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Biomedical Waste Management and Environmental Impact in the Indian Ecosystem

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Articalinfo

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Abstract

Biomedical waste (BMW) is a critical environmental and public health issue in India, generated from hospitals, laboratories, clinics, and research institutions. Improper handling and disposal lead to contamination of soil, water, and air, posing risks to human and ecosystem health. This paper examines the current state of biomedical waste management in India, analyses its environmental impact, and evaluates the implementation status of the Biomedical Waste Management Rules (2016, amended 2018 and 2022). The study emphasizes sustainable waste management practices — segregation, disinfection, recycling, and energy recovery — that are essential for minimizing ecological and health hazards.

Introduction

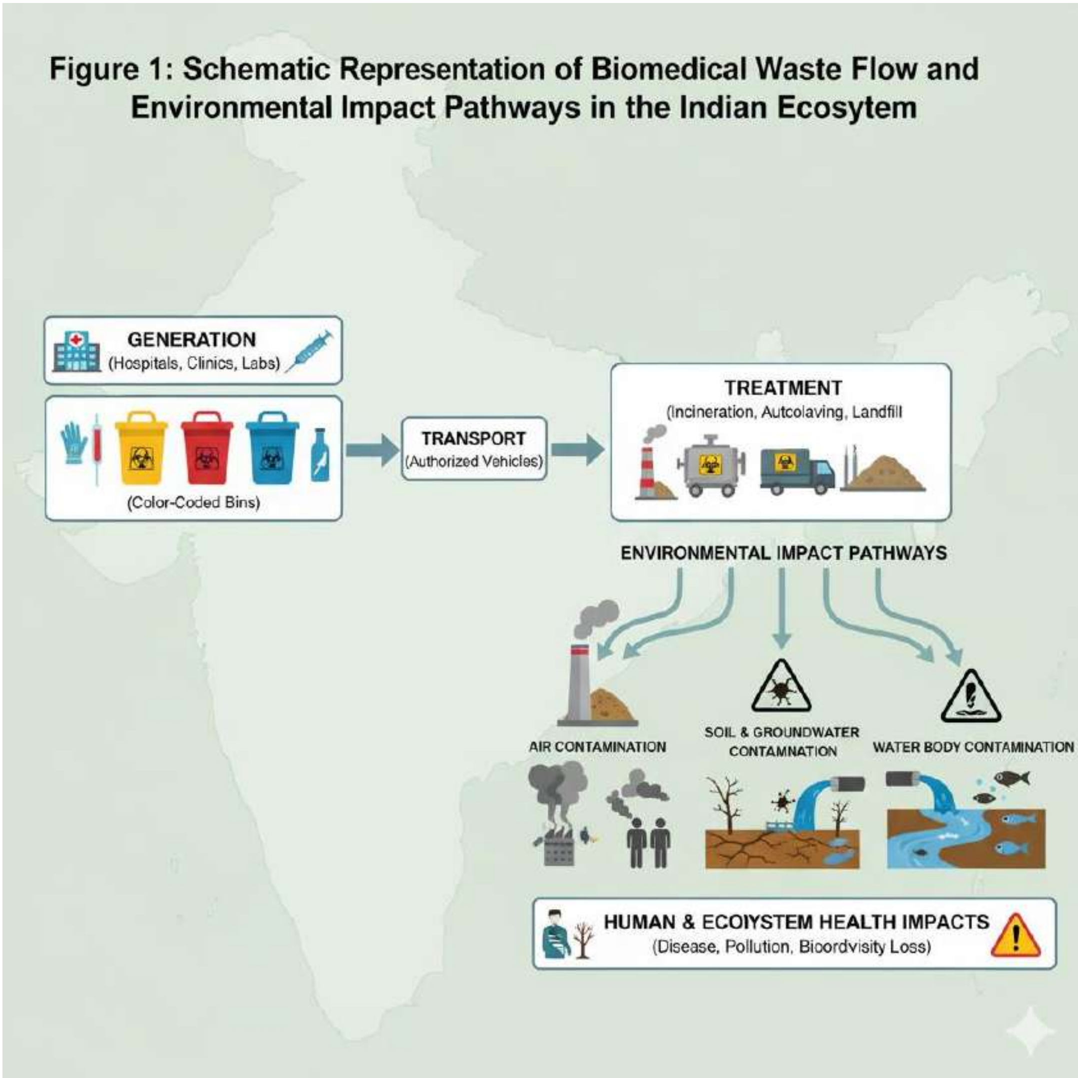
Biomedical waste refers to any waste generated during the diagnosis, treatment, or immunization of humans or animals, or in research activities and production/testing of biologicals. With the rapid expansion of healthcare infrastructure, especially during and after the COVID-19 pandemic, India has witnessed a significant surge in biomedical waste production.

According to the **Central Pollution Control Board (CPCB, 2023)**, India generates approximately **780–800 tonnes of biomedical waste per day**, of which 80–85% is treated through authorized facilities. The remaining fraction often ends up in open landfills or water bodies, leading to **severe environmental degradation**.

Biomedical waste is classified into infectious, pathological, sharps, chemical, pharmaceutical, and plastic wastes — each requiring specialized handling and disposal to prevent infection and pollution.

Objectives of the Study

1. To assess the generation and management of biomedical waste in India.
2. To evaluate its impact on environmental components — soil, water, and air.
3. To examine the implementation of regulatory frameworks.
4. To suggest sustainable management strategies for reducing environmental burden.



(stages — generation → segregation → transport → treatment → environmental pathways like air, soil, and water contamination.)

Materials and Methods

Study design

A mixed-method study combining secondary data review and environmental impact assessment (EIA) was conducted. Data sources included CPCB reports (2019–2024), State Pollution Control Board (SPCB) records, and field studies in selected healthcare facilities in **Bhopal, Indore, Delhi, and Chennai**.

Data analysis

Biomedical waste data were categorized into:

- Quantity generated per bed/day (kg/bed/day)
- Percentage segregation at source
- Treatment methods (autoclaving, incineration, deep burial, recycling)
- Emission and effluent characteristics from treatment units

Environmental impacts were assessed by comparing pollutant levels (heavy metals, dioxins, furans, microbial load) in affected soil and water near treatment sites.

Table-1: Biomedical Waste Generation and Trends in India

Year	Total BMW Generated (tonnes/day)	% Treated	% Untreated	Major Contributing States
2015	517	76	24	Maharashtra, Tamil Nadu, Gujarat, MP
2020	774	82	18	Maharashtra, Delhi, Kerala, UP
2023	798	85	15	Maharashtra, Karnataka, MP, Rajasthan

Observation:
The pandemic years (2020–2022) saw a **spike of 20–25%** in biomedical waste, primarily from PPEs, masks, and testing kits. Post-pandemic, levels stabilized but plastic-based biomedical waste continues to rise.

Environmental Impact Assessment

Soil contamination

Leaching of **heavy metals (Pb, Hg, Cr)** and toxic residues from poorly managed disposal sites has degraded soil quality. Studies near open dumping zones in UP and MP reported:

- Pb concentration: 1.8–2.5 mg/kg (above safe limits)
- Reduced soil microbial biomass by 30–40%

Water pollution

Untreated liquid waste and leachates contaminate groundwater and surface water. CPCB studies show:

- COD and BOD levels in effluents from some treatment units exceed prescribed limits.
- Pathogenic bacteria (E. coli, Salmonella) detected in nearby water bodies.

Air pollution

Incineration remains the dominant treatment method (60–70% of BMW). However, **improper combustion** releases dioxins, furans, and particulate matter:

- Dioxin emission levels up to 0.5 ng/m³ reported in poorly operated incinerators.
- Local communities near incineration sites experience respiratory irritation and allergic symptoms.

Plastic and microplastic accumulation

Increased use of single-use plastics (syringes, PPEs) contributes to plastic pollution and microplastic formation in aquatic ecosystems. These fragments enter the food web, affecting aquatic fauna and, indirectly, human health.

Table-2: Current Management Practices

Category	Treatment Method	Environmental Risk if Mismanaged
Infectious waste	Autoclaving, microwaving	Pathogen spread
Sharps	Shredding, disinfection	Injury, infection
Plastic waste	Recycling post disinfection	Microplastic formation
Pharmaceutical waste	Incineration at >1200°C	Toxic gas release
Anatomical waste	Deep burial/incineration	Groundwater contamination

India has established **208 Common Bio-medical Waste Treatment Facilities (CBWTFs)** covering most districts, yet rural and peripheral areas still rely on unregulated disposal methods.

Regulatory Framework

- **Biomedical Waste Management Rules, 2016 (amended 2018 & 2022):** Mandate segregation at source, color-coded containers, barcoding, and tracking of waste.
- **Pollution Control Boards:** Monitor and authorize treatment facilities.
- **Environmental Impact Assessment (EIA) Notification, 2020:** Includes waste treatment plants under mandatory clearance.
- **Swachh Bharat Mission – Health Wing:** Integrates biomedical waste with solid waste management initiatives.

However, **compliance gaps** exist due to inadequate staff training, limited CBWTF coverage, and poor monitoring in small healthcare units.

Socio-Environmental Implications

- **Public health risk:** Improper disposal causes infections, injuries, and antibiotic resistance spread.
- **Occupational hazard:** Sanitation and waste-handling staff are most vulnerable.
- **Ecological imbalance:** Contamination alters soil biota and aquatic biodiversity.
- **Economic burden:** Cleanup and remediation of polluted sites increase healthcare costs.

Strategies for Sustainable Biomedical Waste Management

1. **Source segregation and barcoding:** Enforce strict segregation at point of generation with digital tracking of waste flow.
2. **Eco-friendly disinfection technologies:** Promote **autoclaving, microwave treatment**, and **plasma pyrolysis** as alternatives to incineration.
3. **Decentralized treatment systems:** Install small-scale treatment units in rural and semi-urban hospitals.
4. **Waste reduction and recycling:** Encourage reusable medical textiles, eco-friendly packaging, and disinfected plastic recycling.

5. **Capacity building and training:** Conduct regular awareness programs for healthcare workers and waste handlers.

6. **Green hospital initiatives:** Integrate waste minimization with energy and water conservation programs.

7. **Strict compliance monitoring:** Strengthen the CPCB and SPCB surveillance with real-time online monitoring of BMW data.

Conclusion

Biomedical waste management is integral to India's public health and environmental sustainability. While significant progress has been made through regulatory reforms and treatment infrastructure, challenges persist in **rural coverage, plastic pollution, and emission control**. Effective waste segregation, eco-friendly treatment, and strict monitoring are crucial for minimizing the environmental footprint.

The future of biomedical waste management lies in a **circular bioeconomy model**, where waste is transformed into resources through biotechnology, energy recovery, and recycling — ensuring a cleaner and safer Indian ecosystem.

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