

Sustainable Waste Management in the Healthcare Sector: An Experience of a Tertiary Care Institute.

Running Title: Sustainable Waste Management in Hospitals.

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Abstract: Background: Hospital waste has significant environmental and health impacts. Improper disposal of hazardous waste leads to environmental pollution, spread of diseases and public health issues. Effective waste management, including segregation, safe disposal, recycling, and proper treatment, minimises the risk of the spread of infections and promotes sustainability and resource conservation. **Objective:** We conducted a study to understand the types of recyclable hospital waste and impact of recycling on the environment. **Methods:** We analysed the records of waste disposal and focussed on waste streams other than biomedical waste. We examined waste disposal procedures of waste items like paper, linen, plastic, metals, and e-waste. **Results:** The trinity of waste management principles is Reduce, Reuse, and Recycle. The Institute has recycled 4461 quintals (446100 Kgs) of wastepaper since 2016 and the carbon footprint is - 2.2 million Kgs CO₂ which shows the positive impact the institute has had on the environment in the last eight years through a simple intervention of recycling wastepaper. Also, the hospital has gained over ₹ 16 million by auctioning waste in the last seven years. **Conclusion:** Recycling is essential in lowering carbon emissions. The study

emphasises that efficient waste management has direct financial savings, and indirect advantages, such as improved institutional reputation, regulatory compliance. In the end, these initiatives lead to better healthcare delivery.

Keywords: Carbon Emissions, Green House Gas Emissions, Recycling wastepaper, Recycling, Sustainable Waste Management, Waste Management.

Introduction

It is a well-known fact that waste significantly impacts the environment. It affects the ecosystem and human health and contributes to climate change. The various ill effects of waste generation include greenhouse gas emissions, particularly carbon dioxide, contributing to global warming, soil contamination, harm to wildlife and aquatic life, depletion of natural resources, and health hazards such as respiratory and skin issues. Due to the nature of their operations, several industries generate harmful, highly toxic, and difficult-to-manage waste. Among these industries, the waste generation in the healthcare industry or hospitals is unique and, at the same time, critical, as it includes the cluster of infectious, sharp, chemical, pharmaceutical, radioactive, and at the same time general waste. Infectious waste is waste contaminated with blood, bodily fluids, or other potentially infectious materials, such as used bandages, gloves, swabs, infected linen, and cultures of

infectious agents. Sharp waste includes items that can puncture or cut, such as needles, scalpels, broken glass, and other sharp instruments. Chemical waste is waste generated in laboratories during cleaning and disinfecting processes. It includes solvents, reagents, and heavy metals. Pharmaceutical waste includes expired, unused, or contaminated pharmaceutical products, such as drugs, vaccines, and sera. General or Domestic waste is the same as household waste, including paper, cardboard, kitchen waste, condemned linen, and packaging materials.

Each type of waste requires specific handling, treatment, and disposal methods. Studies estimate that 15% of the total amount of produced healthcare waste is hazardous, while the maximum chunk of 85% is non-hazardous or general waste [1]. However, the ratio is changing due to the increased use of disposables in healthcare settings [2,3]. Paper is a significant component of hospitals' general or municipal solid waste [4].

In 1972, the United Nations Conference on the Human Environment, held in Stockholm, resolved to take appropriate steps to protect and improve the human environment [5]. India was a participant in the conference. Given this, to protect and improve the environment, the Ministry of Environment, Forest and Climate Change, Government of India enacted The Environment (Protection) Act (EPA) in 1986. It serves as an umbrella legislation that empowers the Central Government to establish authorities to prevent environmental pollution in all its forms and tackle specific environmental problems peculiar to different parts of the country across various sectors [6]. Specific rules about the safe management of different streams of waste viz biomedical waste, hazardous waste, e-waste, solid waste, and plastic waste have been framed under the Act [7-11]. Improper waste management in healthcare settings significantly impacts patient care by increasing the risk of hospital-acquired infections (HAIs), posing safety hazards from sharps and hazardous waste, and contributing to environmental contamination. Non-compliance with waste management regulations can result in legal and reputational consequences, undermining community trust.

The trinity of waste management principles is Reduce, Reuse, and Recycle. Recycling

hospital waste helps reduce the environmental impact, save costs, and ensure that hospitals operate sustainably. The paper aims to study the waste management policies adopted by a tertiary care institute in north India and analyse the reduction in carbon footprint and impact on the environment by recycling wastepaper and condemned linen in the hospital.

Methodology

Study Setting

We conducted the study in a tertiary care teaching hospital in North India with over 2000 beds. The hospital admits close to 100,000 patients annually and employs nearly 15,000 employees to provide the services.

Study Design

We conducted a retrospective, record-based analysis of the quantity and types of waste generated in a tertiary care hospital. We obtained data from the hospital's condemnation store spanning eight years (2017–2024).

Inclusion Criteria

The study included records documenting the disposal of various waste categories, including paper, linen, plastic, metals, and e-waste. Additionally, the analysis included

the records of the revenue generated from the auction of the condemned material.

Data Extraction Process

The authors manually extracted and reviewed the data in August 2024.

Data Cleaning and Quality Control

We reviewed data for completeness and accuracy and excluded records with missing key variables or inconsistent entries from the analysis. Data cleaning involved checking for duplicates and ensuring consistency in categorical variables.

Ethical Considerations

Since this study involved institutional records rather than personal data or human or animal intervention, we did not seek formal ethical approval.

Results

The institute disposes of approximately 100 tons of wastepaper, 40 tons of condemned linen, 1488 tons of Biomedical Waste, and 2872 tons of Solid Waste annually.

Figure 1 depict the wastepaper sent for recycling against the number of A4-size reams received.

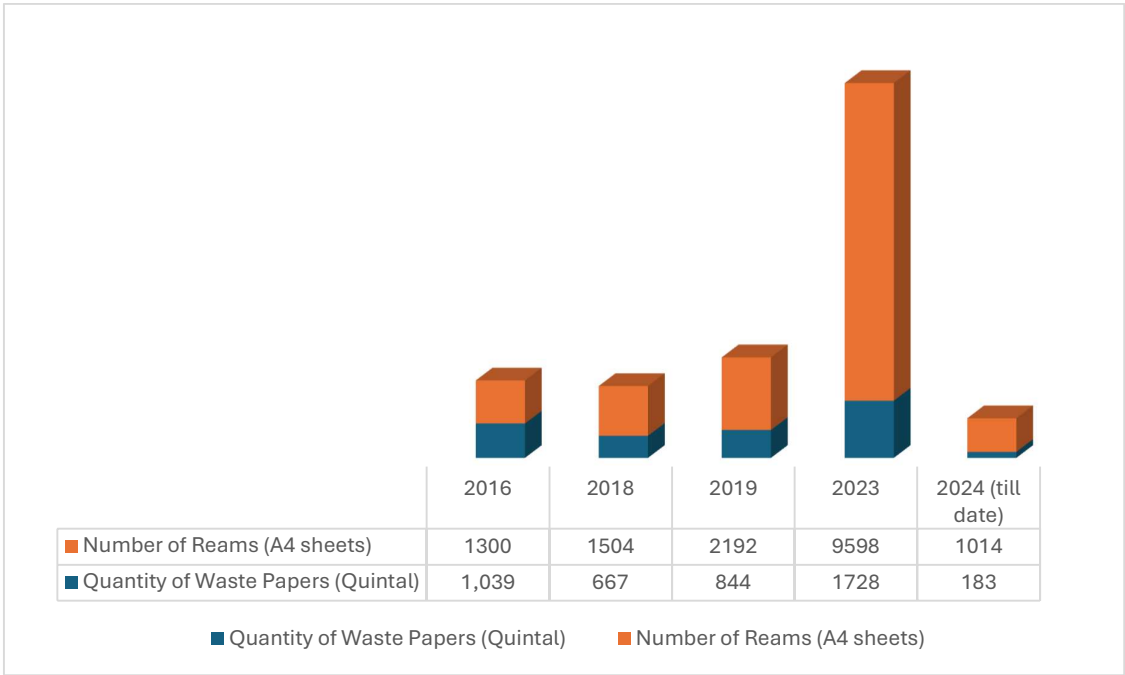


Figure 1: Quantity of Wastepaper recycled against the A4 size Reams received

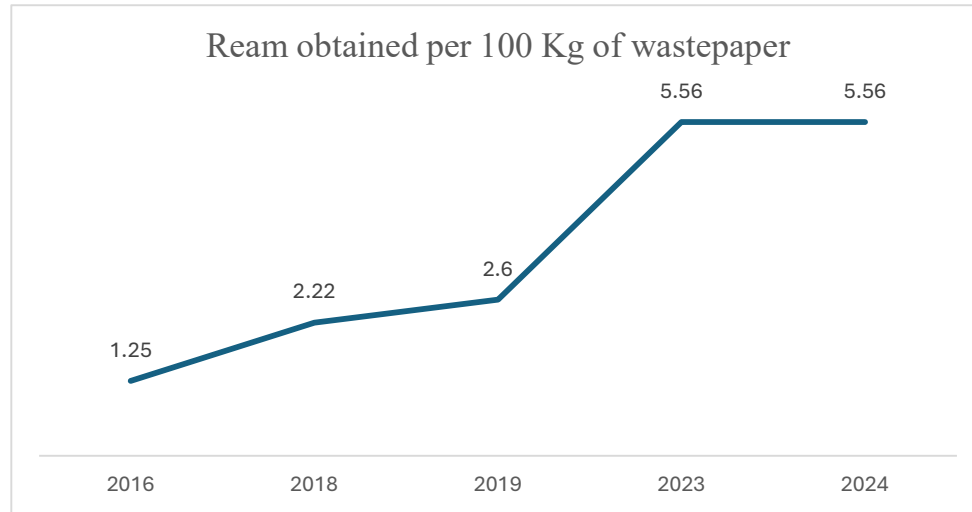


Figure 2: Ream obtained per 100 Kgs of Wastepaper

Figure 2 represents the quantity of A4 size reams obtained per 100 Kilogramme (Kgs) of wastepaper sent for recycling.

Table 1 depicts the total quantity of linen condemned in the past eight years in numbers/pieces and Kgs.

Table 1: Quantity of linen condemned in the past eight years in numbers/pieces and Kgs.

Linen Item	Weight of linen item per piece	2015		2017		2019		2022	
		Pieces	Weight in Kgs	Pieces	Weight in Kgs	Pieces	Weight in Kgs	Pieces	Weight in Kgs
Bedsheet	0.842	7104	5981.57	13579	11433.52	13673	11512.67	31197	26267.87
Blankets	1.682	336	565.15	631	1061.34	708	1190.86	995	1673.59
Curtains	0.371	261	96.83	377	139.87	947	351.34	2860	1061.06
Draw Sheets	0.277	23436	6491.77	43305	11995.49	41139	11395.5	105471	29215.47
Gown	0.452	5374	2429.05	16511	7462.97	20579	9701.71	43454	19641.21
Kurta	0.293	2887	845.89	7737	2266.94	35252	10328.84	15925	4666.03
Pyjama	0.301	3161	951.46	8016	2412.82	9222	2775.822	17592	5295.19
Pillow Cover	0.087	103	8.96	267	23.23	163	14.181	326	28.36
Towel	0.510	914	466.14	2867	1462.17	3317	1691.67	436	222.36

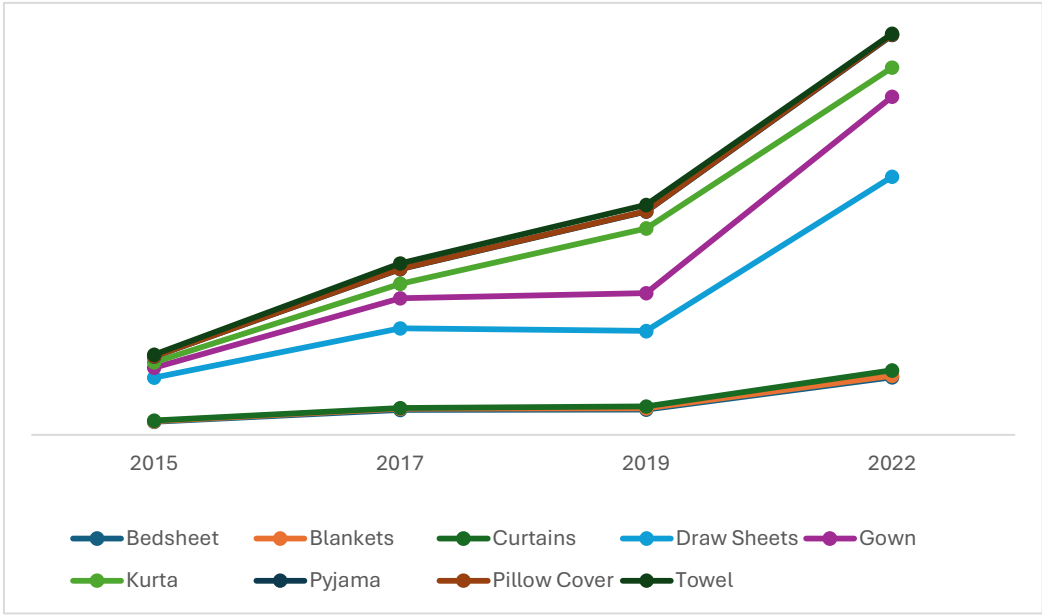


Figure 3: Quantity of linen condemned in the past eight years

Quantity of linen condemned in the past eight years is depicted in Figure 3. Figure 4 depicts the amount of money earned by

auctioning the waste material of various categories generated in the hospital from 2017-2024

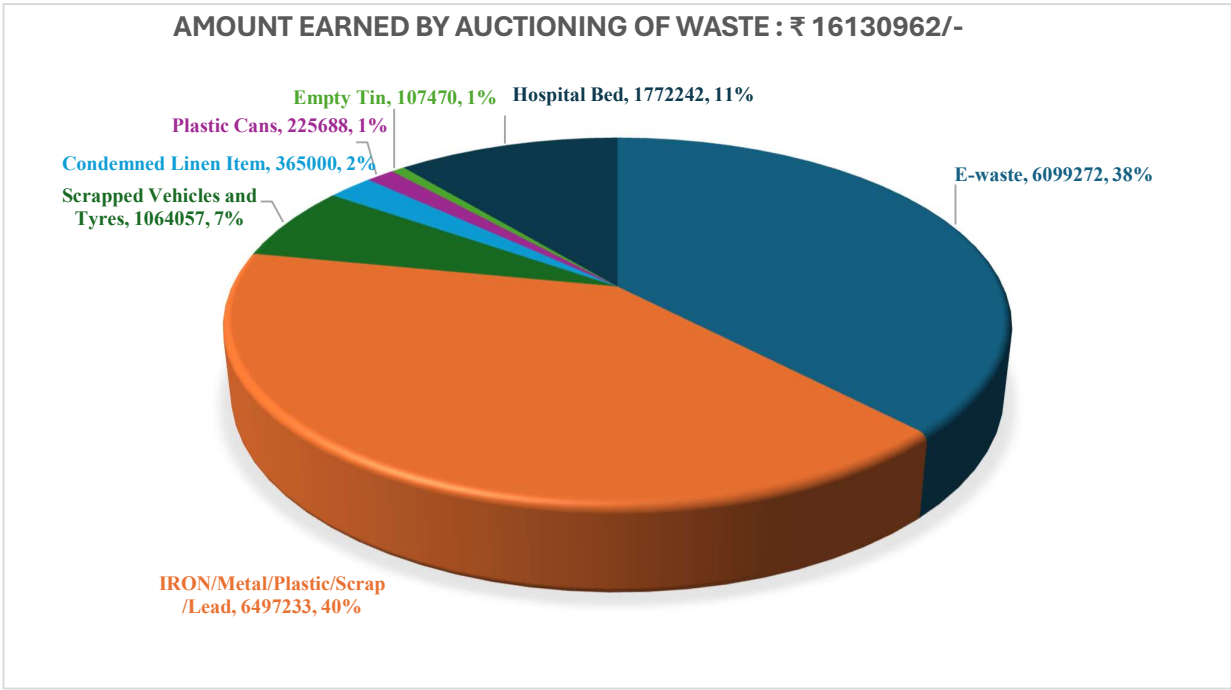


Figure 4: Amount earned by Auctioning the Waste from 2017-2024 (INR)

Discussion

Waste management practices in the country need substantial improvement. Healthcare settings are no exception. Condemned material occupies precious space in hospitals. It increases the fire load, posing a significant hazard [12]. Managing, storing, and securing large volumes of waste material is a cost centre. It includes the costs of physical storage solutions, staff time for material management, and potential legal issues if mismanaged [13]. The focus is on biomedical waste management as the rules are stringent, with non-compliance leading to criminal prosecution. However, we pay less attention to waste materials like paper, linen, plastic, furniture, and other sundry items. As more and more paper or other waste, as mentioned above, accumulates, it is harder for staff to work efficiently and maintain organised, clean environments.

Our hospital has an organised process of condemnation and auction of waste material. In the last seven years, the hospital has gained over ₹ 16 million by auctioning waste, with the maximum money earned by auctioning iron, metal, tin, plastic, and scrap, which is 40% of the total amount (₹ 64.97 lakhs), followed by auctioning e-waste, which is 38% (₹ 60.99 lakhs) of the total amount.

Additionally, we would like to discuss a unique paper recycling system practised in our hospital. Patient records are a significant component of the wastepaper generated in any hospital. Agendas for important meetings, examination papers, minutes of the meetings, other sensitive office records, thesis, and dissertations are stored for practically endless periods without a clear policy towards their disposal. Cumulatively, the institute condemns approximately 100 tons of wastepaper each year. Prior to 2016, the institute was sending this waste for incineration. We could not opt for the alternative of auctioning and selling these documents as scrap because of their confidentiality. Incineration not only pollutes the air or emits harmful toxins but also reduces the option of recycling, as there is a permanent loss of recyclable resources [14].

The environmental effects of paper production include deforestation, the use of enormous amounts of energy and water, air pollution, and waste problems. Every year, more than 300 million acres of forest are destroyed for making paper, resulting in short-term or long-term disruptions to forest ecosystems, further affecting the biodiversity of plants and animals, soil fertility, and water quality. The carbon footprint in the manufacturing of a paper

includes all the Greenhouse Gas emissions, primarily carbon dioxide, associated with the various stages of the lifecycle of the paper, from raw material extraction to production, transportation, use, and disposal. Life Cycle Assessment is a common technique for evaluating a product's carbon storage throughout its life cycle [15].

In order to counter these effects, the institute opted to recycle the wastepaper. The main benefit of recycling is a twofold reduction in environmental impact: it conserves natural resources by reducing the need for raw materials. It minimises the release of harmful compounds into the environment by lowering waste and emissions from manufacturing processes [16]. The entire condemned wastepaper of the institute is given to an authorised paper recycler. The vendor gives an affidavit that it will only use the lifted paper from the institute for pulp-making to maintain the confidentiality of the medical records. The vendor provides fresh paper (A4 size, 500 sheets/ream) in place of the wastepaper. Figure 1 represent the quantity of wastepaper sent for recycling and the number of reams obtained against it. Figure 2 represents the reams obtained against 100 kgs of wastepaper in various years. In the first year, the vendor bartered 1.25 reams per 100 Kg of wastepaper (one ream per 80

Kgs of wastepaper), subsequently increasing every year. In 2024, the institute is getting 5.56 reams per 100 Kgs of wastepaper (one ream per 18 Kgs of wastepaper). Regarding cost-benefit, the institute has come to a state where there is no need to buy paper of A4 size from the market. It not only reduces the tangible cost, considering the cost of one ream is about ₹ 250-300/- but it also reduces the intangible cost in terms of the expenses incurred in the procurement process, such as administrative cost, lead time (external and internal) for buying the product, [17-18] logistics, and transportation cost, inventory holding cost, insurance against damage, theft or loss during storage or transportation, labour cost, opportunity cost [19] and pilferage of the item. These indirect/intangible costs are critical for overall supply chain efficiency. Regarding protecting the environment, sending the paper for recycling through pulping is genuinely beneficial. As per the study by Wencong Yue, Yanpeng Cai et al., the carbon footprint of 1000 kgs copying paper was 647.89 kgs CO₂ while burning wastepaper and -5094 kgs CO₂ while reusing waste paper [15]. The Institute has recycled 4461 quintals (446100 Kgs) of wastepaper since 2016. Based on the calculations mentioned in the study above, the institute could save carbon emissions of more than 2.2 million Kgs CO₂.

$$1000 \text{ Kgs of wastepaper} = -5094 \text{ kgs CO}_2$$

$$446100 \text{ Kgs of wastepaper} = \frac{-5094 \times 446100}{1000}$$

$$\text{Carbon footprint} = -22,72,433.4 \text{ Kg CO}_2$$

It shows the positive impact the institute has had on the environment in the last eight years through a simple intervention of recycling wastepaper.

Besides wastepaper, the institute condemns a large amount of linen yearly. The linen used in any healthcare institute consists of bed sheets, patient and doctor gowns, draw sheets, scrubs, blankets, towels, and curtains. Studies estimate hospital linen can withstand 70 to 120 wash cycles before replacement [20,21].

Table 1 presents the quantity and weight (in kilograms) of various linen items that have been condemned and auctioned from 2017 to the present. Figure 3 illustrates the trends in condemned linen from 2015 to 2022. Although the data collection began in 2017, the linen records include information dating back to 2015. The linen condemned in 2015 could be auctioned and disposed in 2017 only due to factors such as insufficient quantity to evince interest from bidders, delays in the tendering process, and the transition from traditional physical tenders to the Government e-Marketplace (GeM). As a result, the table includes items from the years 2015 to 2022. There was an

increase in the amount of linen auctioned from 2015 to 2017, followed by a period of stability between 2017 and 2019. However, from 2019 to 2022, there was a sharp rise in the quantity auctioned, largely due to a four-year gap in auctions and the increased linen condemnation during the COVID-19 pandemic.

The condemned linen is washed, disinfected, and further auctioned and given to recyclers instead of being sent for incineration. The institute has proactively initiated this step to send the condemned linen for recycling. It contributes to operational efficiency and environmental sustainability. Recycling minimises the environmental impacts by diverting linen away from incinerators and extending its useful life. It also conserves natural resources by reducing the need for new raw materials. Moreover, there is a financial incentive as the linen is auctioned and taken by the highest bidder. As per Figure 3, the institute has earned ₹ 3,65,000/- in the last eight years through the auction of discarded linen.

According to Carrera, doubling the lifespan of garments would reduce the fashion industry's greenhouse gas emissions by 44%. Extending the active life of clothing by just nine months would reduce carbon, water, and waste footprint by 20-30%.

Extending the lifespan of textiles also reduces greenhouse gases, water usage, and waste. An increase of 10% in second-hand sales could save 3% of carbon emissions and 4% of water, according to data from the report *Valuing our clothes: the cost of UK fashion*, published by WRAP in 2017." Recycling hospital linen reduces carbon emissions compared to incineration. For each kg of textile reused, up to **25 kg of CO₂** emissions can be saved. This is primarily due to the reduction in raw material production and energy consumption in making new linens. Though direct evidence of saving in terms of carbon footprint due to recycling may be vague, it is postulated to have a beneficial effect. These savings contribute significantly to a hospital's sustainability goals while minimising environmental impact. Several studies highlight substantial tangible and, more importantly, intangible benefits—most notably a measurable reduction in carbon footprint—thereby supporting the case for waste-reducing interventions which contribute meaningfully to environmental sustainability efforts [22].

Conclusion

In the present study, we examined the procedures for disposing of various waste

materials generated by a tertiary care institute and the financial benefits of recycling these materials. Our findings underscore the significant environmental and economic advantages of implementing systematic waste management strategies, particularly in recycling wastepaper and linen. Given the substantial carbon emissions associated with the production, transportation, and disposal of paper, hospitals that generate large amounts of paper waste contribute to deforestation, landfill overuse, and increased greenhouse gas emissions unless effective recycling programs exist [23]. Similar environmental and financial benefits extend to linen recycling, demonstrating the potential of sustainable waste management practices in healthcare settings.

The insights from this study have important policy and practice implications for healthcare institutions, regulatory bodies, and policymakers. Hospitals can achieve cost savings by institutionalizing structured waste recycling programs while reducing their environmental footprint. The success of waste optimization in a tertiary care institution demonstrates the feasibility of broader adoption across other healthcare settings, including primary and secondary

care hospitals. Institutions can replicate these strategies by:

Implementing Waste Segregation Protocols: Ensuring sorting of the recyclable materials at the source.

Training Healthcare Staff: Educating personnel on best practices for recycling and waste minimization.

Leveraging Technology: Using digital systems for waste tracking, optimization, and regulatory compliance.

Engaging with Sustainability Networks: Partnering with organizations and industry leaders to adopt best practices in green healthcare. Governments and healthcare regulators can encourage such practices by formulating enabling policies:

Developing Standardized Guidelines: Establishing national, regional or local guidelines for the recycling and disposal of waste.

Promoting Public-Private Partnerships: Facilitating collaborations between healthcare institutions and waste management companies to ensure efficient recycling and disposal.

Financial Incentives and Sustainability

Grants: Offering financial rewards, tax benefits, or sustainability grants to healthcare institutions implementing effective recycling programs.

Implementing structured recycling and waste management strategies can help hospitals and other healthcare institutions achieve direct financial savings, regulatory compliance, and enhanced institutional reputation. Moreover, these efforts contribute to broader environmental sustainability goals by mitigating carbon emissions and reducing pollution, ultimately supporting the global shift toward greener healthcare delivery.

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