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# Biomedical Waste Management: Current Practices, Challenges, and Future Prospects

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**Abstract—** Biomedical waste management (BMWM) has emerged as a significant global concern due to its growing volume and potential hazards to human health and the environment. Biomedical waste includes infectious, toxic, and radioactive materials generated from hospitals, clinics, research centres, and laboratories. This review examines the classification, sources, and treatment methods of biomedical waste, with a focus on healthcare institutions in India. It also examines international and national regulations, the challenges of implementation, and the pressing need for awareness, effective policy enforcement, and sustainable waste management technologies. Future directions emphasise the importance of green technology, training, and the 5R approach (Refuse, Reduce, Reuse, Repurpose, Recycle) to achieve a zero-waste healthcare ecosystem.

**Keywords**— Biomedical waste, waste management, environmental pollution, healthcare system, 5R principles

## I. Introduction

Biomedical waste (BMW) refers to waste generated during the diagnosis, treatment, or immunisation of humans and animals, as well as research and biological testing activities (World Health Organisation [WHO], 2020). Proper management of BMW has become a pressing issue due to its implications for healthcare safety and environmental protection. According to WHO, approximately 75–90% of healthcare waste is non-hazardous, while 10–25% is hazardous and potentially infectious (Khan et al., 2019). Improper segregation, storage, and disposal practices can lead to infections, environmental pollution, and long-term ecological damage. This paper reviews the global and Indian context of biomedical waste management, emphasising policies, practices, challenges, and future sustainability strategies.

Odisha Waste Management is a leading provider of sustainable waste management services in India, with a special focus on biomedical waste management. A full-fledged facility, Odisha Waste Management collects, transports, and disposes of biomedical waste with exceptional promptness and safety measures.




Figure: 1 (Biomedical waste)

Odisha Waste Management collaborates with over 200 healthcare facilities across Jharkhand, offering services to 4,000 beds and non-bedded facilities through a comprehensive range of Biomedical waste management solutions. Services can be provided due to cutting-edge technology machinery, such as an Incinerator with a capacity of 200kgs/hr., Autoclave with a capacity of 1275 Ltrs. & shredder 250 Kgs/hr. Can dispose of 4,500 tons of biomedical waste annually on time.

### Classification and Sources of Biomedical Waste

Biomedical waste can be classified into general, infectious, pathological, pharmaceutical, chemical, sharps, radioactive, and cytotoxic waste (WHO, 2020). Sources include hospitals, clinics, laboratories, blood banks, animal research centres, and household healthcare activities. The Central Pollution Control Board (CPCB, 2016) categorises BMW into ten groups, prescribing specific treatment and disposal methods such as incineration, autoclaving, and chemical disinfection. Proper segregation at the point of generation is the most critical step in BMW management (Datta et al., 2018).

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**Table 1 Category of Biomedical Waste and Their Quantities (Bargarh District)**

| Sl. No | Category of Waste | Quantity of Waste Generated or Disposed (Average quantity (kg/month)) |
|---|---|---|
| 1 | Yellow Category: Solid and Liquid Waste | 9192.029Kg |
| 2 | Red Category: Plastic | 4332.816Kg |
| 3 | White Category: Sharp Metals | 1485.075kg |
| 4 | Blue Category: Blood contaminated | 2792.38848 kg |
| 5 | General Solid waste: | 803654.72kg |



Figure: 2 (Segregation of Biomedical Waste)

**Health and Environmental Hazards**

Inadequate handling of BMW poses significant health risks to healthcare workers, waste handlers, and the general public. Infections such as HIV, hepatitis B, and hepatitis C are transmitted through improper disposal of sharps and contaminated materials (Gambhir et al., 2013). Environmental hazards include soil and water contamination, air pollution from incineration, and radiation risks from radioactive materials (Dave et al., 2020). Effective BMWM is therefore essential to safeguard both human and ecological health (State pollution control board 2018-2020).

**Table 2 Collecting Hazards with their quantity (Odisha)- Monthly Report**

| Month | Yellow1 Solid waste (kg) | Yellow2 Liquid Waste (kg) | Red – Plastic (kg) | Blue – Blood Contaminated (kg) | White- Sharpe Metals (kg) | Total (kg) |
|---|---|---|---|---|---|---|
| January | 438.16 | 375.246 | 248.92 | 214.84 | 97.177 | **1374.343** |
| February | 390.361 | 386.275 | 272.956 | 182.905 | 122.22 | **1354.717** |
| March | 339.6 | 379.03 | 277.212 | 201.159 | 126.929 | **1323.93** |
| April | 326.881 | 318.903 | 236.894 | 175.224 | 144.089 | **1201.991** |
| May | 351.23 | 327.531 | 238.355 | 179.071 | 112.414 | **1208.601** |
| June | 584.23 | 386.994 | 371 | 256.28 | 121.926 | **1720.43** |
| July | 421.44 | 354.823 | 338.814 | 239.568 | 131.29 | **1485.935** |
| August | 517.845 | 372.24 | 344.675 | 261.42 | 129.59 | **1625.77** |
| September | 432.24 | 285.08 | 415.5 | 220.471 | 109.98 | **1463.271** |
| October | 443.93 | 279.93 | 451.74 | 243.3 | 131.96 | **1550.86** |

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| | | | | | | |
|---|---|---|---|---|---|---|
| November | 407.01 | 281.25 | 458.52 | 258.94 | 129.04 | **1534.76** |
| December | 455.66 | 336.14 | 678.23 | 359.21 | 128.46 | **1957.7** |
| **TOTAL** | **5108.587** | **4083.442** | **4332.816** | **2792.388** | **1485.075** | **17802.31** |

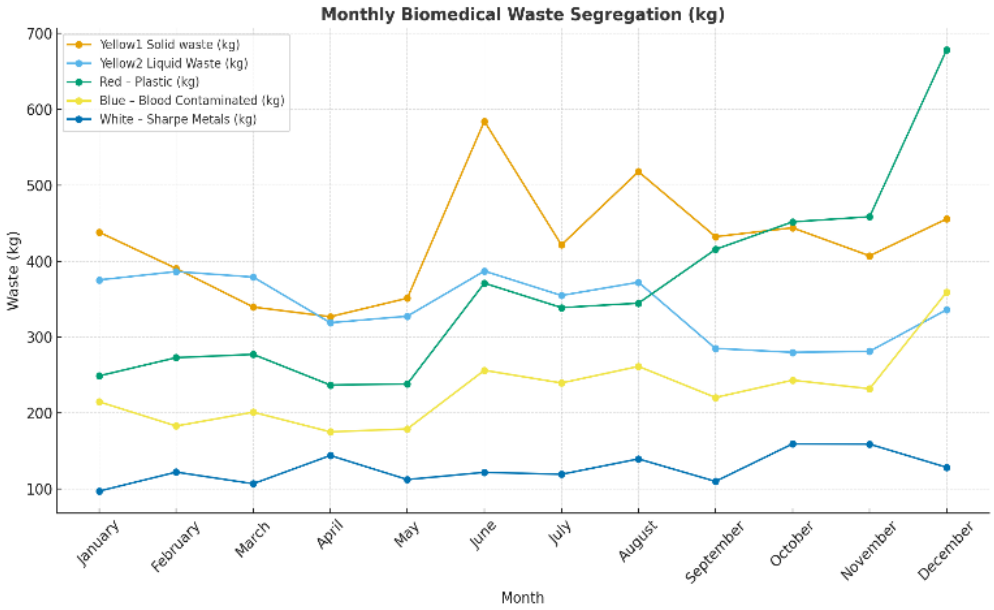



Figure: 3 (Monthly Biomedical Waste Segrigation)

**Treatment and Disposal Technologies**

Biomedical waste treatment involves chemical, thermal, mechanical, irradiation, and biological processes. Chemical disinfection using sodium hypochlorite or hydrogen peroxide is common for liquid waste. Thermal processes such as autoclaving and incineration are widely used for sterilizing infectious waste (Santhanam et al., 2011). Mechanical shredding ensures safe disposal of plastics and sharps after disinfection. Emerging technologies like microwaving and plasma pyrolysis offer eco-friendly alternatives with reduced emissions (Khadem-Ghasemi et al., 2016).

**Policies and Legal Framework**

India implemented the Biomedical Waste (Management and Handling) Rules in 1998, later amended in 2016 under the Ministry of Environment, Forest, and Climate Change (MOEFCC). These rules define waste categories, segregation norms, color coding, and disposal procedures (CPCB, 2016). The Central Pollution Control Board oversees compliance, while the Ministry of Health ensures training and awareness. Similar frameworks exist globally, including the U.S. Medical Waste Tracking Act (1988) and European Union Waste Framework Directive (2008/98/EC), emphasizing waste reduction and eco-friendly treatment.

**Waste Minimization and Managemental Policy**

Waste minimization follows the 5R principle: Refuse, Reduce, Reuse, Repurpose, and Recycle (Archad et al., 2011). Hospitals can reduce waste through efficient procurement, segregation, and recycling of non-infectious materials. Training healthcare personnel and implementing source reduction policies are key components of sustainable BMWM (Pandey et al., 2016). In developing nations, lack of infrastructure and awareness remain major challenges (Caniato et al., 2015).

**II. Discussion and Future Prospects**

The rise of healthcare waste generation, particularly during pandemics, highlights the need for efficient BMWM systems. Adoption of green technologies such as bioremediation, waste valorization, and digital monitoring can significantly enhance sustainability. Community participation, strict enforcement of environmental laws, and collaboration between government and private sectors are vital for long-term success. Future research should focus on cost-effective, low-emission treatment alternatives suitable for resource-constrained regions (Brasovean et al., 2014).

**III. Conclusion**

Biomedical waste management is not merely a regulatory obligation but a public health necessity. Sustainable management practices, technological innovation, and continuous education of healthcare workers are crucial for reducing risks associated with biomedical waste. Effective implementation of existing regulations, combined with strong institutional commitment, can ensure a

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safer, cleaner, and healthier environment.

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