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Sustainable Resource Circulation in Hospitals: A Review of Practices and Challenges

Dr. Shivangi Vashisht, Assistant Professor, Lovely Professional University, shivangi.vashist8989@gmail.com

0009-0007-8714-9316

Shilpi Shaw,MBA(Mittal School of business), shilpishaw62@gmail.com,

0009-0005-1159-0725

Simran Shalu,MBA (Mittal School of business), shalusimran2606@gmail.com

0009-0007-0191-2764

Geetanjali Devi,MBA (Mittal School of business), Geetanjali.tanu73@gmail.com

0009-0001-1387-153X

Meenakshi,MBA (Mittal School of business), Meenakshichoubey916@gmail.com

0009-0002-4351-7520

Mukul Dadwal,MBA(Mittal School of business), mukuldadwal449@gmail.com

0009-0000-7987-9158

Abstract

The research report examines sustainable resource circulation, in hospitals, by combining (1) literature-based discussion on circular economy practices in health care; and (2) survey-based evidence on actual waste segregation and recycling behavior. According to the research hospitals generate multiple streams of waste and that concerted efforts for sustainability must align with infection-control requirements so circular (reduce–reuse–recycle–recover) strategy becomes difficult but still possible. Results of the survey indicated moderate awareness regarding the segregation systems among the employees. In addition, the exposure to training was found to be limited and segregation practices were inconsistent. Moreover, the clarity/implementation of recycling systems were weak, indicating the gap between written systems phase and daily operational phase. The report indicates that training is a key predictor of segregation. In contrast, recycling is more dependent on external systems – vendor availability/ readiness, and infrastructure and reliable collection linkages.

Keywords: *Sustainable resource circulation, hospital waste management, circular economy, waste segregation, recycling systems, training, healthcare sustainability, infection-control constraints.*

I. Introduction

A. Context and Significant of Sustainable Resource Circulation

Facilities built with the intent to protect health generate large and varied waste streams as a result of all routine care activities. Waste includes generation of general waste and hazardous materials including but not limited to infectious waste, sharps, chemicals, pharmaceuticals but also other specialized waste categories. The hospital waste bulk is composed of mixed waste types. There are also other safety elements involved in the hospital waste management. Because of that, the hospital waste management is more sensitive than the ordinary municipal waste management. It requires stronger systems and compliance in daily practice.

The recycling of all resources in hospitals is not limited to ‘safe disposal’. It starts with prevention of waste, keeping materials in use wherever they are safe and

recovering value through circular strategies. This means reducing needless packaging; choosing reusable options where applicable; recycling non-hazardous streams; and supporting approved reprocessing where allowed.

B. Problem Statements

Hospitals generate a large quantity of biomedical waste besides plastics, chemical waste, pharmaceutical waste, e-waste etc. which causes environmental pollution's risk as well as occupational hazards to staff, waste handlers and neighborhood. When hazardous and non-hazardous waste streams are mixed due to poor segregation, the amount of waste requiring costly treatment increases and contamination risks rise.

C. Objectives

- To study the types of waste generated in hospitals
- To examine existing waste management and recycling practices
- To identify challenges in implementing sustainable resource circulation

II. Literature Review

A. Sustainable Resource Circulation in Hospitals

- A Review on Recent Developments in Sustainable Healthcare Waste Management (2025) provides an overview of sustainability and material circularity approaches for healthcare waste management.
- The literature on circular economy in healthcare is reviewed in a systematic way that involves research in the area of circular economy.
- Medical Waste Management in Modern Healthcare (2025) examines the key technologies and sustainable practices used for medical waste management.
- The Circular Economy Modelling for Healthcare Waste Management (2025) describes modelling approaches that can support the implementation of the circular economy in hospital waste systems.
- The 2022 research paper, titled Waste Management and the Perspective of a Green Hospital, investigates hospital waste practices worldwide through the framework of sustainability stemming from a "green hospital" concept.
- A circular-economy model aimed at recovery of bio-waste in hospitals (2025) proposes a proposed circular economy model for hospital bio-waste management.
- The Sustainable Management of Healthcare Waste in University Hospitals (2025) indicates difficulties and affordable solutions for university hospital waste management.
- A Systematic Review of Waste Management Practices in the Healthcare Sector (2025) thematic synthesis of waste management practices in the healthcare sector.
- It is time to improve waste and circular economy on healthcare. Report (2024) identifies healthcare waste types and opportunities for circular-economy applications.
- Mapping Healthcare Waste Management Research: Past Evolution & Current Trends traces the evolution of healthcare waste management research and summarizes current research trends.
- The management of medical waste which identifies effective reduction approaches in line with sustainable green-hospital strategies (2022).
- The article Healthcare Waste and Sustainability: Implications for Circular Systems discusses the emerging methods and implications for circular systems.
- The review of Medical Waste Management Approaches: Challenges and Innovations (2025) reviews the major challenges, innovations, and environmental impact of medical waste management approaches.
- Circular Economy Indicators for Hospital Waste Management (2024) proposes the indicators of circularity for proper design and procurement of healthcare materials and waste systems.
- Dixit and Dutta (2024) determine factors that influence the successful adoption of the circular economy in sustainable healthcare waste management's.
- A framework has been proposed by Fletcher et al. (2021) to evaluate plastic-waste strategies of hospitals with respect to circularity and technological maturity.
- Ali M and colleagues, in 2017, compared hospitals in regard to knowledge and operational efficiency in practices of hospital waste management.
- Blockchain hospital waste management systems refer to digital innovation strategies for enhancing hospital waste.
- Hossain, Ghose & Sahajwalla (2025) outlines the circular-economy applications in health and the risks and restraints.
- AI-Driven Circular Waste Management Tools for Enhancing Circular Economy in Hospitals (2025)

discusses AI-based decision support tools aimed to improve circularity of hospital wastes.

B. Research Gaps

It was observed that while there are many reports that pay attention to the safe biomedical disposal, not much practical attention is being paid to consider waste reduction on the upstream end as well as safe reuse and recycling. The research questions are concerned with the types of waste, current waste management and recycling practices, barriers to resource circulation, and actionable improvements. The study objectives refer to studying the question of waste and recycling practices, examining what is going on, identifying barriers, and making proposals to improve sustainable waste management.

III. Research Methodology

A. Research Design

This research adopts a descriptive and analytical research design. This research is descriptive as it describes the current situation in the hospitals. This covers what people (hospital staff) know about the hospital waste, whether segregation happens and what are the issues they face. Moreover, it is analytical as it compares the responses and checks the relationship between the variables. For example, it checks the relationship between training and awareness. And it also checks the role of the respondent and their waste-handling practices.

B. Sample and Variables

- **Sampling Technique**: Convenience sampling technique.
- **Sampling Size:** 160 respondents took part in the survey.
- Respondents largely consisted of nurses, paramedical staff, housekeeping/waste-handling staff, and came from clinics/nursing homes, medical college hospital, private hospital, and government hospital.

C. Data Collection Methods

- **primary Data** (survey) was collected with the help of a structured questionnaire made in Google Forms. This was done because Google Forms is easy to circulate, saves time, and ensures that everyone answers the same set of questions (voluntary participation).
- **The questionnaire** contained mostly close-ended (MCQ and Likert scale) questions which will ensure the responses are counted and compared.
- **Questionnaire Section:** The questionnaire had three sections: (A) demographic details, (B) knowledge and practices (waste types, undertaken/ not undertaken color-coded bins for waste disposal, segregation/ recycling), and (C) obstacles and recommendations.
- **Secondary Data:** The research team collected secondary data from the research papers, WHO documents/guidelines, government reports and published studies related to hospital waste management and resource circulation.

D. Data Analysis Techniques

- The trends highlighted include awareness, segregation, recycling and other aspects are summarized through frequency percentage and mean values.
- Cross-tabulation compares specific groups with respect to a particular issue (e.g. trained vs untrained staff and segregation practice; role vs awareness).
- The Chi-square assessment measures the link between demographics and waste management awareness and practices.
- Regression analysis was used to check the predictors of (1) waste segregation by training, knowledge on color-coded bin and workload and recycling of paper/plastic by facility type, segregation and training.

IV. Data Analysis and Findings

A. Demographic Profile of Respondents

The highest age group participating in the study was 31 to 40 years (30%) followed by 41 to 50 years (25.6%) and 21 to 30 years (23.1%). Most of the subjects were nurses (29.4%). The second most (26.3%) were paramedical staff. The third most (23.1%) were housekeeping/cadre waste–handling staff. Most of the subjects were from clinics/nursing homes (27.5%). The second most (24.4%) were from medical college hospital. The third most (22.5%) were from private hospital. The fourth most (15%) were from government hospital.

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Age of people	160	1	5	2.56	1.253
Gender	160	1	4	2.39	1.155
Valid N (listwise)	160				

Table 1 Descriptive Statistics

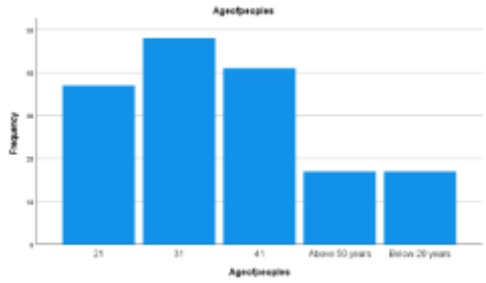

Figure 1 Age of People

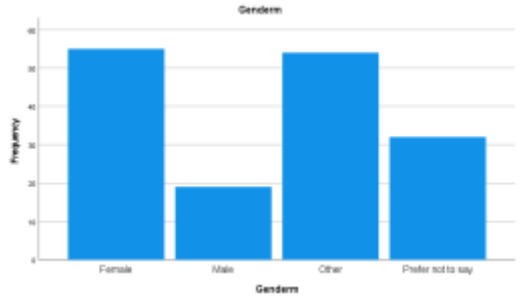

Figure 2 Gender

B. Chi – Square Test

The results of the chi-square analysis showed that age group was not related to waste segregation, response to paper/plastic recycling, and training received (p-values > 0.05), which means that age did not make a significant difference in these practices in this sample.

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.711[a]	8	.568
Likelihood Ratio	6.251	8	.619
Linear-by-Linear Association	3.085	1	.079
N of Valid Cases	160		
a. 4 cells (26.7%) have expected count less than 5. The minimum expected count is 4.14.			

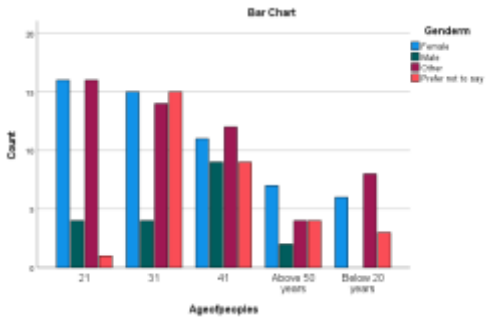

Figure 3 Bar Chart

C. Regression Analysis

Model 1 with dependent variable waste segregation and predictor variables training, knowledge of colour-coded bin and workload was significant but weak (R2≈0.049). In this case training was the only significant predictor of segregation contrary to knowledge of colour-coded bin and workload which were not significant predictor. Model 2 with dependent variable paper/plastic recycling and predictor variables facility type, segregation, training was overall non-significant and had low R2≈0.026. It means predictors do not explain recycling well.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.832	.358		7.904	.000
	Received Training on Waste Management	-.241	.105	-.182	-2.303	.023
	Color Coded Bins	.108	.121	.070	.892	.374
	Workload Affects Waste Segregation	.151	.108	.110	1.397	.164

a. Dependent Variable: Waste Segregation

Table 2 Coefficient

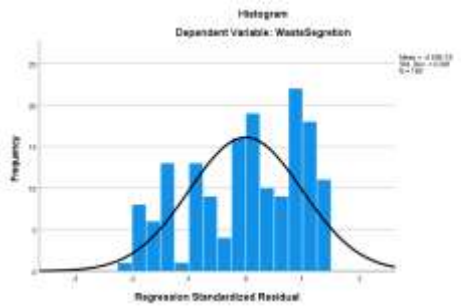

Figure 4 Histogram

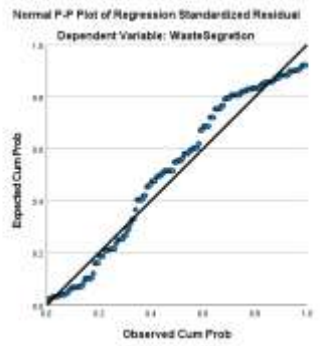

Figure 5 Plot of Regression

D. Correlation

The study identifies the following key statistical methods: descriptive statistics, cross-tabulation, chi-square, and regression. No correlation test or correlation table is provided, so correlation results are not reported.

Correlations					
		Waste Segregation	Workload Affects Waste Segregation	Color Coded Bins	Received Training on Waste Management
Pearson Correlation	Waste Segregation	1.000	.095	.095	-.175
	Workload Affects Waste Segregation	.095	1.000	.085	.116
	Color Coded Bins	.095	.085	1.000	-.087
	Received Training on Waste Management	-.175	.116	-.087	1.000
Sig. (1-tailed)	Waste Segregation	.	.116	.115	.013
	Workload Affects Waste Segregation	.116	.	.143	.071
	Color Coded Bins	.115	.143	.	.137
	Received Training on Waste Management	.013	.071	.137	.
N	Waste Segregation	160	160	160	160
	Workload Affects Waste Segregation	160	160	160	160
	Color Coded Bins	160	160	160	160
	Received Training on Waste Management	160	160	160	160

Table 3 Correlation

E. Findings

The results show that waste segregation is only relatively followed (mean ~2.85/4) and most said "No/Don't know" regarding whether their hospital

recycles paper/plastic. Overall, results suggest training is the most likely factor which results in better segregation, whereas recycling most probably depends on system support rather than individual behavior.

V. Discussion

A. Interpretation of Results

The results indicate a clear "implementation gap." Respondents report a moderate level of day-to-day segregation (mean ≈ 2.85/4). Further, a sizeable portion of responders are unsure if their paper/plastic wastes are recycled. This suggests that written rules exist but the practice on the ground, as well as a visible recycling system, is not strong.

The chi-square results confirm that age is not significantly related to segregation, recycling reaction, or training (p-values > 0.05), meaning performance differences are likely due to the hospital systems (training, monitoring, facilities, and workflow design) rather than respondent age.

Regression Model 1 suggests that training seems to be the only statistically significant predictor of segregation while color-bin awareness and workload are not significant inside the model. This means that training is the most "actionable" lever identified in this dataset. However, it also explains a very small part ($R^2 \approx 0.049$) of segregation behavior. The most recent regression model is insignificant (the R^2 value is very low at approximately 0.026).

B. Limitations of Future Research

As the study uses a questionnaire-based approach and summarizes responses mainly using descriptive statistics plus chi-square and regression, the findings depend on self-reported behavior and cannot fully establish actual segregation/ recycling performance through direct observation or waste audits. The sampling method is convenience-oriented, being limited to 160 respondents. Therefore, the results cannot be indicative of all hospitals or all staff categories, especially with concern to regions and size of the hospitals. The models account for a small share of the variation in segregation and recycling outcomes (low R^2), which means important drivers were left out (e.g., availability of bins at point-of-use, enforcement, vendor tie-ups, storage, and internal monitoring).

VI. Conclusion

This research suggests that sustainable resource circulation in hospitals is still in its infancy stage in everyday practice: the respondents only comply moderately with waste segregation (mean ≈ 2.85/4); many participants answered "No" or "Don't know" when asked whether paper and plastic waste is recycled, which would seem to suggest that recycling systems are not well established and/or clearly visible to staff. The chi square results further indicate that segregation, recycling response, or training received is not affected by age, so the issue is not basically demographic. Rather it is a matter of how the hospital organizes, trains and supports waste-handling routines. The regression analysis bolsters this claim: in the segregation model, the only significant predictor is training, while the other variables knowledge of color-coded bins and workload have non-significant effects within the model, indicating that structured training is indeed the most feasible and measurable step that hospitals can take in improving segregation behavior, even though the model explains only a small percentage of overall variation ($R^2 \approx 0.049$).While examining the recycling model, we find out that it is not substantial and explains very little ($R^2 \approx 0.026$). Thus it suggests that enhancing recycling is not only depending on staff awareness or basic segregation. But rather needs a system-level support like clear recycling protocols, good collection and vendor partnerships, storage arrangements, monitoring and more.

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