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Biomedical Waste Management in Buxar District, India: Challenges and Strategies

[*1] Ajay Kumar Thakur

[*1] Assistant Professor, Department of Geography, Prime Minister College of Excellence, Government Tilak PG College, Katni, Madhya Pradesh, India.

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***Corresponding Author**
Ajay Kumar Thakur
Assistant professor, Department of Geography, Prime Minister College of Excellence, Government Tilak PG College, Katni, Madhya Pradesh, India.

Abstract
Biomedical waste management (BMWM) in India is governed by the Bio-Medical Waste Management Rules, 2016, introduced by the Ministry of Environment, Forest and Climate Change. Effective handling of such waste requires proper segregation, timely collection, and the use of environmentally responsible treatment methods such as incineration, autoclaving, and plasma pyrolysis. These steps are vital for reducing health risks and environmental degradation. In rural districts like Buxar, managing biomedical waste presents unique challenges. This study explores the current practices and issues surrounding BMWM in Buxar, where a lack of adequate infrastructure, improper segregation, and low awareness among healthcare providers and the general public hinder effective waste handling. Common but unsafe practices, such as open burning and dumping of biomedical waste, pose severe threats to both human health and the ecosystem. Although the regulatory framework exists, its enforcement is weak, resulting in poor adherence to the guidelines. To address these shortcomings, the study suggests several improvement strategies, including increased community involvement, educational campaigns, and the development of localized treatment solutions. Strengthening infrastructure, providing training for healthcare personnel, and ensuring stricter policy enforcement are critical steps toward achieving sustainable and effective biomedical waste management in rural settings like Buxar. This article explores the state of biomedical waste management, its environmental consequences, and outlines suitable management practices that can be adopted to address these pressing concerns.

Keywords: Biomedical waste, health hazards, bio-medical waste management rules, 2016.

1. Introduction

Biomedical waste in India is governed by the Biomedical Waste Management Rules, 2016, framed under the Environment (Protection) Act, 1986 and issued by the Ministry of Environment, Forest and Climate Change. These regulations were originally introduced in 1998 and were significantly revised in 2016 to enhance their effectiveness in regulating the segregation, collection, treatment, and disposal of biomedical waste in an environmentally responsible manner (BMWM Rules, 2016). With the continuous rise in the number of healthcare establishments, the volume of biomedical waste generated daily has also increased substantially. Proper handling and disposal of this waste are essential to mitigate associated risks and prevent potential hazards (Bagali *et al*., 2021). Biomedical waste poses significant threats due to its potential to cause environmental pollution and health risks, particularly when it is not managed appropriately in medical settings. Its proper disposal is therefore critical for protecting public health and preserving the environment (Omo *et al*., 2024). Ensuring the safe and sustainable management of biomedical waste is not only a statutory requirement but also a shared social responsibility among healthcare providers, administrators, and regulatory bodies. Effective biomedical waste management (BMWM) plays a vital role in promoting public health and maintaining a clean environment (Datta *et al*., 2018). This category of waste encompasses various byproducts generated during the medical treatment of humans and animals, as well as from biomedical research. These materials often carry infectious or potentially contagious substances, making their safe management crucial (Sarkar *et al*., 2024). All healthcare facilities, regardless of size or type, produce some level of biomedical waste in the course of delivering medical services. However, the delivery of these services often comes with environmental

consequences that can ultimately affect human health (Thakur, 2012). The issue of biomedical waste management has gained increasing prominence in India, particularly following the introduction of the Biomedical Waste (Management and Handling) Rules in 1998 under the Environment (Protection) Act, 1986. These regulations address all stages of waste handling-from generation to final disposal—and were updated in 2016 to ensure more scientific and efficient waste management (Sunil Kumar *et al*., 2012). While the rules provide a strong regulatory framework at the national level, their implementation, especially in rural areas, remains uneven. The Buxar district in Bihar illustrates the unique challenges that rural regions face in complying with these national directives. The inconsistent application of the rules in such areas increases the vulnerability of both healthcare workers and local populations to the adverse effects of improper waste management. This highlights the pressing need for targeted measures, including better infrastructure and region-specific policy execution, to ensure comprehensive and sustainable biomedical waste practices. When exploring biomedical waste management in the Buxar District, the goals can be customized to reflect the area's unique requirements, issues, and potential improvements. Below are potential objectives for such a study.

Main Objectives of Study

This study primarily aims to investigate the current scenario of biomedical waste generation and its management in the Buxar district of Bihar. It focuses on evaluating how well healthcare facilities, both public and private, adhere to the Biomedical Waste Management Rules, 2016. The research further examines the extent to which these facilities are linked to Common Biomedical Waste Treatment Facilities (CBWTFs), highlighting the gaps in connection, especially among private and small government-run healthcare units. Another goal is to assess the capacity and efficiency of the district's biomedical waste treatment infrastructure, with a comparison between centralized and in-house treatment systems. The study also explores the key obstacles faced by healthcare institutions in rural settings in managing waste, including issues in segregation, temporary storage, and final disposal. It seeks to analyze the training and awareness levels among healthcare workers and waste handlers regarding proper waste handling protocols. Ultimately, the study aims to offer practical recommendations and policy-oriented solutions for strengthening the biomedical waste management framework in Buxar, including potential community-based or public-private approaches that align with national environmental health goals.

2. Geographical and Demographic Profile of Buxar District, Bihar

Buxar district is located in the western region of Bihar, forming part of the Patna Division and lying within the expansive Gangetic Plains. It shares its northern boundary with Ballia district in Uttar Pradesh, separated by the Ganges River. To the east, it is bordered by Bhojpur district; to the south by Rohtas district; and to the west by Ghazipur district, also in Uttar Pradesh. The landscape of Buxar is predominantly flat, characteristic of the fertile plains of the Ganga basin, which supports extensive agricultural activity.

The district is shaped roughly like a rectangle and comprises a mix of rural and semi-urban areas. Geographically, Buxar lies between latitudes 25.28° N and 25.65° N and longitudes 83.50° E and 84.10° E. It spans an area of approximately 1,703 square kilometers, with an average elevation of about 65 meters (213 feet) above sea level.

According to the 2011 Census, Buxar has a population of approximately 1.7 million, of which around 93% (1,541,853) reside in rural areas, while the remaining 7% (164,499) live in urban settings. The district has a population density of 1,002 individuals per square kilometer. Its advantageous location along the Ganges and its agriculturally rich lands contribute significantly to the cultural and economic vibrancy of the region.

3. Methodology

This study employs a descriptive research approach, utilizing secondary data to evaluate the biomedical waste management practices in Buxar district. Data for this research was sourced from a variety of credible secondary resources. These include official publications from government agencies such as the Central Pollution Control Board (CPCB) and the Bihar State Pollution Control Board (BSPCB), records from municipal bodies and health departments, scholarly articles, policy documents, legal guidelines, and reports issued by government organizations and international bodies like the World Health Organization (WHO). Both qualitative and quantitative analysis methods were applied to interpret the collected data. This structured methodological framework enables a comprehensive understanding of the biomedical waste management scenario in Buxar. The findings aim to support decision-makers, healthcare professionals, and other stakeholders in developing more efficient and sustainable waste management strategies.

4. Brief Summary of Bio-Medical Waste Management in India

At the national level, the management of biomedical waste is governed by the Bio-Medical Waste Management Rules, 2016, established under the Environment (Protection) Act, 1986. These rules provide the regulatory framework for the collection, handling, treatment, and disposal of biomedical waste across India. The Central Pollution Control Board (CPCB) is responsible for overseeing and ensuring the implementation of these regulations throughout the country (BMWM, 2016). Given the hierarchical nature of waste management, it is essential to assess biomedical waste management from a broader national perspective down to localized contexts-such as Buxar district in Bihar.

Table 1 presents a comparative overview of biomedical waste management in India from 2019 to 2023, highlighting trends related to the growth of healthcare infrastructure, waste generation, treatment capabilities, and regulatory compliance. During this period, the total number of healthcare facilities (HCFs) rose from 322,576 in 2019 to 434,966 in 2023, marking a 34.8% increase. Both bedded and non-bedded facilities witnessed significant expansion. Bedded HCFs grew from 106,796 to 137,132 (an increase of 28.5%), while non-bedded HCFs increased from 215,780 to 297,584 (a rise of 37.9%). The number of hospital beds also rose from 2.48 million to 3.04 million, reflecting a 22.3% growth (CPCB, 2023).

Table 1: Status of biomedical waste management in India

Status of Biomedical Waste Management	2019	2023	Change (%)
Total No. of HCFs	322576	434966	+34.8%
Total No. of bedded HCFs	106796	137132	+28.5%
Total No. of non-bedded HCFs	215780	297584	+37.9%
Total No. of beds	2486327	3041937	+22.3%
Total No. of CBWTFs Operational	202	234	+15.8%
Total No. of CBWTFs under construction	35	30	-14.3%
Total No. of HCFs granted authorization	153885	144905	
Total No. of HCFs utilizing CBWTFs	235571	310606	+31.8%
Total No. of HCFs having Captive Treatment Facilities	18015	15870	-11.9%
Total No. of Captive Incinerators Operated by HCFs	136	69	-49.3%
Quantity of bio-medical waste generated (kg/day)	619119	743148	+20%
Quantity of bio-medical waste treated and disposed (kg/day)	544903	694308	+27.4%
Quantity of BMW treated by captive treatment facility (kg/day)	55059	22315	-59.5%
Quantity of BMW treated by CBWTFs (kg/day)	489844	671993	+37.2%
Total No. of HCFs & CBWTFs violated BMW Rules	29062	20081	-30.9%
Total No. of Show-cause notices/Directions issued to defaulter HCFs & CBWTFs	17435	8082	-53.6%

Source: Annual report on biomedical waste management for the year 2019 and 2023, Central Pollution Control Board, Ministry of Environment, Forest & Climate Change.

This infrastructure growth led to a proportional rise in biomedical waste generation, which increased from 619,119 kg/day in 2019 to 743,148 kg/day in 2023-an increment of 20%. This rise corresponds with the expansion of healthcare services and patient capacity. Meanwhile, the quantity of waste that was properly treated and disposed of improved from 544,903 kg/day to 694,308 kg/day, indicating a 27.4% increase in treatment capacity. Treatment efficiency also improved, with 93.4% of generated waste being treated in 2023 compared to 88% in 2019 (CPCB, 2023).

Centralized Biomedical Waste Treatment Facilities (CBWTFs) increased from 202 to 234, a 15.8% rise, thereby strengthening centralized waste management. However, the number of CBWTFs under construction slightly declined from 35 to 30, indicating a slowdown in new facility development. The number of healthcare facilities using CBWTFs rose from 235,571 to 310,606, a 31.8% increase, indicating a growing preference for centralized treatment options (MoEF&CC, 2023).

Conversely, there was a noticeable decline in in-house (captive) treatment facilities. Facilities with captive treatment systems dropped from 18,015 to 15,870 (down by 11.9%). The number of operational captive incinerators fell sharply from 136 to 69-a 49.3% decrease. Consequently, the amount of waste treated through captive facilities declined significantly from 55,059 kg/day to 22,315 kg/day (a reduction of 59.5%). These figures clearly indicate a national shift from in-house waste processing to the use of centralized treatment infrastructure (WHO India, 2022).

On the regulatory front, enforcement has become more effective. Violations of the BMW Rules dropped from 29,062 in 2019 to 20,081 in 2023-a 30.9% decrease. Additionally, the number of show-cause notices and official directions issued fell from 17,435 to 8,082 (a reduction of 53.6%). This reflects a substantial improvement in compliance levels and regulatory oversight (CPCB, 2023).

In summary, the data illustrates a robust expansion of healthcare infrastructure, resulting in increased biomedical waste production. However, this growth has been accompanied by enhanced treatment capabilities and a clear transition from captive to centralized waste treatment. Furthermore, improved monitoring and regulatory action have led to better adherence to waste management norms and fewer violations.

5. Brief Summary of Bio-Medical Waste Management in Bihar

In Bihar, the management of biomedical waste is overseen by the Bihar State Pollution Control Board (BSPCB), which ensures that healthcare institutions comply with the national Bio-Medical Waste Management Rules, 2016 (BMWM, 2016). Hospitals, clinics, diagnostic centers, and laboratories are required to follow strict waste segregation and disposal protocols to prevent health risks and environmental degradation. Given this context, it becomes important to evaluate the current state of biomedical waste management (BMWM) within the state.

Table 2 shows that between 2019 and 2023, Bihar witnessed gradual progress in the healthcare sector, as reflected in data from this period. The total number of healthcare facilities (HCFs) increased by nearly 6%, indicating a slow but steady expansion of healthcare infrastructure (CPCB, 2023). A more notable trend is the significant 40.7% rise in bedded healthcare facilities, which points toward a shift in focus from smaller clinics to larger hospitals. Simultaneously, the number of non-bedded facilities saw a slight decline of 2.4%, further supporting this shift. An encouraging sign is the 48.7% growth in hospital bed capacity, signalling improved access to inpatient healthcare services across the state (BSPCB, 2023).

Interestingly, the total volume of biomedical waste generated during this period declined by approximately 25.1%. This reduction could be attributed to several factors, including improved waste segregation practices, more efficient disposal mechanisms, or potentially decreased medical activity following the COVID-19 pandemic (WHO, 2022; CPCB, 2023). The efficiency of biomedical waste treatment also improved significantly, with a 36.4% increase in the amount of waste being treated properly, suggesting enhanced compliance with waste management protocols. Meanwhile, there has been a sharp 46.3% drop in captive waste treatment

practices, highlighting a growing reliance on centralized biomedical waste treatment facilities (CBWTFs) (CPCB, 2023).

Despite these improvements, there are some areas of concern. The number of operational CBWTFs in Bihar remained unchanged at four over the five-year period. Although one previously non-operational facility became functional by 2023, the overall lack of new treatment infrastructure could pose challenges as the healthcare sector continues to grow (BSPCB, 2023). However, more HCFs are now utilizing CBWTFs for waste disposal, showing an 18% increase, which reflects a state-wide trend toward centralized treatment. On the other hand, only one hospital in Bihar continues to maintain a captive treatment facility, compared to three in 2019. This steady decline in in-house treatment options underscores the increasing dependency on shared, centralized facilities. Furthermore, the number of captive incinerators remained constant at one, reinforcing the reliance on CBWTFs for the bulk of BMW treatment (CPCB, 2023).

From a regulatory standpoint, the data presents a promising picture. Violations of biomedical waste management regulations decreased by 60.9% between 2019 and 2023, which may suggest improved compliance among healthcare providers. Similarly, the number of regulatory actions taken also dropped by the same percentage, potentially reflecting either enhanced adherence to rules or a possible reduction in active enforcement efforts (CPCB, 2023).

Table 2: Status of Biomedical Waste Management in Bihar

Parameters	2019	2023	Change (%)
Total No. of HCFs	24996	26472	+5.9%
Total No. of bedded HCFs	4821	6781	+40.7%
Total No. of non-bedded HCFs	20174	19691	-2.4%
Total No. of beds	70563	104943	+48.7%
Total No. of CBWTFs operational	04	04	No Change
Total No. of CBWTFs without operational	01	0	-100%
Total No. of HCFs granted authorization	2809	2427	-
Total No. of HCFs utilizing CBWTFs	7853	9262	+17.9%
Total No. of HCFs having Captive Treatment Facilities	03	01	-66.7%
Total No. of Captive Incinerators Operated by HCFs	01	01	No Change
Quantity of BMW generated in (kg/day)	34813	26061	-25.1%
Quantity of BMW treated and disposed (kg/day)	10777	14702	+36.4%
Quantity of BMW treated by captive treatment facility (kg/day)	268	144	-46.3%
Quantity of BMW treated by CBWTFs (kg/day)	10509	14558	+38.5%
Total No. of HCFs/CBWTFs violated BMW Rules	809	316	-60.9%
Total No. of Show-Cause notices/Directions issued to defaulter HCFs/CBWTFs	809	316	-60.9%

Source: Annual report on biomedical waste management for the year 2019 and 2023, Central Pollution Control Board, Ministry of Environment, Forest & Climate Change.

Overall, the findings highlight a mixed landscape. On the positive side, the period from 2019 to 2023 saw considerable growth in healthcare infrastructure, including a near 41% increase in bedded facilities and a 49% rise in hospital beds. Waste generation declined by 25%, possibly due to better segregation, and 36% more waste is now being effectively treated. Additionally, regulatory violations have been reduced significantly, suggesting better rule enforcement and institutional accountability. However, stagnation in the number of CBWTFs remains a concern, as no new facilities have been established to support the growing demand. The diminishing use of captive treatment methods also increases pressure on centralized systems. Without further expansion of CBWTF capacity, the state may face operational bottlenecks in the future, especially as more healthcare institutions come online.

6. Status of Biomedical Waste Management in Buxar District

In Buxar district, the total amount of biomedical waste produced daily is approximately 251.82 kilograms. Out of the 285 healthcare facilities in the region, 212 facilities are connected to Common Biomedical Waste Treatment Facilities (CBWTFs), leaving 73 facilities without proper waste treatment linkage. A closer analysis reveals that the majority of these are government-run healthcare facilities, numbering 203, which collectively generate around 133.46 kg/day of biomedical waste. Importantly, all government facilities are connected to CBWTFs, suggesting better compliance within the public sector (CPCB, 2023; BSPCB, 2023).

In contrast, private healthcare facilities, although smaller in number, contribute a significant portion of biomedical waste, producing 101.90 kg/day. Alarmingly, 49 private facilities are not linked to CBWTFs, pointing to a major gap in the safe handling and disposal of biomedical waste in the private healthcare sector (MoEF&CC, 2016). In addition, smaller government institutions, especially those that are non-bedded (23 out of 24), are also excluded from CBWTF networks and generate 16.46 kg/day of biomedical waste. These findings emphasize a clear infrastructure and regulatory disparity, especially affecting non-bedded and private healthcare providers (WHO, 2022; Datta *et al*., 2018).

Table 3: Status of healthcare facilities and bio-medical waste generation in Buxar district.

Nature of Health Care Facility (HCF)	No. of HCF	No. of Bedded HCF	No. of beds (If HCF is bedded)	No. of Non-Bedded HCF	BMW generated (In kg/day)	HCFs Attached to CBWTF	HCFs not attached to CBWTF
						(In Nos.)	(In Nos.)
Govt. HCF	203	40	322	163	133.46	203	0
Private HCF	58	25	360	33	101.90	9	49
Other Govt. HCF	24	01	80	23	16.46	0	24
Total	285	66	762	219	251.82	212	73

Source: Action plan for management of biomedical waste in the state of Bihar, Department of Health, Government of Bihar, 2019.

This uneven distribution in waste management coverage presents a significant challenge for public health and environmental safety in Buxar. Addressing the gaps in CBWTF connectivity, particularly among private clinics and non-bedded government facilities, is essential. Additionally, ensuring consistent waste segregation, collection, and treatment practices across all types of healthcare institutions will be critical for establishing a sustainable biomedical waste management framework in the district.

Recent Developments: In 2021, Buxar commissioned a decentralized biomedical waste incinerator designed by Ganesh Engineering Works under the Waste to Wealth Mission. With a capacity of 50 kg/hour, the incinerator offers a local solution for treating biomedical waste such as contaminated plastics and cotton. However, a single incinerator is not sufficient to handle the total biomedical waste generated across the district.

7. Key Challenges in Biomedical Waste Management in Buxar District

1. **Absence of a Local Common Biomedical Waste Treatment Facility (CBWTF):** The Biomedical Waste Management Rules, 2016, mandate the availability of a CBWTF within a 75 km radius of healthcare facilities to ensure efficient waste treatment and disposal (BMWM Rules, 2016). Currently, Buxar lacks such a facility, requiring transportation of biomedical waste to Patna, around 125 km away. This increases logistical costs and heightens the risk of improper handling or delays. Although a decentralized incinerator was introduced in Buxar in 2021, its capacity is limited and cannot meet the district's growing waste needs.
2. **Improper On-site Segregation:** As per BMWM Rules, 2016, biomedical waste should be segregated into categories using a color-coded system. However, many rural healthcare centers in Buxar do not follow these practices, resulting in biomedical waste being mixed with general waste. This failure compromises safe disposal and increases environmental hazards.
3. **Lack of Training and Awareness:** Healthcare professionals and waste handlers in Buxar often lack adequate training in biomedical waste handling, segregation, and disposal. This leads to unsafe practices, exposing workers and the public to infectious waste (Mathur *et al*., 2011).
4. **Financial and Resource Constraints:** Many small clinics and facilities in Buxar operate on tight budgets and cannot afford proper waste management infrastructure. The lack of financial support and subsidies contributes to poor compliance (D'Souza *et al*., 2015).
5. **Weak Monitoring and Regulation:** Regulatory oversight is often weak due to understaffing or lack of resources. Irregular inspections and inconsistent enforcement result in frequent violations of biomedical waste management norms.
6. **Risks from Informal Waste Collection:** Informal collectors or rag-pickers often handle improperly disposed biomedical waste, such as syringes and contaminated materials. This creates serious health risks and highlights the need for public education and regulatory enforcement.
7. **Limited Public and Institutional Awareness:** While some training and workshops have been conducted by the Bihar State Pollution Control Board, they have not been sufficiently widespread. Limited outreach and community education have resulted in low public awareness about the risks of improper biomedical waste disposal (Kaur *et al*., 2015).

8. Recommendations

1. **Establish Local CBWTFs:** Buxar urgently needs a localized CBWTF to reduce dependency on distant treatment centers and improve efficiency.
2. **Regular Training Programs:** Healthcare staff and waste handlers should undergo regular training to reinforce best practices in segregation, storage, and disposal.
3. **Strengthen Regulatory Oversight:** More frequent inspections and penalties for non-compliance should be enforced to ensure consistent adherence to biomedical waste management rules.
4. **Community Awareness Initiatives:** Public awareness campaigns should target both healthcare personnel and communities to minimize unsafe waste practices and promote better hygiene.
5. **Introduce Financial Incentives:** Government subsidies or low-cost biomedical waste management packages could help small clinics comply with regulations and maintain sustainable practices (D'Souza *et al*., 2018).
6. **Expand Decentralized Solutions:** Installing more small-scale treatment units, such as decentralized incinerators, can significantly ease pressure on centralized systems and improve coverage in remote areas.

Conclusion

Biomedical waste management in Buxar reflects many of the systemic challenges prevalent in rural India. Limited infrastructure, training, and regulatory capacity contribute to non-compliance and environmental risks. With strategic investments in infrastructure, workforce training, and community outreach, the district can strengthen its biomedical waste management system and serve as a model for other rural regions.

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