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Medical Waste Management: A Case of Tier-II Cities

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Abstract:

Medical waste management is a critical aspect of healthcare operations, ensuring the safe handling, treatment, and disposal of waste generated from medical activities. This report provides a comprehensive overview of Medical waste management practices, regulations, and challenges. It highlights the importance of adhering to regulatory frameworks, such as the Medical Waste Management Rules, to mitigate health risks and environmental impacts associated with improper waste management.

Keywords : Medical waste management, Regulations, Healthcare facilities, Hazardous waste, Waste handling, Waste disposal

1. Background

Medical waste management is crucial for healthcare operations, involving the proper handling, treatment, and disposal of waste from medical, surgical, and diagnostic procedures. This waste, often infectious, toxic, or hazardous, poses serious public health and environmental risks if not managed effectively. Implementing stringent protocols helps prevent infections, protects healthcare workers and the public, and minimizes environmental impacts. Proper segregation, packaging, and disposal reduce disease transmission risks, such as from needlestick injuries or exposure to contaminated materials.
Environmentally sound treatment methods, like autoclaving and chemical sterilization, prevent pollutant release and reduce pollution. Prioritizing safe medical waste management ensures public health, occupational safety, and environmental sustainability.

Managing medical waste is crucial because it can harm people's health and the environment if not handled properly.We need to study and Improve how medical waste is managed in Healthcare Facilities in Urban Area because it's essential to keep the community and environment safe. (World Health Organisation, n.d.)

Who are at risk?:-
Individuals who would be at risk would include anyone working in proximity with Medical waste, that would be

- **Generators -** all individuals working in health care facilities who generate Medical waste
- **Handlers -** who handle Medical waste at health care facilities or at treatment and disposal facilities
- **Exposed group -** who are exposed to hazardous Medical waste due to consequence of careless actions of generators and handlers.

State/UTs	BMW GENERATED	TREATMENT CAPACITY	GAP %
KERALA	66.6	89.5	+134%
J&K	8.4	13.9	+165%
Karnatak	94.5	72.6	-23%
Haryana	27.9	21	-25%
DATA SHOWING BEST EXAMPLES WITH GAP/SURPLUS IN TREATMENT			

Figure 1 BMW generated Treatment Capacity and Gap% for best result in Indian states Source:CPCB

2. Aim

To understand medical waste management in Tier- II cities in India.

3. Objectives:

- **Classification :** To classify and characterize the types of Healthcare Facilities and Medical waste generated by them.
- **Resource Evaluation** : To review and evaluate technological practices for medical waste management,including waste-to-energy conversion and advanced treatment technologies existing with the best suitable practices.

The scope of this research encompasses medical waste management within medical units, with a focus on the diverse types of waste generated by these institutions. It includes a detailed evaluation of various technological solutions for managing medical waste, such as waste-to-energy conversion, advanced treatment technologies, and other emerging methods. The study will conclude with practical recommendations to guide healthcare facilities towards more sustainable medical waste management practices. However, the research is limited as it does not consider liquid waste and is based on surveys conducted solely in urban areas of
Tier-II cities.

4. Research Question

How can the management of medical waste is done to reduce environmental impact and enhance public health outcomes while ensuring compliance with regulatory standards?

5. Methodology

The research framework for medical waste management and treatment. It is divided into two main objectives:
Obj01: Focuses on the classification of healthcare facilities and the types of waste generated, while Obj02: Examines emerging technologies for medical waste management.

The study involves a literature review, analysis of government reports, and local health data to categorize healthcare infrastructure and medical waste characteristics. It aims to analyse waste generators and their impacts, leading to outcomes and practical recommendations for sustainable medical waste management practices.

6. Literature Study

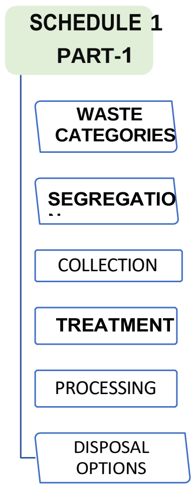
Enhancing Medical Waste Management: Insights from Literature

To gain comprehensive insights into effective waste management practices, this report examines key literature sources including reports from reputable organizations and standards set by regulatory bodies.

6.1. Medical Waste Management – 2016

The Medical Waste Management Rules of 2016 serve as a foundational framework for Medical waste management in India.

The Medical Waste Management Rules of 2016 (BMW Rules 2016), enacted on 28th March 2016, are essential for regulating the handling, treatment, and disposal of medical waste from healthcare facilities in India. These rules, comprising eighteen provisions and four detailed schedules, emphasize compliance to safeguard public health and the environment. Schedule 1 categorizes medical waste into ten types, including human anatomical waste, animal waste, microbiological waste, discarded medicines, and solid waste. It provides guidelines for the segregation, collection, treatment, and disposal of each category, ensuring safe and efficient medical waste management.



Category	Types of Waste	Treatment & Disposal options
YELLOW	• Human Anatomical Waste/Animal Anatomical Waste	Incineration / Plasma Pyrolysis Deep Burials
	• Soiled Waste	AutoClaving / Micro Waving / Hydroclaving Sterlizitation + Shredding
	• Expired / Discarded Medicines	Incineration > 1200 deg. Cel.
	• Chemical Wastes	Incineration / Plasma Pyrolysis
	• Chemical Liquid Waste	Pretreated before mixing with waste water
	• Discarded Linen, Mattresses, Beddings Contaminated with blood / body fluid.	Incineration
RED	• Contaminated Waste	AutoClaving / Micro–Waving / Hydroclaving Sterlizitation + Shredding
WHITE	• Waste Sharps Including Metals	Autoclaving / Dry Heat Sterillization Shredding+AutoClaving
BLUE	• Glassware • Metallic Body Implants	Disinfection (sodium Hypochlorite

Time of Collection

Dispose of human anatomical, animal anatomical, soiled, and biotechnology waste within 48 hours to minimize contamination risks and ensure timely disposal. Set collection times based on waste volumes, prioritizing high-waste areas to prevent mixing with general waste.

Packaging

Fill medical waste bags and sharps containers up to three-quarters full to prevent overfilling and spillage. Seal them securely with ties or plastic tags, avoiding staples to maintain packaging integrity. Ensure replacement bags or containers are readily available at collection points for efficient waste management. Use color-coded bags and containers marked with the biohazard symbol, including details such as the date of collection, type of waste, quantity, sender-receiver information, and barcoded labels for tracking and traceability.

Labelling

Label all containers used for medical waste with appropriate hazard symbols, such as the Biohazard or Cytotoxic Hazard symbols, as per the Medical Waste Management Rules of 2016. Follow CPCB guidelines to use barcoded labels on medical waste bags and containers, ensuring effective tracking and management throughout the disposal chain. (MoEFCC, 2016)

Interim Storage

Sodium hypochlorite (NaOCl) with a 10% concentration and 30% residual chlorine is recommended for disinfection, requiring at least 20 minutes of contact time. Medical waste, including incineration ash with toxic constituents, should be mutilated, shredded, or disposed of through authorized methods to reduce environmental risks. Human anatomical waste, such as dead fetuses below viability, should be placed in yellow bags at medical waste facilities with a Medical Termination of Pregnancy certificate. Schedule 2 outlines standards for treatment processes like incineration, autoclaving, microwaving, and chemical treatment, ensuring compliance with safety and environmental standards. It also provides guidelines for final disposal methods, including landfilling, deep burial, and recycling, to minimize environmental and health risks. (MoEFCC, 2016)

Stack Height

Height – 30 M (ISM, 2014)

11% Oxygen on dry basis. (ISM, 2014) ; Dioxins and Furans of 0.1ngTEQ/Nm^3 (ISM, 2014)

6.2. Literature Study: 02

Cities are increasingly adopting smart technologies like IoT and blockchain to build sustainable infrastructure, with IoT-based waste management solutions gaining prominence. Sensor-based waste sorting, utilizing proximity, humidity, gas, and ultrasonic sensors, is becoming more efficient. Proposals for biomedical waste sorting using IoT and cameras are emerging, along with suggestions for real-time waste tracking using RFID, GPS, cloud computing, and mobile apps. Robotic solutions, including robotic arms and vehicles with robotic hands, are proposed for waste sorting and collection. (M/s)

Existing models and innovations feature smart bins, cloud-based encryption for secure waste management, and real-time tracking platforms. IoT plays a crucial role by integrating identification, data acquisition, spatial, and communication technologies, although current literature primarily focuses on municipal waste rather than biomedical waste. To address this gap, a comprehensive smart solution has been developed, covering waste management from generation to disposal. (Pradesh, n.d.)

This includes deploying smart devices in hospitals, warehouses, vehicles, and processing units, and integrating AI and big data for optimization and collaboration among stakeholders, with Explainable AI (XAI) enhancing transparency and understanding. These advancements aim to mitigate risks associated with biomedical waste, promote infection prevention, and ensure the safety of healthcare workers and the public.

6.3. Literature Study: 03

Before digitalization, countries like Korea and Malaysia relied on manual documentation for waste management, leading to communication inefficiencies among stakeholders.

In Korea, RFID waste bags now enable precise measurement and tracking of disposal, with WiFi-enabled CCTV detecting segregation violations to prevent improper disposal.

Malaysia introduced the Electronic Schedule Waste Information (eSWIS) system in 2007, allowing waste

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generators to check scheduled waste facilities and manage storage, transport, and treatment online. Estonia aims for total digital waste management with a tracking system similar to postal parcels, though currently limited to municipal waste.
India employs a color-coded system for CBMWTFs to quantify waste, determine treatment, and provide annual reports.

Central Pollution Control Board Report:
The Central Pollution Control Board (CPCB) regularly publishes reports on Medical waste management, providing data, insights, and regulatory updates to enhance compliance and environmental sustainability. These reports offer valuable statistics on waste generation, treatment technologies, and enforcement mechanisms, guiding policymakers and healthcare facilities in their waste management endeavours. (BOARD, 2019)

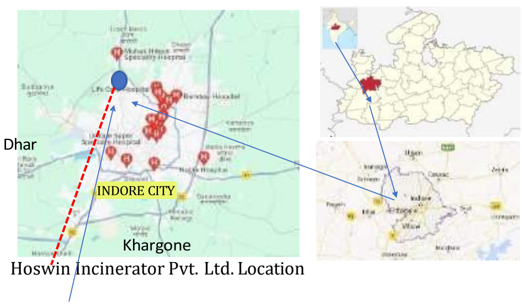
6.4. National Accreditation Board for Hospitals Standards:

The National Accreditation Board for Hospitals & Healthcare Providers (NABH) sets rigorous standards for healthcare facilities, including requirements for Medical waste management. NABH accreditation signifies adherence to quality standards and best practices, driving continuous improvement in waste management processes and ensuring patient safety. (NABH, 2024)

7. Advancing Medical Waste Management: Live Case Studies

7.1. Case Study # 01 Indore

Indore, a dynamic tier 2 city situated in the heart of Madhya Pradesh on the southern edge of the Malwa Plateau, spans 525 square kilometers and boasts a population of 3,272,335 people as per the 2011 Census. Recognized for its outstanding achievements in the Swachh Bharat Mission, Indore has secured the top position for six consecutive years. As the largest and most populous city in Madhya Pradesh, Indore serves as a vital commercial hub, driving significant business activities across the western part of the state. Its consistent success in promoting cleanliness, sustainability, and community well-being underscores its commitment to urban excellence. With robust infrastructure, strategic location, and a vibrant socio-economic landscape, Indore continues to set high standards in progressive urban development, positioning itself as a beacon of success in India.



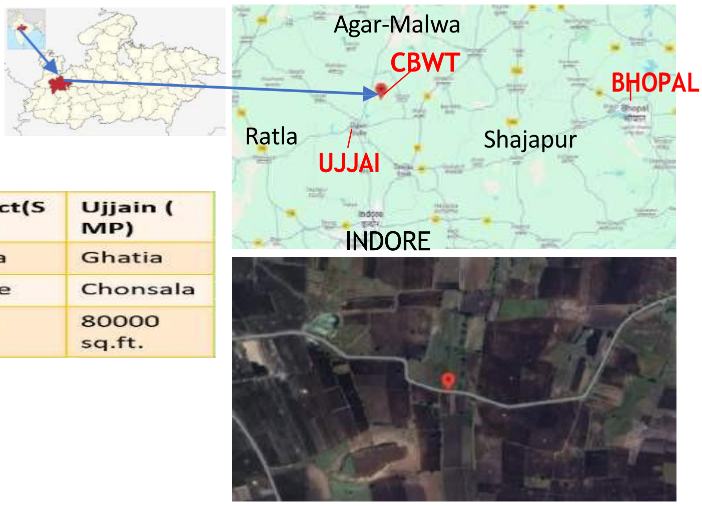
District (State)	**INDORE (MP)**
Taluka	INDORE
Village	Industrial area Indore
Area	48976 sq.ft.

Hoswin Incinerator Pvt. Ltd. , IndoreCBWTF Details

Figure 2 Indore CBWTF Location

7.2. Case Study # 02 UJJAIN

Ujjain, positioned as a tier 2 city and the largest in Madhya Pradesh, India, commands a central presence on the southern edge of the Malwa Plateau. Spanning a vast geographic area of 6091 square kilometers, the district of Ujjain is home to a substantial population of 1,986,864 individuals as per the Census of 2011. Renowned as a central power city and a major commercial capital of Madhya Pradesh, Ujjain holds sway across various sectors including commerce, finance, media, art, fashion, research, technology, education, and entertainment. (Pradesh, n.d.)



District(State)	Ujjain (MP)
Taluka	Ghatia
Village	Chonsala
Area	80000 sq.ft.

Figure 3 Ujjain CBWTF Location

The proposed Common Bio-Medical Waste Treatment and Disposal Facility by M/S Sunfluence Labs in Ujjain, Madhya Pradesh, addresses the critical need for efficient medical waste management in the region. Located at 46, Sakhipura, Ujjain (M.P.) 456010, the facility is designed to handle 300 Kg/Hr capacity operations, operating six days a week.

Encompassing a radius of about 150 kilometers, it serves healthcare facilities in Ujjain and neighboring areas like Dewas, Agar Malwa, Shajapur, Rajgarh, Nagda, and Barod. The facility spans 41,225 square feet, including dedicated areas for waste treatment machinery, administrative functions, waste and fuel storage, internal transportation, and a significant green belt for environmental conservation. (BOARD, 2019)

8. Study Comparison

SN NO.	Particulate	Description	
		INDORE	UJJAIN
1	Name of the Proponent	M/S Hoshwin Incinerator Pvt. Ltd.	M/S Sunfluence Labs
2	Project Capacity	500 Kg/Hr	300 Kg/Hr
3	Operation days	6 days in a week	6 days in a week
4	Freshh Water Requirnment	15KLD	10.5KLD
5	Source of Water	Pipeline & Open Well	Borewell & Water Tanker
6	Effluent Treatment Plant System	15 KLD	20 KLD
7	Electricity Required	170 KW	50 KW
8	Man Power	60	25
9	Total Project Cost	4.36 Cr	3.00 Cr
10	Land Required	48976 Sq. Ft.	80000 Sq. Ft.
11	Distance from main city(75 KM)	6.40 KM	27 KM
12	HCFs under covered area	935	364
13	No. of Bed	13113	8092
14	Waste Amount Generated	4524 Kg/Day	2000-2100 Kg/Day

Table 1 Study Comparison

Comparing the proposed The proposed Common Bio-Medical Waste Treatment and Disposal Facilities (CBWTF) in Indore and Ujjain showcase notable differences across various parameters. In Indore, managed by M/S Hoshwin Incinerator Pvt. Ltd., the facility boasts a capacity of 500 Kg/Hr, requiring 170 KW of electricity and accommodating 60 personnel. It covers 935 healthcare facilities with 13,113 beds, generating 4,524 Kg of waste daily at a project cost of 4.36 Cr, situated 6.40 KM from the city center on 48,976 Sq. Ft. of land. In contrast, Ujjain's CBWTF by M/S Sunfluence Labs operates at 300 Kg/Hr capacity, needing 50 KW of electricity and employing 25 personnel. It serves 364 healthcare facilities with 8,092 beds, generating 2,000-2,100 Kg of waste daily at a project cost of

3.00 Cr, located 27 KM from the city center on 80,000 Sq. Ft. of land. These differences underscore the varied requirements and impacts of CBWTFs in each city, highlighting the importance of tailored approaches to medical waste management based on local needs and conditions. (Author)

9. Analysis And Inferences - Standards, Case 01 (Indore) & Case 02(Ujjain)

Si. No.	**Particulate**	**Standards/Inferences**	**Indore**	**Ujjain**
1	Waste Generated Per Bed Per Day	0.5 Kg Per Bed Per Day	0.34 Kg/Bed/Day	0.25 Kg/Bed/Day
2	Lake or Pond	200 mt.	At 900 m in SE	At 1.50 km in NNW
3	Flood Plain	100 mt.	1.90 km in SE	Not in flood plain.
4	Highway States or National	500 mt.	The A-M Exp. Is 5.10 km from the site in east direction.	SH/27-7 km in WNW

5	Habitation Notified Habituated Area	500 mt.	Bhawrasla 0.80 km in NE	Chonsala Village at 1.50 km in WNW direction
6	Public Park	500 mt.	No Public Park within 500 mt.	No Public Park within 500 mt.
7	Critical Habitat area in which one or more endangered species	Not suitable	There is no endangered species in the site.	There is no endangered species in the site.
8	Waste Handling Capacity		500 kg/day	300 kg/day
9	Construction Cost		4.36 Cr	3 Cr
10	Average Cost	90 Lakh Per Quintal	0.87 Crore Per Quintal.	1 Cr. Per Quintal

Table 2 Analysis & Inferneces(Standard; Case01; Case 02)

Comparing Case 1 (Indore) and Case 2 (Ujjain) reveals significant differences and some similarities across various parameters in their waste management practices. Both cities effectively manage waste generation per bed per day, maintaining rates below the standard of
0.5 Kg as specified. However, they differ in proximity to water bodies; Indore's site is 900 meters from a lake in the SE direction, whereas Ujjain's site is farther at 1.50 km in the NNW direction. Both adhere to regulations concerning distances from flood plains and highways and maintain the required distance from inhabited areas, albeit with specific location differences. (Author)

Neither city has a public park within a 500-meter radius, meeting regulatory standards. Additionally, both locations confirm the absence of endangered species, demonstrating compliance with environmental conservation norms. Noteworthy variations include differences in waste handling capacity, construction costs, and average costs per quintal, with Indore generally reflecting higher figures compared to Ujjain. (Author)

In conclusion, while both cities adhere to essential standards in medical waste management, the differences underscore the unique characteristics and considerations that shape each locality's approach to this critical aspect of public health and environmental sustainability.

CONSTRUCTION COST PER QUINTEL/HR = TOTAL COST / WASTE HANDLING CAPACITY(Q./day).

OBSERVATION:

ETP + DISTANCE INCREASES FROM HCFs
INCREASES COST OF UNIT

I.E Indore – 15KLD + 6.40 KMS

Ujjain – 20 KLD + 27 KMS

USER CHARGES ON HCFs – RS 11/BED/DAY

In the analysis, key factors influencing the cost and efficiency of Medical waste management units, particularly in Indore and Ujjain, have been identified. It has been observed that the capacity of effluent treatment plants (ETPs) increases with the distance from healthcare facilities (HCFs), thereby impacting unit costs. This observation highlights the necessity for strategic placement of facilities to minimize transportation costs and enhance operational efficiency. Furthermore, the consideration of user charges set at Rs 11 per bed per day underscores the financial aspects of waste management services, which affect overall sustainability. By integrating construction costs, waste handling

capacity, and waste generation rates, insights into cost-effectiveness are offered, guiding decision- making processes in waste management planning to promote sustainable healthcare environments. (Author)

9.1. Location Criteria:-

Choosing the right location for a Common Bio-Medical Waste Treatment Facility (CBWTF) involves minimizing transport distances to meet the requirement of treating Medical waste within 48 hours of generation (MoEFCC, 2016). Industrial areas without buffer zones are preferred for their existing infrastructure and zoning regulations. If located away from such areas, maintaining a 500-meter buffer mitigates risks to health and the environment, subject to regulatory adjustments based on site specifics. Integration with a Hazardous Waste Treatment Storage and Disposal Facility (TSDF), with proper approvals, ensures efficient waste management but requires careful planning to prevent operational overlaps and environmental risks. (BOARD, 2019)

9.2. Land Requirnment:-

Land requirements for Common Bio-Medical Waste Treatment Facilities (CBWTFs) are crucial, ideally requiring at least one acre to accommodate essential facilities such as waste storage, treatment equipment, administrative rooms, and vehicle parking (MoEFCC, 2016). However, the State Pollution Control Board (SPCB) or Pollution Control Committee (PCC) may relax this requirement to 0.5 acres under specific conditions like zero liquid discharge systems and adherence to stringent emission norms (MoEFCC, 2016). CBWTFs typically serve within a 75-kilometer radius, extending to 150 kilometers where healthcare facilities exceed 10,000 beds, ensuring waste treatment within 48 hours (MoEFCC, 2016). Treatment charges are set by SPCBs/PCCs in consultation with the State Advisory Committee, ensuring equitable fees aligned with operational costs and regulatory standards for sustainable waste management.

9.3. Regulatory Framework:-

The 1998 Medical Waste Management Rules are essential for protecting public health and the environment (MoEFCC, 2016). Adherence mitigates risks to healthcare workers, patients, communities, and the environment from improper waste management. The study evaluates waste quantities and compositions, examining handling, treatment, and disposal methods. It highlights hazards from inadequate management and system deficiencies. Recommendations include tailored policies, training programs for healthcare workers, and implementing color-coded segregation systems. The study finds about 10% of hospital waste is hazardous, stressing the need for stricter protocols. It also notes that disposing of Medical waste with municipal waste increases risks.

10. Conclusion

In conclusion, the research stresses the need for stringent enforcement of legal provisions, improved environmental management systems, and the formulation of comprehensive waste management policies. It advocates for a holistic approach centered on the principles of 'reduce, recover, reuse, and dispose' to minimize waste generation and promote sustainable waste management practices. Education, training, and commitment are identified as essential components for achieving effective Medical waste management and ensuring the well-being of society and the environment.

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