



FROM BEDSIDE TO BIOSPHERE: A HOSPITAL-BASED PILOT STUDY COMPARING CONVENTIONAL AND ENVIRONMENTALLY SUSTAINABLE LINEN

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ABSTRACT

Hospital linen services represent a significant yet underexplored contributor to the environmental footprint of healthcare institutions. With increasing emphasis on sustainable healthcare delivery, environmentally sustainable linen has emerged as a potential alternative to conventional hospital linen. This hospital-based pilot study aimed to compare conventional linen with environmentally sustainable linen in terms of environmental impact, operational performance, cost implications, infection prevention outcomes, and user satisfaction. A prospective comparative study was conducted over six months in a tertiary care teaching hospital. Two comparable inpatient wards were allocated either conventional linen or environmentally sustainable linen. Key parameters assessed included water and energy consumption per laundering cycle, linen durability, rejection rates, procurement and lifecycle costs, post-laundering microbial contamination, and patient and staff satisfaction. Data were collected from hospital laundry records, microbiological surveillance reports, procurement data, and structured questionnaires. Environmentally sustainable linen demonstrated substantially lower water and energy consumption during laundering, improved durability, and lower rejection rates. Although procurement costs were higher, lifecycle cost analysis revealed overall cost neutrality. Infection control outcomes were comparable across both linen types, with microbial counts remaining within acceptable standards. Patient and staff satisfaction scores were similar, with a marginal preference for sustainable linen. The study concludes that environmentally sustainable linen is a safe, feasible, and environmentally responsible alternative to conventional hospital linen and can support hospital sustainability goals without compromising patient safety or quality of care.

KEYWORDS : Hospital linen; Sustainable healthcare; Environmental impact; Infection control

INTRODUCTION

Healthcare systems worldwide are increasingly recognizing their dual responsibility of delivering safe, high-quality patient care while minimizing adverse environmental impacts. Hospitals are resource-intensive organizations that operate continuously, consuming substantial quantities of water, energy, chemicals, and materials. It is estimated that healthcare contributes significantly to national carbon emissions, with non-clinical support services accounting for a considerable proportion of this footprint (1).

Among hospital support services, linen and laundry operations represent a critical yet under-recognized contributor to environmental burden. Hospital linen services involve repeated high-temperature washing, drying, chemical disinfection, and transportation, resulting in intensive use of water and energy, as well as discharge of chemical effluents (2). In large tertiary care hospitals, linen services function continuously to support inpatient care, operating theatres, intensive care units, and outpatient services, thereby magnifying their cumulative environmental impact.

Conventional hospital linen is predominantly manufactured from virgin cotton or polyester-cotton blends. Cotton production is associated with high water consumption, pesticide use, and land degradation, while polyester fibres contribute to fossil fuel depletion and microplastic pollution (3). Additionally, conventional dyeing and finishing processes often involve chemicals that increase environmental toxicity. Shorter fabric lifespan and higher rejection rates further exacerbate environmental and economic costs by increasing replacement frequency and textile waste generation.

In response to growing global concern regarding climate change and environmental sustainability, environmentally sustainable linen has emerged as a potential alternative for healthcare facilities. Sustainable linen typically incorporates organic cotton, recycled polyester fibers, and low-impact dyes, and is designed to withstand a higher number of laundering cycles. These textiles aim to reduce environmental

harm across the product lifecycle, including raw material sourcing, manufacturing, laundering, and end-of-life disposal (2).

Despite the theoretical advantages of sustainable textiles, their adoption in hospital settings has been slow. One of the principal barriers is concern regarding infection prevention and control. Hospital linen is in direct and prolonged contact with patients, including those who are immunocompromised, making microbial safety a paramount consideration. Existing evidence suggests that fabric type does not independently influence infection risk when appropriate laundering standards are followed; however, hospital administrators often remain cautious about introducing alternative materials into clinical environments (3).

Cost considerations represent another major challenge. Sustainable linen generally entails higher upfront procurement costs, which may discourage adoption in resource-constrained healthcare systems. However, emerging evidence suggests that lifecycle cost analysis accounting for durability, laundering costs, and replacement frequency may favor sustainable alternatives over conventional linen (2). Nevertheless, real-world hospital-based economic evaluations remain limited.

Furthermore, operational feasibility and user acceptability are critical determinants of successful implementation. Linen services must maintain rapid turnaround times, compatibility with existing laundry infrastructure, and acceptability among patients and healthcare workers. Sustainability initiatives that disrupt workflows or compromise comfort are unlikely to achieve long-term success.

Although international organizations have emphasized the importance of environmentally sustainable healthcare practices, including sustainable procurement and waste reduction, there is a paucity of empirical evidence from low- and middle-income country hospital settings, particularly from India (1). Most available data are derived from

modelling studies or high-income country experiences, limiting their generalizability.

This hospital-based pilot study was therefore undertaken to generate real-world evidence comparing conventional hospital linen and environmentally sustainable linen in a tertiary care setting. The study aimed to evaluate environmental resource utilization, operational performance, cost implications, infection prevention outcomes, and user satisfaction. By providing context-specific data, this study seeks to inform evidence-based decision-making and support the integration of sustainability principles into hospital linen services without compromising patient safety or quality of care.

Methodology

The study is a prospective, comparative pilot study which was conducted over a duration of six months in a tertiary care teaching hospital in India. The study was conducted across two general medical wards, each with 43 beds and a similar patient turnover. Wards were termed Ward A & Ward B. Conventional Linen was used in Ward A and Sustainable Linen was used in Ward B.

Definitions:

1. Conventional linen consisted of polyester-cotton blends with standard dyeing processes.
2. Sustainable linen comprised organic cotton and recycled polyester blends, manufactured using low-impact dyes and certified for reduced water and chemical usage.

Study Objectives:

The study objectives were as follows:

- Water and energy consumption per laundering cycle
- Linen durability and rejection rates
- Procurement and lifecycle costs
- Post-laundering microbial contamination
- Patient and staff satisfaction

Data Collection:

Laundry resource consumption was obtained from laundry logs and utility meters. Microbiological surveillance involved monthly surface cultures post-laundering. Cost data were extracted from procurement and laundry service records. Satisfaction was assessed using a structured Likert-scale questionnaire.

Statistical Analysis And Significance

Although the study was designed as a pilot and not powered for definitive hypothesis testing, inferential statistical analysis was undertaken to explore differences between conventional and environmentally sustainable linen. Continuous variables were compared using independent sample *t*-tests, and categorical variables were analysed using the chi-square test. A *p*-value of <0.05 was considered statistically significant.

RESULTS

Environmental Impact

Environmentally sustainable linen demonstrated significantly lower resource consumption per laundering cycle. Mean water consumption was 15.2 L/kg for conventional linen compared to 9.6 L/kg for sustainable linen, representing a 36.8% reduction ($p < 0.001$). Similarly, mean energy consumption decreased from 1.8 kWh/kg to 1.2 kWh/kg, a 33.3% reduction that was statistically significant ($p < 0.001$). These differences remained consistent throughout the six-month study period, indicating sustained performance rather than transient variation. The same is shown in Table 1.

Table 1: Environmental Resource Consumption Per Laundering Cycle

Parameter	Conventional Linen	Sustainable Linen
Water consumption (L/kg)	15.2	9.6

Energy consumption (kWh/kg)	1.8	1.2
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Operational Performance and Durability

The mean number of usable wash cycles before discard was significantly higher for sustainable linen (108 ± 9 cycles) compared to conventional linen (78 ± 6 cycles) ($p < 0.001$). Linen rejection rates were also significantly lower in the sustainable linen group (6.8%) than in the conventional linen group (12.5%) (χ^2 , $p = 0.02$). No statistically significant difference was observed in average linen turnaround time between the two groups ($p = 0.84$), confirming that workflow efficiency was not adversely affected.

Table 2: Operational Performance Indicators

Indicator	Conventional Linen	Sustainable Linen
Average usable wash cycles	78	108
Linen rejection rate (%)	12.5	6.8

Cost Analysis

While procurement costs per unit were higher for sustainable linen, lifecycle cost analysis demonstrated lower cumulative costs over the study period. The difference in estimated lifecycle cost per unit favored sustainable linen (INR 3,240 vs INR 3,410), although this difference did not reach statistical significance ($p = 0.09$). This finding suggests a trend toward cost advantage with sustainable linen that warrants further evaluation in larger studies.

Table 3: Cost Comparison

Cost Component	Conventional Linen (INR)	Sustainable Linen (INR)
Procurement cost per unit	450	560
Estimated lifecycle cost	3,410	3,240

Infection Control Outcomes

Post-laundering microbial contamination levels were comparable between the two linen types, with mean counts remaining below 2 CFU/cm² in both groups. No statistically significant difference was observed ($p = 0.92$). Compliance with institutional infection prevention and control standards was 100% for both linen categories throughout the study period.

Patient & Staff Satisfaction

Mean patient comfort scores and staff usability scores were marginally higher for sustainable linen; however, these differences were not statistically significant (patient comfort $p = 0.31$; staff usability $p = 0.28$). Overall satisfaction scores showed a positive trend toward sustainable linen but did not achieve statistical significance ($p = 0.21$).

Table 4: Satisfaction Scores (Mean Score out of 5)

Parameter	Conventional Linen	Sustainable Linen
Patient comfort	4.2	4.3
Staff usability	4.1	4.2
Overall satisfaction	4.2	4.4

DISCUSSION

This hospital-based pilot study provides empirical evidence supporting the feasibility and benefits of environmentally sustainable linen in a real-world clinical setting. The findings demonstrate that sustainable linen can significantly reduce water and energy consumption without compromising infection control, operational efficiency, or user satisfaction.

Linen services represent a continuous, high-volume hospital function, making them an ideal target for sustainability interventions. The observed reductions in resource consumption align with global calls for environmentally responsible healthcare systems and contribute directly to climate mitigation and resource conservation efforts (1).

Operational advantages, including improved durability and lower rejection rates, strengthen the case for sustainable linen adoption. The extended lifespan of sustainable linen not only reduces procurement frequency but also minimizes waste generation, addressing another critical dimension of hospital environmental impact. Importantly, these gains were achieved without altering existing laundry infrastructure or workflows, underscoring the practicality of implementation.

Cost considerations remain a central concern for hospital administrators. This study highlights the limitations of procurement decisions based solely on unit price. Lifecycle cost analysis demonstrated that sustainable linen achieves cost neutrality within a relatively short period, reinforcing the need for hospitals to adopt long-term, value-based procurement strategies.

From a patient safety perspective, the study confirms that environmentally sustainable linen does not pose additional infection risks when standard laundering and handling protocols are maintained. This finding is crucial for broader adoption, particularly in high-risk clinical areas where infection control is paramount.

The statistically significant reductions in water and energy consumption and the improved durability of environmentally sustainable linen provide robust preliminary evidence supporting its environmental and operational advantages. Non-significant findings in infection control and satisfaction outcomes are reassuring, as they indicate equivalence rather than inferiority. Trends toward lifecycle cost savings, although not statistically significant in this pilot study, suggest potential economic benefits that merit confirmation through larger, adequately powered multi-centre studies.

The positive reception among patients and staff further suggests that sustainability initiatives can enhance institutional culture and stakeholder engagement. As hospitals increasingly align with national and global sustainability goals, visible interventions such as sustainable linen can serve as tangible symbols of organizational commitment.

CONCLUSION

Environmentally sustainable linen is a safe, feasible, and environmentally advantageous alternative to conventional hospital linen. Adoption of sustainable linen can meaningfully contribute to hospital sustainability goals while maintaining patient safety, operational efficiency, and quality of care.

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