Biomaterials – Challenges and Opportunities

Mains: *GS-III – Science & Technology | Bio-technology | Developments and their applications and effects in everyday life*

Why in News?

As countries look to shift to cleaner processes to manufacture consumer products, be it plastics or textiles, biomaterials will become the new frontier of materials engineering.

What are biomaterials?

- **Biomaterials –** The materials derived wholly or partly from ***biological sources***, or engineered using ***biological processes***, that are designed to replace or interact with conventional materials.
- **Applications –** They are increasingly used across sectors such as packaging, textiles, construction, and healthcare.
- **Common examples** include –
  - Bioplastics made from plant sugars or starch,
  - Bio-based fibres used in textiles, and
  - Medical biomaterials such as biodegradable sutures and tissue supports.
- **Categories** – Biomaterials can be broadly categorised into 3 types -
  - **Drop-in biomaterials** – It is *chemically identical to petroleum-based materials* and can be used in existing manufacturing systems (such as bio-PET);
  - **Drop-out biomaterials** – It is *chemically different* and require new processing or end-of-life systems (such as polylactic acid or PLA); and
  - **Novel biomaterials** – It offer *new properties* not found in conventional materials, such as self-healing materials, bioactive implants, and advanced composites.

Why does India need biomaterials?

- **Green Growth Pathway** – For India, biomaterials address multiple goals, including environmental sustainability, industrial growth, revenue generation, and supporting farmer livelihoods through a single pathway.
- **Import reduction** – Indigenous biomaterials biomanufacturing can reduce India's heavy dependence on fossil-based imports for plastics, chemicals, and materials.
- **Farm Income Diversification** – It would also enable diversified value for agricultural feedstocks and residues, offering farmers new income streams beyond food markets.
- **Global Competitiveness** – As global regulations and consumer preferences shift toward low-carbon and circular products, biomaterials position the Indian industry to

remain competitive in export markets.
- **Policy Alignment** – Biomaterials also support domestic policy goals around waste reduction, such as the ban on single-use plastics and climate action goals.

Where does India stand today?

- **Strategic Growth Opportunity** – India's biomaterials sector, spanning bioplastics, biopolymers, and bio-derived materials, is rapidly emerging as a strategic industrial and sustainability opportunity.
- **Market value** – With the bioplastics market alone valued at around $500 million in 2024 and forecast to grow strongly through the decade.
- **Major PLA investment** – Balrampur Chini Mills planned Poly Lactic Acid (PLA) plants investment in Uttar Pradesh is one of the biggest investments in India.
- **Domestic innovation & startups** – Like Phool.co, converting temple flower waste into biomaterials and Praj Industries, who have their own demonstration-level bioplastics plant in progress.

What are other countries doing?

- **EU –** It has moved to a single, binding Packaging and Packaging Waste Regulation (EU) 2025/40 (PPWR) that recognises that compostable packaging has demonstrable environmental benefits for specific applications.
- **UAE –** It is positioning itself as a major manufacturing base via large-scale PLA investment.
    - **For Example,**Emirates Biotech is building a PLA plant using Sulzer technology, with two phases of 80,000 tonnes per year, the plant is expected to start in 2028, once complete, *will be the world's largest PLA facility*.
- **U.S. –** It is leading in a number of transformative technologies, securing it as a leader in biomaterials.
- A push for biomaterials comes through its federal purchasing power through the USDA's BioPreferred program.

What are the issues need to be addressed?

- **Feedstock competition –** If feedstocks also do not scale with increased demand, there could be feedstock competition with food sources.
- **Water stress & Soil degradation –** Aggressive agricultural practices could lead to water stress and soil deterioration.
- **Weak infrastructure –** Further, weak waste-management and composting infrastructure could undermine environmental benefits.
- **Fragmented policy coordination –** Lack of alignment across agriculture, environment, and industry policies may slow adoption.
- **Risk of import dependence –** Failure to act quickly could leave India dependent on imports as other countries advance faster.
- **Technology dependence –** Although India has a rich agricultural base, in some sectors, there is foreign dependence for the technologies required for the transformation of feedstocks into market-ready final products.

What lies ahead?

- **India's advantage** – India has an advantage in building a biomaterials industry, leveraging agricultural diversity and industrial potential.
- **Scaling biomanufacturing infrastructure** – Policy actions should focus on expanding fermentation and polymerisation capacity to meet industrial demand.
- **Enhancing feedstock productivity** – Emerging technologies can improve yields of sugarcane, maize, and agricultural residues for sustainable feedstock supply.
- **Invest in R&D** – Investing in research, innovation, and standards are crucial to develop both drop-in substitutes and novel biomaterials.
- **Regulatory clarity** – Clear definitions, labelling norms, and end-of-life pathways (recycling/composting) are essential to build consumer and industry confidence.
- **De-risking early investments** – Government procurement, time-bound incentives under frameworks, and support for pilot plants and shared facilities can reduce risk for investments.

Reference

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