Bioremediation - Need of the Hour

Mains: ***GS III – Environment pollution and degradation***

Why in News?

Recently, the Bioremediation process has gained attention and importance due to ever increasing pollutions in many waterbodies in India.

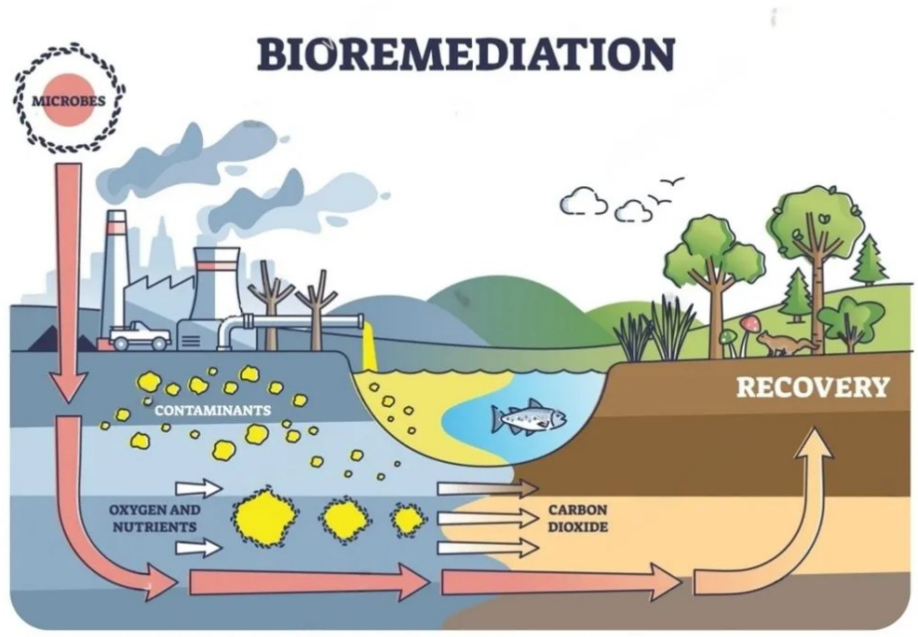
What is bioremediation?

- **Bioremediation** – It literally means "*restoring life through biology."*
- It harnesses microorganisms such as bacteria, fungi, algae and plants to sequester or transform toxic substances such as oil, pesticides, plastics, or heavy metals.
- These organisms metabolise these pollutants as food, breaking them down into harmless by-products such as water, carbon dioxide, or organic acids.
- In some cases, they can convert toxic metals into less dangerous forms that no longer leach into the soil or groundwater.
- **Types** – There are two broad types:
    - **In situ bioremediation**, where treatment happens directly at the contaminated site — think oil-eating bacteria sprayed on an ocean spill.
    - **Ex situ bioremediation,** where contaminated soil or water is removed, treated in a controlled facility, and returned once cleaned.
- Modern bioremediation combines traditional microbiology with cutting-edge biotechnology.
- First, new biotechnologies are enabling humans to gain unprecedented insight into biology, allowing them to identify biomolecules with useful characteristics.
- Second, these technologies allow humans to replicate these biomolecules under desired conditions of use, such as sewage plants or agricultural lands.
    - **For example**, genetically modified (GM) microbes are designed to degrade tough chemicals like plastics or oil residues that natural species struggle with.
- **Biosensing** – Synthetic biology also allows for "biosensing", organisms that change colour or fluorescence when they detect toxins, providing early warnings of contamination.

Why does India need bioremediation?

- **Heavy industrialization in India** – India's rapid industrialisation has come at a heavy environmental cost.
- Although pollution has been reducing, rivers such as the Ganga and Yamuna receive untreated sewage and industrial effluents daily.

- Oil leaks, pesticide residues, and heavy-metal contamination threaten both ecosystems and public health.
- **Issues with traditional methods** – Traditional clean-up technologies are expensive, energy-intensive, and often create secondary pollution.
- **Potential of Bioremediation –** It offers a cheaper, scalable, and sustainable alternative, especially in a country where vast stretches of land and water are affected but resources for remediation are limited.
- **Advantage of India's diverse biodiversity** – Indigenous microbes adapted to local conditions, such as high temperatures, salinity, or acidity, can outperform imported strains in environmental recovery.



Where does India stand today?

- **The Department of Biotechnology (DBT)** – It has supported several projects through its Clean Technology Programme, encouraging partnerships between universities, public research institutions, and industries.
- **CSIR-National Environmental Engineering Research Institute** – It has a mandate to propose and implement programmes related to bioremediation.
- **IITs** – Researchers at the Indian Institute of Technology have experimented with a nanocomposite material synthesised from cotton that can be used to mop up oil spills and others have identified bacteria that can consume toxic pollutants in soils.
- **Startups** – Firms like Biotech Consortium India Limited (BCIL) and Econirmal Biotech offer microbial formulations for soil and wastewater treatment.
- **Challenges** – Widespread adoption faces several challenges
    - Technical ones such as a lack of site-specific knowledge and the complex nature of pollutants, and
    - Regulatory ones such as a lack of unified bioremediation standards.

What are other countries doing?

- **Japan** – It integrates microbial and plant-based cleanup systems into its urban waste

strategy.

- **The European Union** – It funds cross-country projects that use microbes to tackle oil spills and restore mining sites.
- **China** – It has made bioremediation a priority under its soil pollution control framework, using genetically improved bacteria to restore industrial wastelands.

What are the opportunities and risks?

- **Ecology restoration** – Bioremediation can help restore rivers, reclaim land, and clean industrial sites, while creating jobs in biotechnology, environmental consulting, and waste management.
- **Integration of schemes** – It can also integrate with the government's Swachh Bharat Mission, Namami Gange, and other green technology initiatives.
- **Concerns with GMOs** – The introduction of genetically modified organisms (GMOs) into open environments need to be strictly monitored to prevent unintended ecological effects.
- **Lack of monitoring** – Inadequate testing or poor containment or monitoring can create fresh problems while solving old ones.

What needs to be done?

- **National standards** – There is a need to develop national standards for bioremediation protocols and microbial applications.
- India will need new biosafety guidelines, certification systems, and trained personnel to scale this technology responsibly.
- **Building regional bioremediation hubs** – Linking universities, industries, and local governments would enable better understanding of local issues and identifying appropriate technologies for their resolution.
- This can be implemented through support for local startups and community projects through the DBT–BIRAC ecosystem.
- **Public engagement** – It would raise awareness that microbes can be allies, not threats, in environmental restoration

Reference

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