Impact of replacing disposable sterile barrier systems with containers: sustainability and cost savings in hospitals

Impacto da substituição de barreira estéril descartável por contêineres: sustentabilidade e economia em hospitais

Impacto de la sustitución de la barrera estéril desechable por contenedores: sostenibilidad y economía en hospitales

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ABSTRACT: Objective: To compare reusable container systems and disposable sterile barrier systems in terms of waste management, as well as their environmental and economic benefits in hospitals. **Methods:** A descriptive study conducted through the collection of primary data from two hospitals that implemented sustainable technologies (containers). Waste volumes and costs of sterile barrier systems (flexible/disposable and rigid/reusable) were analyzed. Data collection was carried out in large hospitals over a one-year observation period. **Results:** An 88% reduction in solid waste generation was observed with the use of containers when replacing the flexible/disposable sterile barrier system (SMS). When comparing total costs of flexible packaging with containers, the initial investment may be offset after the fourth year. **Conclusion:** The adoption of sustainable technologies leads to a significant reduction in waste, with relevant economic gains, contributing to the strengthening of hospital sustainability in Brazil.

Keywords: Sustainable hospitals. Environmental management. Energy efficiency. Conservation of natural resources. Biomedical technology.

RESUMO: Objetivo: Comparar tecnologia de sistemas reutilizáveis e sistema de barreira estéril descartável em termos de gestão de resíduos, bem como seus benefícios ambientais e econômicos em hospitais. **Métodos:** Estudo descritivo realizado por meio da coleta de dados primários em dois hospitais que implementaram tecnologias sustentáveis (contêiner). Foram analisados volumes de resíduos e custos dos sistemas de barreira estéril (flexível/descartável e rígido/reutilizável). A coleta de dados foi realizada em hospitais de grande porte, com período de observação de 1 ano. **Resultados:** Houve redução de 88% na geração de resíduos sólidos com o uso de contêineres ao substituir o sistema de barreira estéril flexível/descartável (SMS). Comparando os custos totais para uso da embalagem flexível com o contêiner, pode-se haver a compensação do custo inicial após o quarto ano. **Conclusão:** A adoção de tecnologias sustentáveis promove significativa redução de resíduos, com ganhos econômicos relevantes, contribuindo para o fortalecimento da sustentabilidade hospitalar no Brasil.

Palavras-chave: Hospitais sustentáveis. Gestão ambiental. Eficiência energética. Conservação dos recursos naturais. Tecnologia biomédica.

RESUMEN: Objetivo: Comparar tecnologías de sistemas reutilizables y sistemas de barrera estéril desechables en términos de gestión de residuos, así como sus beneficios ambientales y económicos en hospitales. **Métodos:** Estudio descriptivo realizado mediante la recolección de datos primarios en dos hospitales que implementaron tecnologías sostenibles (contenedores). Se analizaron los volúmenes de residuos y los costos de los sistemas de barrera estéril (flexible/desechable y rígido/reutilizable). La recolección de datos se llevó a cabo en hospitales de gran porte, con un período de observación de un año.

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Resultados: Se observó una reducción del 88 % en la generación de residuos sólidos con el uso de contenedores al sustituir el sistema de barrera estéril flexible/desechable (SMS). Al comparar los costos totales del uso del embalaje flexible con el contenedor, se evidenció que el costo inicial puede compensarse a partir del cuarto año. **Conclusión:** La adopción de tecnologías sostenibles promueve una reducción significativa de residuos, con relevantes beneficios económicos, contribuyendo al fortalecimiento de la sostenibilidad hospitalaria en Brasil.

Palabras clave: Hospitales sostenibles. Gestión ambiental. Eficiencia energética. Conservación de los recursos naturales. Tecnología biomédica.

INTRODUCTION

Sustainability in the hospital sector has become a strategic priority amid increasing pressure to adopt environmentally responsible practices. Hospitals rank among the largest consumers of energy, water, and disposable materials, resulting in a substantial environmental impact[1].

In this context, green hospitals have emerged as a technical and operational response aimed at reducing the environmental impact of the healthcare sector. These institutions adopt rigorous resource management protocols, including the optimization of energy consumption, water reuse, implementation of recycling systems, and replacement of disposable materials with reusable alternatives[2]. Sustainability in the hospital setting has become essential for reducing the environmental footprint of healthcare while improving patient outcomes and operational efficiency. Its effective implementation requires integrated strategies encompassing facility design, resource management, and staff engagement; however, it faces challenges related to regulatory standards, institutional awareness, and operational preparedness.

The Brazilian hospital sector faces significant challenges related to energy consumption and associated costs, an issue that warrants special attention given its operational and financial implications. Comparative analyses with international institutions reveal substantial disparities in consumption patterns, particularly when contrasted with European hospitals, which demonstrate markedly more efficient energy use rates[3].

Aligned with the United Nations (UN) Sustainable Development Goals (SDGs) established by the 2030 Agenda, changes in hospital resource management aim to promote sustainability practices and environmental responsibility across sectors, including healthcare[4]. In particular, SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) play a critical role in reducing waste and encouraging the adoption of sustainable technologies — such as the use of reusable rigid containers for the sterilization of surgical instruments, which represent a viable alternative for minimizing waste and enhancing operational efficiency[4-6]. These goals guide hospital initiatives to reduce environmental impact and improve operational practices[7,8].

In light of the concepts outlined above, this article aimed to compare reusable system technology and disposable sterile barrier systems in terms of waste management and their environmental and economic benefits in hospital settings.

OBJECTIVES

Reusable system technology and disposable sterile barrier systems are compared in terms of waste management, as well as their environmental and economic benefits in hospital settings.

METHODS

This study is characterized as a descriptive investigation with a quantitative approach, focusing on its application in two large hospitals that have implemented sustainable technologies. The research was conducted in three main stages: data collection, document analysis, and comparative analysis.

Location and period of the study

The study was conducted in the sterile processing departments (SPD) of two large private hospitals with comparable characteristics and clinical profiles, encompassing specialties from conventional surgeries to highly complex procedures, such as robotic surgeries and heart transplants. The analysis was performed over a one-year period, from June 2024 to June 2025, during which the implementation of a new technology was monitored. Both hospitals, located in the Copacabana neighborhood of Rio de Janeiro, adopted reusable containers for the sterilization of surgical instruments. Hospital A has 141 beds and 12 operating rooms, performs an average of 620 surgical procedures per month, and processes approximately 15,326 medical devices monthly. Hospital B has 236 beds and 11 operating rooms, with an average of 790 surgical procedures and 11,698 medical devices processed per month.

Data collection and source

Data collection was conducted using a supplementary primary source comprising the operational records of the participating hospitals. These records included comprehensive data on the volume of waste generated, cover bags and Spunbond-Meltblown-Spunbond (SMS) materials used in disposable systems, as well as seals and filters.

Data analysis

The comparative analysis encompassed several fundamental aspects of hospital operations. Initially, waste management was assessed through a comparison between the flexible/disposable sterile barrier system (SMS) and the rigid/reusable sterile barrier system (containers), with the objective of identifying differences in the volume of waste generated. In addition, a comprehensive analysis of operational costs was performed, comparing conventional systems with the implemented sustainable alternatives and considering both direct and indirect costs associated with the technology.

Ethical aspects

Because this study analyzed operational data and did not directly involve patients or healthcare professionals, approval from a Research Ethics Committee was not required. Nevertheless, the confidentiality principles of the participating institutions were strictly maintained.

RESULTS

Data were collected from both hospitals to determine the quantity and weight of each input consumed in Hospitals A and B when using flexible packaging (SMS) and to compare these values with the scenario involving reusable packaging (containers). This approach made it possible to identify the amount of hospital waste generated per sterilization cycle (Table 1). The results indicate that the use of flexible packaging for sterilization generates 156 g of waste, whereas the use of containers generates 18 g of waste.

The collected data showed that Hospital A uses 74 sterilization boxes, whereas Hospital B uses 114 boxes. Each box undergoes sterilization 20 times per month; therefore, by multiplying the number of boxes by the monthly number of sterilization cycles, it was possible to estimate the monthly and annual reprocessing volumes for each institution. Accordingly, Hospital A performs 17,760 sterilizations per year, while Hospital B performs 27,360 sterilizations annually.

Using data on the amount of hospital waste generated per processing cycle and the estimated annual number of sterilizations for each institution, it was possible to calculate the annual weight of hospital waste produced and to compare it with the scenario in which containers were used (Table 2). The findings indicate that, in Hospital A, waste generation would decrease from 2,770.56 kg to 319.68 kg, while in Hospital B it would be reduced from 4,268.16 kg to 492.48 kg — representing an overall reduction of 88% in waste generation.

Table 1. Quantity of supplies consumed by technology.

Supply	Flexible			Container		
	Units	Weight (g)	Total (g)	Weight (g)	Units	Total (g)
SMS	2	76	152	0	0	0
Cover-Bag	1	4	4	0	0	0
Filter	0	0	0	2	2	4
Seal	0	0	0	7	2	14
	Total		156	Total		18

Table 2. Annual waste generated.

	Hospital A (Flexible)	Hospital A (Container)	Hospital B (Flexible)	Hospital B (Container)
Waste per processing (g)	156	18	156	18
Number of annual processings	17,760	17,760	27,360	27,360
Annual waste generated (Kg)	2,770.56	319.68	4,268.16	492.48

Beyond the environmental impacts, the different technologies — flexible packaging (SMS) and containers — also have economic implications for healthcare institutions, particularly with regard to the cost of waste disposal. Based on data provided by the hospitals, the disposal cost was R$ 4.21 per kilogram. By multiplying this value by the total annual weight of waste generated, it was determined that Hospital A would reduce its disposal costs from R$ 11,664.06 to R$ 1,345.85, and Hospital B from R$ 17,968.95 to R$ 2,073.34, if containers were adopted for the sterilization process (Table 3).

For a more comprehensive economic analysis, the cost of acquiring inputs was also considered. For flexible packaging, data were based on the use of two units of SMS at R$ 4.00 each and one cover-bag at R$ 0.14. These costs were compared with those associated with the container system, which included two filter units at R$ 1.08 each and two seals at R$ 0.80 each. Accordingly, the total input acquisition cost was R$ 8.14 for flexible packaging and R$ 3.76 for the container system.

Using the calculated input acquisition costs and considering that these inputs must be purchased for each processing cycle, together with the estimated number of processings presented in Table 2, it was possible to calculate the annual cost of input acquisition and to compare it with the scenario involving the use of containers. Under the flexible packaging system, Hospital A incurs an annual cost of R$ 144,566.40, which could be reduced to R$ 66,777.60 with the adoption of containers. Similarly, Hospital B would reduce its annual costs from R$ 222,710.40 to R$ 102,873.60, as shown in Table 4.

In addition to supply acquisition costs, the purchase of the containers was also considered to estimate cumulative expenses over a 10-year period. Assuming an acquisition cost of R$ 4,500 per container and considering that Hospital A uses 74 boxes, the total acquisition cost amounts to R$ 333,000; for Hospital B, which uses 114 boxes, the corresponding acquisition cost would be R$ 513,000.

By comparing supply acquisition costs with waste disposal costs, it was observed that Hospital A incurs an annual expense of R$ 156,230.46 under the flexible packaging system; with the adoption of containers, this amount would be reduced to R$ 68,123.45. In Hospital B, the combined cost of supplies and waste disposal using flexible packaging is R$ 240,679.35 and would decrease to R$ 104,949.94 with the use of containers. In addition, container acquisition was included as part of the cumulative cost analysis. Accordingly, despite the high initial investment required for container purchase, a return on investment would be achieved from the fourth year onward due to the substantial reduction in supply costs (Table 5).

DISCUSSION

The results obtained in this study corroborate current trends in innovation in hospital sterilization technology, as discussed by Bahk[9]. The author emphasizes that traditional sterilization processes using porous barriers present significant limitations related to processing and cooling times. The documented experience with the implementation of the container system demonstrates that, in addition to optimizing these processes, this method results in a substantial reduction in hospital waste generation, aligning with the increasing demand for sustainability in the healthcare sector.

Table 3. Annual disposal costs.

	Hospital A (Flexible)	Hospital A (Container)	Hospital B (Flexible)	Hospital B (Container)
Annual waste generated (Kg)	2,770.56	319.68	4,268.16	492.48
Cost per kg of hospital waste	R$ 4.21	R$ 4.21	R$ 4.21	R$ 4.21
Annual disposal cost	R$ 11,664.06	R$ 1,345.85	R$ 17,968.95	R$ 2,073.34

Table 4. Annual cost of supply acquisition.

	Hospital A (Flexible)	Hospital A (Container)	Hospital B (Flexible)	Hospital B (Container)
Supply acquisition cost per processing	R$ 8.14	R$ 3.76	R$ 8.14	R$ 3.76
Number of annual processings	R$ 17,760.00	R$ 17,760.00	R$ 27,360.00	R$ 27,360.00
Annual cost of supply acquisition	R$ 144,566.40	R$ 66,777.60	R$ 222,710.40	R$ 102,873.60

Table 5. Cumulative cost over ten years: considering acquisition, supplies, and disposal.

Year	Hospital A (Container)	Hospital A (Flexible)	Hospital B (Container)	Hospital B (Flexible)
0	R$ 333,000.00	R$ -	R$ 513,000.00	R$ -
1	R$ 401,123.45	R$ 156,230.46	R$ 617,946.94	R$ 240,679.35
2	R$ 469,246.91	R$ 312,460.92	R$ 722,893.88	R$ 481,358.71
3	R$ 537,370.36	R$ 468,691.37	R$ 827,840.82	R$ 722,038.06
4	R$ 605,493.81	R$ 624,921.83	R$ 932,787.76	R$ 962,717.41
5	R$ 673,617.26	R$ 781,152.29	R$ 1,037,734.70	R$ 1,203,396.77
6	R$ 741,740.72	R$ 937,382.75	R$ 1,142,681.64	R$ 1,444,076.12
7	R$ 809,864.17	R$ 1,093,613.20	R$ 1,247,628.59	R$ 1,684,755.48
8	R$ 877,987.62	R$ 1,249,843.66	R$ 1,352,575.53	R$ 1,925,434.83
9	R$ 946,111.08	R$ 1,406,074.12	R$ 1,457,522.47	R$ 2,166,114.18
10	R$ 1,014,234.53	R$ 1,562,304.58	R$ 1,562,469.41	R$ 2,406,793.54

The issue of operational efficiency, identified in this article as one of the limitations of the traditional disposable sterile barrier system (SMS), is clearly reflected in the financial outcomes of this study. The inefficiencies described by Bahk[9], particularly those related to the vulnerability of SMS packaging to adverse events, were shown to have a substantial impact not only on daily operations but also on institutional costs. The transition to the container system supports the perspective presented in the literature regarding the potential of this technology as a safer, more durable, and economically viable alternative, providing measurable benefits in resource management and the environmental sustainability of hospital sterilization practices[10].

In addition to the quantitative reduction in waste, the use of rigid containers decreases the demand for disposable packaging, the production of which is highly dependent on fossil fuels. Life cycle studies of hospital materials indicate that the manufacture of SMS generates a substantial carbon footprint, whereas containers, when reused, offset the initial environmental impact of their production after a few years of continuous use[10]. These findings are supported by Friedericy et al.[11], who demonstrated through a Life Cycle Assessment (LCA) that reusable systems can have up to an 85% lower carbon impact than disposable systems, with measurable benefits observed after as few as 68 cycles of use.

Another example of waste reduction reported in the literature is the rationalization of surgical instrument kits, which has proven to be an effective strategy for reducing the number of instruments used, with direct effects on lowering operational costs and optimizing resource utilization. According to Santos et al.[12], the implementation of this approach can lead to significant reductions in surgical instrument consumption and sterilization time without compromising patient safety. These operational improvements not only enhance hospital efficiency but also contribute to sustainability by reducing the use of disposable materials and decreasing the carbon footprint associated with the sterilization process[10].

Experimental studies further advance the discussion on the impact of the design of baskets and accessories used in the processing of surgical instruments, with direct implications for operational efficiency and sustainability. These findings underscore the importance of technically sound decisions in the selection of basket accessories, as optimizing cleaning and drying performance not only enhances patient safety but also contributes to reduced consumption of resources such as energy and water, aligning with the hospital sustainability objectives addressed in this study[10].

Considering environmental impact and long-term costs, the choice between reusable and disposable sterilization systems should account not only for the purchase price but also for the entire product life cycle. Friedericy et al.[11] argue that, although containers require a higher initial investment, their environmental and financial costs are diluted over time through repeated use, and their performance surpasses that of SMS systems across multiple sustainability indicators (carbon footprint, ecological cost, and human toxicity). These findings reinforce the importance of incorporating environmental criteria into hospital procurement decisions, in alignment with the transition toward a more sustainable healthcare model.

Despite the relevance of the findings and the innovative nature of this study, important limitations must be acknowledged, as it was not designed as a cost-minimization analysis,

which would be more appropriate for comparing health technologies that yield similar outcomes. Therefore, further investigations are recommended, preferably adopting a cost-minimization analysis framework and adhering to the methodological guidelines established for Health Technology Assessment[13].

CONCLUSION

This study demonstrated that the implementation of sustainable technologies and practices in hospital settings can result in substantial environmental and economic benefits.

These findings suggest that the transformation of conventional hospitals into green hospitals is not only feasible but also economically advantageous. The systematic implementation of sustainable practices, supported by efficient technologies and well-established protocols, can lead to a significant reduction in the environmental impact of the healthcare sector while improving operational efficiency and reducing costs. Future research is recommended to examine the implementation of these practices in different hospital contexts, taking into account institution-specific variables, in order to develop more comprehensive implementation guidelines.

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CONFLICT OF INTERESTS

The authors declare there is no conflict of interests.

AUTHORS' CONTRIBUTION

LRLR: Data curation, Writing – review & editing, Validation. LGS: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. EFL: Formal analysis, Data curation, Writing – review & editing, Validation. CF: Writing – review & editing, Supervision, Validation.

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