungal genera like *Aspergillus*, *penicillium*, *Rhizopus*, *phlebia*, *Pleurotus* and many more helps in bioremediation process. Primarily, the bacteria eliminate heavy metal is adsorption on their cell surface. The

gram negative bacteria, namely, *Enterobacter sp.* bioremediating copper metal. The *Acinetobacter brisouii*, *Pseudomonas abietaniphila*, and *Planococcus rifietoensis* were degrading cadmium and arsenic. The carcinogenic heavy metals such as lead, cadmium and chromium detoxified by microbes such as *Gemella sp.*, *Hafnia sp.*, and *Micrococcus sp.*

3. Bioremediation of xenobiotics

Bioremediation of xenobiotics means breaking harmful substance into small pieces due to this surrounding is less polluted. Catabolism of aromatic compounds by hydrolysis, oxidation and dealkylation. Fungi like *White rot species* produce ligninase and laccases for degrading harmful compounds. Genetically engineered strains such as *P. putida* breakdown alpha-pollutants. It offers eco-friendly, cost effective solution for persistent xenobiotics using microbial activity. It is an promising strategy for our environment.

Techniques for a bioremediation

The eco-friendly and cheap techniques should be developed for bioremediating some toxic substance such as paper and pulp effluent, heavy metals, etc. . By this various methods the environment became less pollutant. Various microbes are used in the techniques such as in-situ and ex-situ. These microbes found in soil, land, drainage and water.

1. In-situ technique

In-situ is the application of biological treatment to clean chemicals from subsurface of earth. It offers powerful

and natural approach. There are sub division in in-situ bioremediation.

a) Biosparging

It makes the air-pressure high below the water table to increase ground water oxygen concentration to degrade the microbes. It mixes the soil and ground water concentration.

b) Bioventing

Bioventing stimulates the natural in-situ biodegradation of aerobically degradable within soil using microorganism. Oxygen is supplied in soil by means of wells. Fuels residuals are biodegraded and volatile compounds are degraded as vapour through biologically active soil.

2. Ex-situ technique

Ex-situ techniques involve collection of pollutants from a polluting sites by digging and take it to another site for treatment. It is categorised into solid-phase and slurry-phase depending on the types of pollutants. Agriculture, sewage sludge, industrial waste, domestic waste, municipal solid waste treatment include in solid-phase treatments. While, soil biopile, land treatment, petroleum hydrocarbon and many more treatments are included in slurry-phase treatments. Common techniques involves in ex-situ are composting, bioreactors and land farming. It is an environment friendly technique.

Conclusion

Bioremediation is a promising strategy for future. It can control pollution and it is also limited by type, specific, pH, temperature, etc. . It is a valuable tool. It uses natural processes for breakdown

toxic substance. It is also cheaper than excavation and incineration. It completely destroys the contaminants.

Reference

1. Chakraborty, S., Talukdar, A., Dey, S. et al. Role of fungi, bacteria and microalgae in bioremediation of emerging pollutants with special reference to pesticides, heavy metals and pharmaceuticals. *Discov Environ* 3, 91 (2025). <https://doi.org/10.1007/s44274-025-00217-7>
2. El-Sheekh, M.M., El-Kassas, H.Y. & Ali, S.S. Microalgae-based bioremediation of refractory pollutants: an approach towards environmental sustainability. *Microb Cell Fact* 24, 19 (2025). <https://doi.org/10.1186/s12934-024-02638-0>
3. Kour D, Khan SS, Kour H, Kaur T, Devi R, Rai PK, Judy C, McQuestion C, Bianchi A, SpeS, Mohan R, Rai AK, Yadav AN. Microbe-mediated bioremediation: Current research and future challenges. *J App Biol Biotech*. 2022;10(Suppl 2):6-24. DOI: <https://doi.org/10.7324/JABB.2022.10s202>
4. Sharma, S. (2012). Bioremediation: Features, strategies and applications. *Asian Journal of Pharmacy and Life Science*, 2(2), 202–213. https://www.researchgate.net/publication/264889107_Bioremediation_Features_Strategies_and_Applicationsde328b

Tiny Titans: How Nanoparticles are Shaping the Future

*Author: Heer Gandhi, Mahek Satasiya
Semester 2, First Year
Department of Biotechnology*

Imagine a world where cancer is treated with minimal drug doses, hospital visits decrease, and the therapies used do not leave toxic traces in future's environment. Nanotechnology at the 1–100 nm scale is not only transforming medicine but is also emerging as a key tool for sustainable healthcare systems that are efficient, resource-conserving, and environmentally responsible. By manipulating matter atom by atom, nanotechnology creates materials with high surface area, unique chemistry, and smart responsiveness that can cut waste, reduce side effects, and support greener synthesis routes such as plant-based nanoparticles.

Nanomedicine and Sustainable Healthcare

Nanotechnology in medicine supports sustainability by improving prevention, diagnosis, and treatment while lowering the overall ecological and economic burden of disease. Today, nanoparticles assist in multimodal bioimaging, blood coagulation control, and in vivo or in vitro detection, but their real sustainability impact lies in doing “more with less”: less drug, less energy, and fewer procedures for the same or better outcomes.

Types of nanoparticles in medical field includes:

- Metallic nanoparticles (gold, iron, Silver) often synthesized using methods to avoid toxic solvents.
- Lipid-based nanoparticles (solid-lipid nanoparticles, liposomes) derived from natural, biodegradable sources.
- Polymeric nanoparticles (micelles, protein nanoparticles) designed for recyclability and minimal environmental persistence.
- Plant-based nanoparticles (e.g., silver nanoparticles synthesized from neem leaves) promoting sustainable, bioderived production.

Revolutionary Applications:

1. Precision Drug delivery

Nanotechnology has revolutionized the field of drug delivery by providing an effective and targeted delivery of drugs, minimizing side effects, toxicity and increasing the therapeutic efficacy of drugs. Their miniature size enables enhanced permeability and retention effects, allowing them to selectively accumulate in areas such as tumor microenvironments thereby delivering high doses with much smaller quantities. This has several advantages such as lower drug consumption, reduced side effects, and targeted controlled release; minimize manufacturing demands, resource use,

pharmaceutical waste, treatment duration, and overall healthcare carbon footprint.

2. Super-Early Diagnosis

Nanoparticles make it possible to spot diseases very early by glowing cancer cells, telling tumors apart from healthy parts, and finding disease signs in just one drop of blood. This lets doctors use gentler treatments. For sustainability, catching issues early stops them from getting worse, so patients skip heavy treatments like lots of chemo or big operations. These tiny sensors use fewer chemicals and samples, creating less lab trash. Better imaging with nanoparticles in scans like PET, MRI, or ultrasound needs less dye and fewer tests, saving energy and cutting harmful exposure. They boost signals from rare disease markers for easy blood tests, reducing painful biopsies, supplies, drugs and lab work.

3. Next-Gen Therapies

Nanotechnology is revolutionizing gene therapy and immunotherapy by delivering long-term or curative benefits with reduced lifetime treatment burdens. In gene therapy, lipid nanoparticles, polymeric carriers, and carbon-based nanomaterials serve as protective "nano-vans" for CRISPR, siRNA, or mRNA, enhancing stability and cellular uptake to transform chronic diseases into one-time or infrequent treatments, thereby cutting drug use and clinical demands. For immunotherapy, nanoparticles enable targeted co-delivery of checkpoint inhibitors, cytokines, antigens, or mRNA to immune cells or tumors on a single platform, boosting efficacy to require fewer cycles, minimizing systemic toxicity and supportive care,

and supporting personalized formulations that avoid overtreatment. Using biodegradable, bio-derived, or recyclable components further enhances sustainability by preventing tissue or ecosystem accumulation post excretion.

4. Fighting Superbugs & Viruses

Antimicrobial resistance (AMR), a medical and environmental crisis driven by antibiotic overuse, can be addressed by nanoparticle-based antimicrobials and antiviral strategies that operate at the microbial scale—disrupting membranes, releasing metal ions, or blocking viral entry and replication. These approaches promote sustainability by enabling lower-dose, shorter-duration therapies that minimize antibiotic release into wastewater and soils; targeted delivery improves bioavailability and stability, reducing reliance on broad-spectrum regimens; and effective alternatives slow resistance evolution, preserving drugs while curbing high-footprint R&D. However, metallic nanoparticles like silver and copper require safe-by-design principles to prevent toxicity to beneficial microbes and aquatic life.

5. Green Nanoparticles Unleashed for Sustainability

Truly sustainable nanomedicine requires attention not only to clinical performance but also how nanoparticles are produced, used, and disposed of. Green synthesis methods using plant extracts, microorganisms, or low-energy processes minimize hazardous solvents and high-temperature reactions.

Key sustainability strategies includes:

- Using renewable feedstocks (botanical extracts, biopolymers) for nanoparticle production.
- Optimizing formulations for biodegradability and minimal bioaccumulation.
- Conducting life-cycle assessments (LCA) to quantify energy use, emissions, and waste from lab to clinic and back to the environment.
- Implementing regulatory frameworks that require eco-toxicological evaluation and encourage safer alternatives.

Conclusions

Nanotechnology is revolutionizing sustainable medicine through precise drug delivery, early diagnosis, and therapies that cut drug use, hospital resources, and environmental harm. Eco-friendly plant based nanoparticles, biodegradable carriers, and smart nanoplatfoms advance low-waste, patient-centric care aligned with global sustainability goals. Yet challenges like toxicity, environmental persistence, regulatory gaps, and scaling green synthesis demand safe-by-design principles, rigorous testing, and responsible commercialization. With smart governance, these tiny titans can fuel medical breakthroughs and a greener, equitable global health future.

References

1. Ajaz, M., Rasool, W., & Mahmood, A. (2024). Comprehensive Review of Nanotechnology: Innovations and Multidisciplinary Applications. *Futuristic Biotechnology*. <https://doi.org/10.54393/fbt.v4i01.81>
2. Campora, Simona and Gherzi, Giulio. "Recent developments and applications of smart nanoparticles in biomedicine" *Nanotechnology Reviews*, vol. 11, no. 1, 2022, pp. 2595-2631. <https://doi.org/10.1515/ntrev-2022-0148>
3. Sharmin, S., Rahaman, M., Sarkar, C., Atolani, O., Islam, M., & Adeyemi, O. (2021). Nanoparticles as antimicrobial and antiviral agents: A literature-based perspective study. *Heliyon*, 7. <https://doi.org/10.1016/j.heliyon.2021.e06456>
4. Patra, J., Das, G., Fraceto, L., Campos, E., Rodriguez-Torres, M., Acosta-Torres, L., Díaz-Torres, L., Grillo, R., Swamy, M., Sharma, S., Habtemariam, S., & Shin, H. (2018). Nano based drug delivery systems: recent developments and future prospects. *Journal of Nanobiotechnology*, 16. <https://link.springer.com/article/10.1186/s12951-018-0392-8>
5. Rehan, F., Zhang, M., Fang, J., & Greish, K. (2024). Therapeutic Applications of Nanomedicine: Recent Developments and Future Perspectives. *Molecules*, 29. <https://doi.org/10.3390/molecules29092073>

Green Pharmaceuticals: Rethinking Healthcare for a Sustainable Future

*Author: Kavya Dhaval Shah
Semester 4, Second year
Department of Biotechnology*

Introduction:

Medicines have transformed human health, saving millions of lives and improving quality of life across the world. However, behind every tablet, capsule, or injection lies a complex production system that often places pressure on the environment. Conventional pharmaceutical manufacturing involves energy-intensive processes, toxic solvents, excessive packaging, and large-scale waste generation. Additionally, pharmaceutical residues entering water bodies pose risks to ecosystems and public health.

In response to these challenges, the concept of green pharmaceuticals has emerged. This approach integrates environmental responsibility into drug development and healthcare systems, ensuring that innovation does not come at the cost of environmental sustainability.

What Are Green Pharmaceuticals?

Green pharmaceuticals focus on designing and producing medicines using environmentally friendly

principles. The approach is inspired by green chemistry, which emphasizes reducing hazardous substances, conserving energy, and minimizing waste throughout the drug life cycle.

Instead of treating pollution after it occurs, green pharmaceutical practices aim to prevent environmental damage at the source. This shift is especially important as global demand for medicines continues to grow.

Green Chemistry: A Foundation for Sustainable Drug Production

Traditional drug synthesis often requires multiple reaction steps, high temperatures, and harmful chemicals. Green chemistry offers safer alternatives by improving efficiency and reducing waste generation.

Key green chemistry practices include:

- Using safer or bio-based solvents

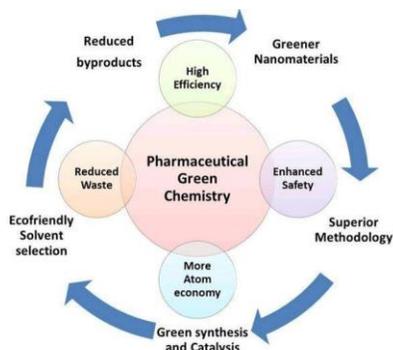


Figure:1 representation of the procedures of pharmaceutical industries towards green chemistry principles
Courtesy: ResearchGate

Reducing the number of reaction steps

- Improving atom economy to minimize by-products
- Lowering energy consumption through efficient reaction conditions

These strategies make pharmaceutical production cleaner while maintaining drug quality and effectiveness.

Biotechnology and Sustainable Drug Development

Biotechnology plays a vital role in advancing green pharmaceuticals. Biological systems such as microorganisms and enzymes enable drug production under mild conditions, reducing the need for harsh chemicals.

Examples include:

- Microbial fermentation for antibiotics and vaccines
- Enzyme-based drug synthesis
- Plant-derived pharmaceutical compounds

These biotechnological methods are not only environmentally friendly but also scalable and cost-effective.

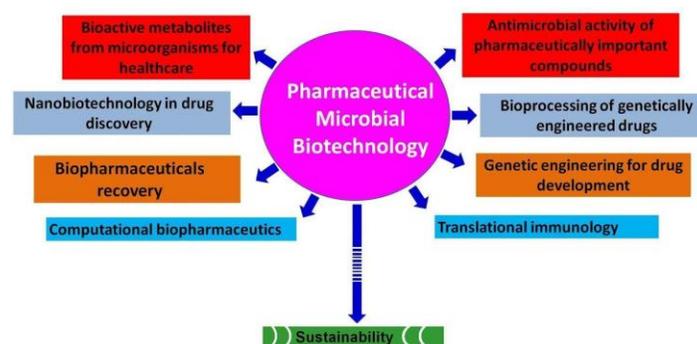


Figure-2: Current trends in pharmaceutical microbial biotechnology
Courtesy: Journal of applied pharmaceutical science

Greening the Pharmaceutical Supply Chain

Sustainability in pharmaceuticals extends beyond manufacturing. Packaging, transportation, and storage contribute significantly to environmental impact. Green pharmaceutical supply chains focus on reducing carbon emissions and waste through:

- Eco-friendly and recyclable packaging
- Optimized transportation routes

- Energy-efficient storage systems

Reducing excess packaging and improving logistics also help minimize drug wastage and resource consumption.

Environmental Safety and Responsible Drug Use

Many pharmaceutical compounds persist in the environment after use, affecting aquatic life and promoting antimicrobial resistance. Green pharmaceutical design encourages the development of biodegradable drugs that break down into non-toxic substances.

Public awareness, proper disposal practices, and medicine take-back programs further support environmental protection.

Benefits of Green Pharmaceuticals

The shift toward green pharmaceuticals offers several benefits:

- Reduced environmental pollution
- Safer manufacturing processes
- Long-term economic efficiency
- Improved public trust in healthcare systems
- Contribution to global sustainability goals

Challenges and the Road Ahead

Despite growing interest, challenges such as high initial costs, regulatory barriers, and limited access to green technologies slow adoption. However, advancements in synthetic biology, digital supply chains, and circular bioeconomy models offer promising solutions.

Collaboration among researchers, industries, and policymakers will be essential for accelerating sustainable pharmaceutical innovation.

Conclusion

Green pharmaceuticals represent a balanced approach to healthcare—one that protects human health while preserving environmental integrity. By integrating green chemistry, biotechnology, and sustainable supply chain practices, the pharmaceutical industry can innovate responsibly and build a healthier future for both people and the planet.

References:

Anastas, P. T., & Warner, J. C. (1998). *Green chemistry: Theory and practice*. Oxford University Press.

Kümmerer, K. (2010). Pharmaceuticals in the environment. *Annual Review of Environment and Resources*, 35, 57–75. 223

World Health Organization. (2022). *Sustainable healthcare and pharmaceutical practices*.

Sustainable Healthcare: Antimicrobial Stewardship to Reduce Antibiotic Resistance

*Author: Heer Shah
Semester 4, Second Year
Department of Biotechnology*

Abstract

Antibiotics are one of the most significant discoveries in the history of medicine that effectively treats bacterial infections but its inappropriate use leads to antibiotic resistance – a global threat in which bacteria becomes resistant to antibiotics resulting into prolonged illness. In order to overcome this crisis, the concept of Antimicrobial Stewardship (AMS) was introduced. Antimicrobial stewardship refers to a coordinated and systematic approach in order to ensure the use of antimicrobial drugs (antiviral, antibacterial, antifungal etc) in an appropriate proportion in order to reduce its adverse effects like: antimicrobial resistance, lower healthcare costing and minimise harmful effects of drugs. Antimicrobial stewardship is about using antimicrobials responsibly that promotes actions including the balance between an individual's need for appropriate treatment and the need of society for sustained access to effective therapy.

Emergence Of Antimicrobial Stewardship

John E. McGowan Jr and Dale N. Gerding of USA were the first one's to publish an article on antimicrobial stewardship suggesting the use of

antibiotics only when necessary. Then in 1997, two American colleagues included it for the prevention of antimicrobial resistance in hospitals in the guidelines of SHEA (Society for Health Epidemiology of America) and IDSA (Infectious Diseases Society of America). In 1999 this term crossed Atlantic Ocean due to the informal contacts of two European colleagues, Ian Gould and Jos van der Meer who founded ESGAP (the European Society of Clinical Microbiology and Infectious Diseases Study Group for Antimicrobial stewardship) that helped to amplify the use of word 'Antimicrobial Stewardship' worldwide.

Role of AMS in reducing antimicrobial resistance

The principles established in Antimicrobial Stewardship Program helps to achieve reduced antibiotic resistance through judicious use of antibiotics. Different strategies such as educating general citizens and healthcare professionals about distinct characteristics of bacterial infections, emphasizing personal hygiene and promoting responsible antibiotic prescription practices can help in managing resistance.

De-escalation strategies: It refers to modifying the initial antimicrobial

regimen according to the patient's requirement and laboratory data analysis. It involves shifting to a narrow spectrum of antibiotics from a broader one or even discontinuing the treatment if necessary.

Improving antibiotics: Multidrug resistant bacteria kills lakhs of people annually. As the efficiency of drug decreases, the demand for improving antibiotics rises. As a result, changes can be made by increasing the life of current antibiotics or by making a combination of two of them or changing adjuvants of already existing drugs.

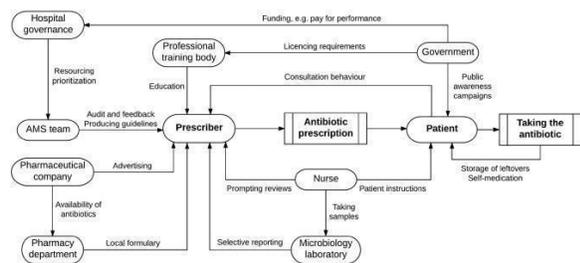


Fig 1: Examples of actors and actions within antimicrobial stewardship (AMS)

[courtesy: sciencedirect.com]

Antimicrobial Stewardship and Sustainable Healthcare

Antimicrobial stewardship is closely linked to sustainable healthcare. By promoting rational use of antibiotics, not only patient outcomes can be improved but also the healthcare costing is reduced by minimising adverse drug effects, shortening hospital stays and also avoiding expensive treatments for resistant infections. It also contributes to ecological sustainability as it protects the environment from pharmaceutical pollution as reduced discharge of antibiotics into the water bodies would

limit the growth of resistant bacteria into the environment. Stewardship ensures long term effectiveness of the existing drugs reducing reliance on development of new costlier drugs.

Challenges in Implementing AMS

The challenges identified from studies in implementing Antimicrobial Stewardship Program includes lack of knowledge of administration and their cooperation regarding AMS programs and strategies. Lack of resources such as finances, human resources, microbiology facilities to support Culture and Drug Sensitivity Testing and IT support hinders the successful implementation of the program. Prescription of irrational antibiotics by the healthcare professionals due to uncertainty in diagnostics, treatment failure or pressure from patients could also be a challenge. Limited monitoring of antibiotic consumption and resistance patterns makes it difficult to evaluate the effectiveness of stewardship interventions. The figure mentioned below describes challenges:

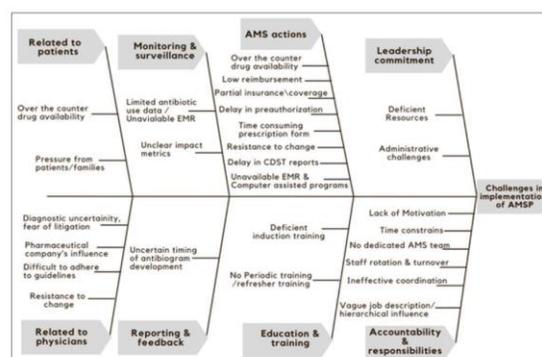


Fig 2: Describes the challenges in implementing ASMP

[Courtesy: researchgate]

Conclusion

Sustainable Antimicrobial Stewardship is a vital strategy in the global fight against antibiotic resistance and the advancement of sustainable healthcare system. It is fundamental to maintaining equitable and long-term access to effective antimicrobial therapies for present and future populations. By promoting the rational, evidence-based use of antimicrobials, stewardship programs help preserve the effectiveness of existing antibiotics, improve patient outcomes, and reduce the economic and environmental burden associated with resistant infections. Integrating antimicrobial stewardship into healthcare policies and clinical practice strengthens health system resilience, particularly in resource-limited settings where access to new antimicrobials is constrained.

References

1. O.J. Dyar ¹, B. Huttner ², J. Schouten ³, C. Pulcini ⁴ on behalf of ESGAP (ESCMID Study Group for Antimicrobial Stewardship). *Clinical Microbiology and Infection*.
2. Sagar N. Khadse, Sarita Ugemuge, Charu Singh. *Impact of Antimicrobial Stewardship on Reducing Antimicrobial Resistance*.
3. Shikha Yadav, Mayank Sharma, Kavita Rajesh, Priyanka Khuda, Shailja Anand, Vibhor Dudhraj, Suneet Kaur, Arti Bahl, Sujeet Kumar Singh. *Challenges Faced by Health Facilities in Implementing Antimicrobial Stewardship Program: A Narrative Review*

Prescribing Sustainability: The Green Evolution of Healthcare

*Author: Priyanshi R. Patel
Semester 4, Second Year
Department of Biotechnology*

Introduction

In the 21st century, the global healthcare sector faces a paradox: while striving to improve human health, it contributes significantly to environmental degradation. Pharmaceuticals, in particular, are essential for treating illness and saving lives—but their lifecycle, from discovery to disposal, poses environmental and health challenges. As the world confronts climate change, biodiversity loss, and pollution, the notion of green pharmaceuticals—eco-friendly drug design, production, and usage—is gaining traction as a critical element of sustainable healthcare.

1. The Environmental Footprint of Pharmaceuticals

Pharmaceuticals, while vital for medical treatment, exert a considerable environmental burden. During manufacturing, energy-intensive processes and hazardous chemicals generate waste containing active pharmaceutical ingredients (APIs) and solvents. If inadequately treated, this waste contaminates water bodies and soil.

After consumption, a significant portion of drugs is excreted unchanged or as metabolites, entering wastewater systems. Conventional treatment plants

are often incapable of fully removing these compounds, leading to their presence in rivers and oceans.

Ecologically, pharmaceuticals act as persistent pollutants. Hormones disrupt aquatic reproduction, antibiotics accelerate antimicrobial resistance (AMR), and certain painkillers have caused dramatic declines in wildlife populations. Improper disposal of unused medicines and excessive plastic packaging further exacerbate environmental pollution.

2. What Are Green Pharmaceuticals?



Figure 1- Concept of biotechnology. Courtesy: Springer Nature

Green pharmaceuticals refer to medicines that are designed, manufactured, used, and disposed of in ways that minimize environmental impact while ensuring patient safety

and therapeutic effectiveness. The concept emphasizes sustainability across the entire pharmaceutical lifecycle.

The key features of green pharmaceuticals include:

- **Environmentally Benign Drug Design:**
Drugs are designed to degrade into non-toxic substances after use, reducing persistence in water, soil, and living organisms.
- **Application of Green Chemistry Principles:** safer solvents, renewable raw materials, energy-efficient processes, and reduced waste generation are prioritized during drug synthesis.
- **Reduced Environmental Toxicity:** Active pharmaceutical ingredients are evaluated for eco-toxicity, bioaccumulation, and long-term environmental effects.
- **Efficient Manufacturing Processes:** Cleaner production technologies aim to lower emissions, wastewater contamination, and hazardous byproducts.
- **Rational and Responsible Use of Medicines:** Appropriate prescribing, optimized dosing, and shorter treatment durations help reduce unnecessary drug release into the environment.
- **Sustainable Packaging and Distribution:** Use of recyclable, biodegradable, and minimal packaging materials decreases plastic waste and carbon footprint.

- **Safe Disposal and Waste Management:**
Take-back programs and controlled disposal methods prevent pharmaceutical residues from entering ecosystems.

Overall, green pharmaceuticals integrate environmental responsibility with healthcare delivery, supporting sustainable development without compromising medical efficacy.

3. Strategies for Sustainable Pharmaceutical Practices

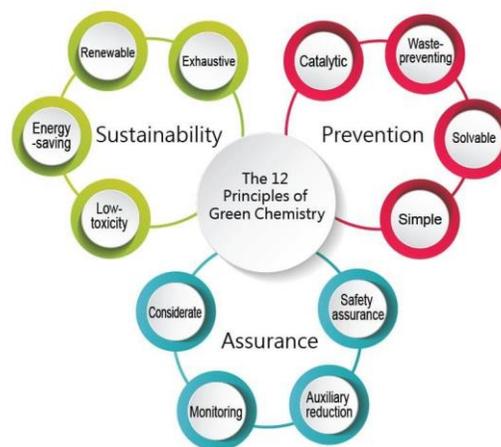


Figure 2- principles of green pharmaceuticals.

Courtesy: Everlight Chemical

a) Green Drug Design

Green drug design focuses on developing molecules that degrade into harmless substances after exerting their therapeutic effect. Such drugs reduce environmental persistence and toxicity while maintaining clinical efficacy.

b) Green Chemistry in Manufacturing

Applying green chemistry principles minimizes solvent use, reduces hazardous reagents, improves energy efficiency, and lowers waste generation, making pharmaceutical production cleaner and safer.

c) Advanced Wastewater Treatment

Technologies such as membrane filtration, advanced oxidation processes, and bioreactors improve the removal of pharmaceutical residues from wastewater before environmental release.

d) Rational Prescribing and Use

Healthcare professionals play a crucial role by avoiding overprescription, especially of antibiotics, and ensuring appropriate dosage and treatment duration. Patient awareness also reduces misuse.

e) Take-Back Programs and Safe Disposal

Medicine take-back initiatives prevent improper disposal by collecting unused drugs for safe treatment, reducing environmental contamination.

f) Sustainable Packaging

Use of recyclable materials, reduced plastic content, and minimalist packaging designs significantly lowers pharmaceutical waste.

g) Monitoring and Research

Continuous monitoring of pharmaceutical residues and ecotoxicological research help identify

risks and guide sustainable policy development.

4. Policy and Regulatory Dimensions

Strong regulatory frameworks support green pharmaceutical adoption. Environmental risk assessments (ERAs) evaluate ecological impacts before drug approval. Antimicrobial stewardship programs regulate antibiotic use to limit resistance. Extended Producer Responsibility (EPR) policies hold manufacturers accountable for product lifecycle impacts. International cooperation further strengthens global sustainability efforts.

5. Challenges in Implementing Green Pharmaceutical Practices

Economic constraints, scientific complexities, regulatory inconsistencies, and lack of awareness remain major barriers. High implementation costs, limited global standards, and behavioral resistance among prescribers and patients slow the transition toward green pharmaceuticals.

6. Benefits of a Greener Pharmaceutical Future

Green pharmaceuticals promote healthier ecosystems, reduce public health risks, lower long-term costs, and enhance ethical responsibility within healthcare systems. Sustainable practices also support innovation and resilience.

7. Spotlight on Innovation and Emerging Trends

Innovations such as biodegradable drug carriers, AI-based drug design, continuous manufacturing, and circular economy models are shaping the future of sustainable pharmaceuticals through collaborative efforts.

Conclusion

Green pharmaceuticals represent a paradigm shift in how society understands and manages health and environmental well-being. By embedding sustainability into the entire pharmaceutical lifecycle—from discovery to disposal—healthcare systems can continue to save lives without compromising ecological integrity. Transitioning to sustainable healthcare is complex but necessary, requiring innovation, policy support, and collective responsibility. In an era of environmental urgency, green pharmaceuticals offer a path where medicine heals both people and the planet.

References:

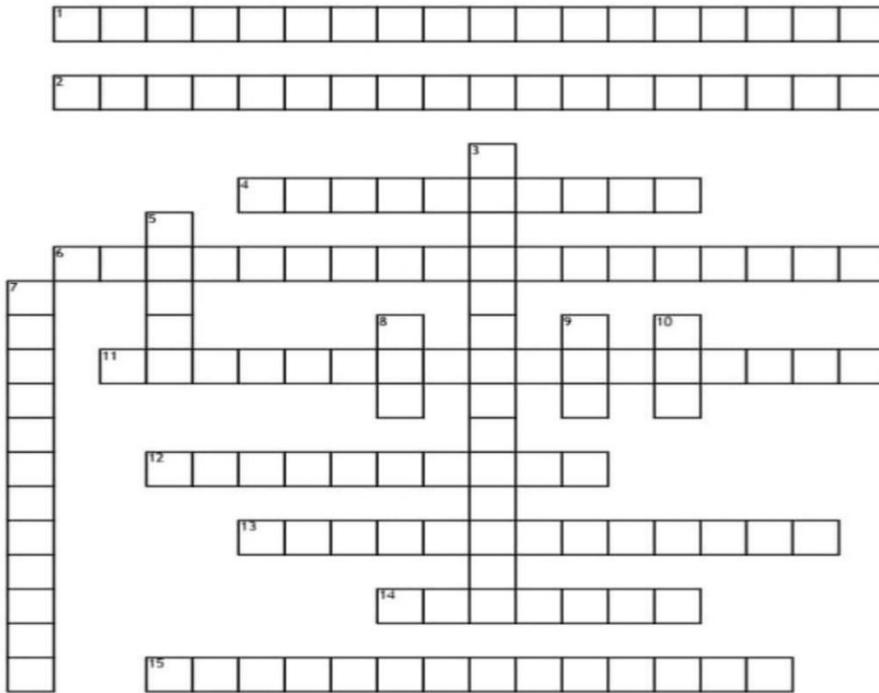
Caroline T.A Moermond, Neel Puhlman, A Ross Brown, Stewart F. Owen, Jim Ryan, Jason Snape, Bastiaan J. Venhuis, and Klaus Kiummerrer.- Green pharmaceutical and more sustainable healthcare (2022). Site environmental science and technology letters.

https://link.springer.com/chapter/10.1007/978-981-97-9707-3_3

Int.J Environ. Res. Public Health 2023, 20(2), 908, <https://doi.org/10.3390/ijerph20020908>

CREATIVE CORNER

Cross Word



Across

1. process of making changes in DNA code of living organisms
2. genetic alternation of a cell
4. continued breeding of the individuals with similar characteristics of a line of organisms
6. procedure used to spread and analyze DNA fragments by placing a mixture of DNA fragments at one end of a porous gel and applying an electrical voltage from different sources
11. enzyme that cuts DNA at a specific sequence of nucleotides
12. term used to refer an organism that contains genes from other organisms
13. breeding technique that involves crossing dissimilar individuals to bring together the best traits of both organisms

14. small circular piece of DNA

15. method of breeding that allows only those individual organisms with desired characteristics to produce the next generation

Down

3. DNA produced by combining DNA from different sources
5. member of a population of genetically identical cells
7. gene that makes it possible to distinguish bacteria that carry a plasmid with foreign DNA from those that don't
8. technique that allows molecular biologists to make many copies of a particular gene
9. stands for ribonucleic acid
10. stands for deoxyribonucleic acid

Solve the jumble words

1. MYETACZIN		8. ENWELBRAOIBSROUCES	
2. RHYTOMEDITAENOPA		9. IONNVEOCOTAI	
3. NORFIBXACITANO		10. TSAEWOTSECRUROE	
4. NEREEGMNEEZIGNYNE		11. CETSYHNTOECCOLOYG	
5. XOCOTOLGICEOY		12. EGRENTRAVIEE	
6. TAMGNEOICSME		13. COBIMIREMO	
7. YIBRLMCOAYSNREGY		14. CIRALRUITOYBIC	

Fields of Biotechnology

S E L E C T I V E B R E E D I N G H W C R G M C
 M P Y B G L R E C O M B I N A N T D N A F V P N
 N K G C Q O I G J W M L A I Q F U S G B I E Y E
 O Z O K S Q N V A I A G R I C U L T U R A L R Y
 Y G L R P C D W L V H U E C A O J E T X L S O G
 S T O A X N O I T A I D E M E R O I B N W R T M
 M R N G M F H O P K T L J J Q C H C V D K L A R
 Q A H E W O R A A Y S V M Y H A I F R R P B L E
 I N C N U Y B P C P H E R V E S E Y I C W Y U O
 Z S E E P K O C D S D N Z R N R H G X H S H G Z
 Y G T C M Z Q G I I G D U E M P V F M Z C E E L
 G E O L T W M F C Z Y T R E A W F X A S K R R T
 O N N O Q X B A I G L O N R R W N S T H R N Q L
 L I A N J M L A W U F T E S V O Y E A O P X I Q
 O C N I A Z X M C Z A H U S O M M R C T X J U H
 N P K N K Y Y A W T T J X C C C B H I Y C N V B
 H L T G L Q U O I E Q X B G E I Z X K L L E A N
 C A A R D Q L O N N Y A Q L V A M G Y T S J N D
 E N V D A O N E S X L K L Y J M E O C R K M U D
 T T B D R N G T R A N S G E N I C A N I M A L S
 O S E P H F K A F B N V O V F X Z Z B E R K M P
 I R K J Y Z C I T A U Q A G U B U U T F G D V F
 B B B A J D C U G Q W V M Y X E W A L S Y B K C
 N B Z E F L A M I N A S V L M I C R O B I A L S

transgenic animals	selective breeding	transgenic plants	recombinant DNA
nanotechnology	bioremediation	gene therapy	biotechnology
agricultural	gene cloning	fermentation	aquaculture
regulatory	stem cell	microbial	genomics
forensic	medical	aquatic	animal

Fun Facts

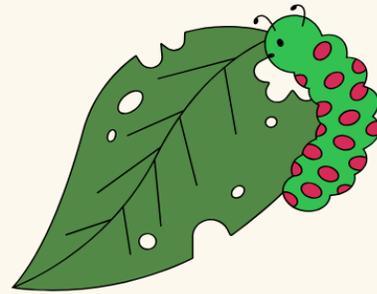
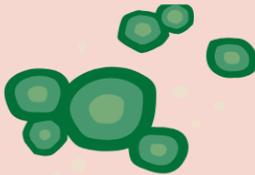


1

Penicillin was discovered because of moldy food

Alexander Fleming forgot to clean his lab. Result? Antibiotics that saved millions of lives.

 Moral of biotech: sometimes laziness = Nobel Prize.



2 **Plant can cry for help** 

When attacked by insects, plants release chemical signals saying "HELP, I'M BEING EATEN." Biotechnology reads these signals to protect crops. Plants are dramatic... and biotech understands them.

5

Yeast decides how soft your bread is

Same organism produces bread, alcohol, biofuel.

Yeast has more career options than humans



3

Curd = biotechnology experiment in your kitchen

Milk + bacteria = curd
No lab coat.
No PhD.
No permission.

Yet you're literally culturing microbes at home.



6

Vaccines don't fight disease

They train Your immune system does the fighting.

Vaccine = crash course, not bodyguard.



4

Your heartbeat is controlled by electricity, not muscles

Heart muscles listen to electric signals 
Power cut = problem.



Answer for cross words
Across

1. Genetic Engineering:
2. Transformation:
4. Inbreeding:
6. Gel Electrophoresis:
11. Restriction Enzyme:
12. Transgenic:
13. Hybridization:
14. Plasmid:
15. Selective Breeding:
Down
3. Recombinant DNA
5. Clone:
7. Genetic Marker:
8. PCR:
9. RNA:
10. DNA:

Answer for jumble words

1. ENZYMATIC
2. PHYTOREMEDIATION
3. CARBON FIXATION
4. ENZYME ENGINEERING
5. ECOTOXICOLOGY
6. METAGENOMICS
7. MICROBIAL SYNERGY
8. RENEWABLE BIOSOURCES
9. ECOINNOVATION
10. WASTE TO RESOURCE
11. SYNTHETIC ECOLOGY
12. REGENERATIVE
13. MICROBIOME
14. BIOCIRCULARITY

Gallery of Achievements and Activities



Teacher's Day Celebration held by Students on 05/09/25 in MG Science Institute.



Students of Sem-II B.S. Biotechnology came second in the poster and Model presentation held at Charusat University.



Diya Shah of Sem-IV B.S. Biotechnology secured second position in the Minaxi Lalit Science Award 2025 organised by Gujarat Science Academy.



Students of Sem-IV B.S. Biotechnology visited the Gujarat Biotechnology Research Centre.

Gallery of Achievements and Activities



Shreeraj Mistry of Sem-II B.S. Biotechnology earned Player of the match in MG Premier League.



Students from FY & SY B.S. Biotechnology became champions by ranking First in multiple sport events held during MG Science Sports Week.



Students from Sem-II B.S. Biotechnology won many competitions during the Cultural Fest.



Students of FY & SY posing for Group photo during the cultural fest held at MG Science Institute.

Gallery of Achievements and Activities



Karan Kuchhadiya of Sem-IV B.S. Biotechnology winning multiple medals in various games during sports week at MG Science Institute.



Students of FY & SY winning the debate competition held at MG Science Institute.



Students of FY & SY B.S. Biotechnology celebrating Sir Gregor Mendel's birth anniversary by playing treasure hunt based on the scientist's research.



Students of Sem-IV B.S. Biotechnology attending a workshop based on mushroom cultivation held at MG Science Institute.

Gallery of Achievements and Activities



Students of Fine Arts Club organized Art Carnival Event.



Core Team of BioGazette.



Technical Team of BioGazette.



Members of BioGazette.



The Editorial Board with Faculties.

NOTE OF THANKS

*The publication of the first edition of **BioGazette**, the departmental magazine of the Department of Biotechnology, marks a significant milestone for our department. This achievement has been made possible through the collective efforts, dedication, and support of many individuals, and we take this opportunity to express our sincere gratitude to all who contributed to bringing this inaugural edition to life.*

*We extend our heartfelt appreciation to the authors and student contributors, whose thoughtful articles, innovative ideas, and creative expressions form the foundation of this magazine. Your enthusiasm and commitment have enriched **BioGazette** with academic depth and originality, making this first edition a true reflection of the intellectual curiosity and scientific spirit of our department.*

We are deeply grateful to our respected faculty members and especially Dr. Shivani Raval for their invaluable guidance, encouragement, and academic support throughout the process. Your mentorship and constant motivation played a crucial role in shaping both the quality of the content and the confidence of the students involved. We sincerely appreciate the time and effort you dedicated to reviewing contributions and inspiring excellence in the field of biotechnology.

*Our sincere thanks also go to the editorial team, whose dedication, coordination, and teamwork ensured the successful compilation and presentation of this magazine. From managing submissions to editing, designing, and finalizing the layout, your behind-the-scenes efforts were instrumental in making the first edition of **BioGazette** a success.*

*Finally, we extend our warm thanks to our readers—students, faculty, alumni, and well-wishers—whose interest and encouragement give purpose and meaning to this initiative. Your support motivates us to continue developing **BioGazette** as a platform for learning, collaboration, and innovation.*

*With sincere appreciation,
The Editorial Team
BioGazette.*

"Sustainability is not merely preservation — it is innovation guided by responsibility.

Through biotechnology, we learn to read nature's code, redesign its possibilities, and restore its balance. The future will not be built by replacing life, but by understanding it — engineering solutions that heal ecosystems, nourish populations, and redefine progress. To sustain and innovate is to recognize that every discovery today becomes the living foundation of tomorrow."

SCAN FOR WEBSITE & FEEDBACK



For any query: biotech.mgsi@gmail.com
Follow us on Instagram: biotech_corner.mgsi



BIOTECH CORNER

M.G. Science Institute

Dada Saheb Mavlankar Campus,, MG Science College Rd, Opposite
Gujarat University University, Navrangpura, Ahmedabad, Gujarat 380009