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AI-Enabled Recycling of Thermoplastic Polymer Waste in Hospitals: A Circular Economy Pathway Toward Green Hospital Certification

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Abstract

This review research explores the latest role of AI in improving thermoplastic waste management for hospitals in terms of segregation accuracy, operational efficiency, and circular economy outcomes. Seventy-five relevant studies were analysed, and it was reported that AI-based systems, especially CNNs, YOLO models, and sensor-fusion approaches, achieved high accuracy in the identification and sorting of medical plastics, often above 90%. Early evidence also reveals improvements in the reduction of contaminants, purity of recyclables, and optimization of logistics. Real-world deployment remains limited, however, as the majority of studies are confined to laboratory or pilot levels. Overall, key gaps include restricted validation at the hospital scale, lack of standard performance metrics, and limited cost–benefit and life-cycle assessments. In spite of these limitations, the results indicate that AI-powered waste technologies can significantly support hospital circularity, reducing environmental burdens and strengthening pathways toward green-hospital certification. Furthermore, the integration of AI with existing hospital waste management policies, staff training programs, and regulatory frameworks is essential for successful implementation. Collaboration between healthcare institutions, technology developers, and environmental agencies will also play a crucial role in ensuring scalable and sustainable adoption. Future research should therefore focus on large-scale clinical validation, development of standardized evaluation indicators, economic feasibility analysis, and alignment with global sustainability and accreditation standards to enable practical and long-term application of AI-driven thermoplastic waste management systems in healthcare settings.

Keywords: Artificial intelligence; hospital waste management; thermoplastic plastic; waste management; healthcare; green hospital.

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INTRODUCTION

Hospitals are among the major contributors to plastic pollution worldwide, considering the wide use of single-use thermoplastic materials, viz., polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), and acrylonitrile-butadiene-styrene (ABS) in diagnostic, therapeutic, and infection-control practices that have been further intensified in the COVID-19 era. Conventionally, these are disposed of either by incineration or landfilling due to bio-contamination issues, complicated regulatory regimes, and inefficient segregation systems. Hence, this leads to severe environmental negative externalities and undermines the goals of sustainable healthcare [1,2]. In this backdrop, the circular economy has emerged as a gamechanging strategy for health care waste management that ensures resource recovery and material flow sustainability. In this context, artificial intelligence has become a key enabler for the development of the circularity of thermoplastic medical waste, enabling real-time identification and segregation, coupled with contamination control by deep learning, computer vision, and IoT-enabled smart systems beyond the limitations of manual picking and improvement in feedstock quality in recycling processes [3,4]. Additionally, quality preservation of recovered polymers and their refeeding into non-clinical applications within hospitals or even external industrial utilities are guaranteed by AI-driven optimisation of mechanical and chemical recycling processes, which also ensures improved material circularity and a smaller environmental impact [5]. Researchers have demonstrated that integrating agro-waste-based fillers into polymer matrices enhances mechanical strength and environmental sustainability, offering a viable pathway for greener laminate development[33] ,AI also can revolutionise plastic waste management by facilitating high-purity sorting, material flow tracking, material stream predictive analytics, and integrating with circular economy supply chains, all of which have a substantial impact on hospital-generated waste streams [6]. In the face of developing global frameworks of sustainable healthcare and Green Hospital Certification standards that put increasing emphasis on waste reduction, eco-procurement, and circular resource use strategies, AI-enabled pathways for plastic valorisation provide a strategic opportunity for hospitals to improve environmental performance, enhance regulatory compliance, and strengthen climate resilience [7]. This review explores how AI-enabled solutions are emerging to address thermoplastic polymer waste in healthcare settings, promoting creative circular economy practices and helping hospitals become certified as Green Hospitals. In the process of developing sustainable hospital waste systems, opportunities for further study and policy development were identified, in addition to related difficulties and knowledge gaps.

LITERATURE REVIEW

Thermoplastic Polymer Waste in Hospitals

Hospitals generate substantial volumes of thermoplastic polymer waste predominantly composed of polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET), widely used in IV bags, syringes, catheters, sterile packaging, PPE, and diagnostic accessories [7].Studies indicate that thermoplastic medical plastics can constitute 20–35% of total hospital solid waste, depending on facility size and medical activity, with higher volumes reported during pandemic periods due to intensified PPE usage[8,9]. Despite their recyclability and high material value, the majority of these polymers are treated as infectious waste and subjected to incineration or landfilling, leading to greenhouse-gas emissions, toxic compounds such as dioxins (especially from PVC), and loss of circular-resource potential [7,10]. These include operation theatres, intensive-care units, emergency departments, and diagnostic laboratories wherein the usage of single-use thermoplastics is fundamental to infection control and sterility assurance [9]. However, this is hampered by several factors that limit or eliminate the recovery of these valuable polymers via circular flows: strict infection-control policies, perceived bio-contamination risks, ineffective manual segregation of non-infected material, lack of staff training, and poor clarity on the composition of waste streams when generated [7]. Contamination uncertainty and segregation inefficiencies remain the biggest barriers to polymer recovery, it has been reiterated, underlining the need for high-level sterilization and smart-sorting systems [9]. The value of properly treated natural fibres in next-generation FMLs is further proven by studies on bio-based hybrid composites, which show that these fibres can greatly increase structural stability while lowering ecological burden [34]. Recent technological advancements prove that AI-enabled waste identification-automated polymer-sorting systems could offer good solutions to overcome these limitations in manual sorting using machine learning, computer vision, and IoT-enabled track-and-trace capabilities to identify polymer types, detect contamination, and optimize segregation [11]. Recent molecular studies show that enhanced natural-fiber reinforcements improve material stability and sustainability, supporting more efficient recycling and circular-economy outcomes [36]. Integrated on-site treatment methods such as microwave disinfection and shredding have also been pointed out to ensure the safe recovery of feedstocks before recycling [10]. Despite this progress, there is a clear gap in current research on integrating AI-enabled thermoplastic waste recycling with the standards of Green Hospital Certification, compliance with sustainability accreditation requirements, and circular economy performance indicators of hospitals [11].

AI Technologies for Detection, Segregation & Sorting

Artificial intelligence is now emerging as a transformative tool for the improvement of the detection, segregation, and sorting of thermoplastic medical waste streams in hospitals. Recent studies show that computer-vision techniques, particularly convolutional neural networks (CNNs) and advanced YOLO-based models, offer high precision in recognizing medical plastic items such as PPE, syringes, and IV-related disposables, achieving classification accuracies above 90% in controlled and semi-clinical environments [3,4]. Machine-learning classifiers coupled with robotic sorting arms and conveyor-based separation systems further enhance segregation efficiency by automating handling, reducing contamination risks, and allowing for further waste processing [12]. Sensor-fusion systems that combine NIR spectroscopy with AI vision networks have demonstrated improved polymer detection capabilities, especially for differentiating between visually similar polymers such as PP, PE, and PVC, which could lead to higher-quality recycling streams [13]. Several such AI-supported systems report benefits related to better throughput, less manual-sorting error, reduced pathogen-handling exposure, and costs attributed to savings from reduced labor and increased quality recyclates [3]. In medical waste applications, AI pipelines often depend on lab-curated imaging datasets or pilot-scale hospital waste samples. Full-scale hospital validations are so far limited because of infection-control protocols, biological contamination risks, and general operational challenges under sterile conditions [9,10]. Furthermore, most current models lack real-time adaptive learning to handle variable waste conditions and require sterilization-compliant handling infrastructure to ensure safe feeding of waste into AI-based systems [8].While early evidence strongly supports AI-assisted plastic segregation as a pathway to high-quality recycled polymer streams, gaps persist in large-dataset availability, clinical-environment trials, and integration with healthcare regulations and circular-economy certification frameworks such as green hospital standards [11].

Process Optimization, Logistics & Material Recovery

In order to move hospital thermoplastic waste from disposal to resource recovery, process flows and logistics must be optimised. By cutting down on travel time, fuel consumption, and contamination risks, recent studies show that predictive models and sophisticated routing algorithms greatly increase the efficiency of medical waste collection [14]. Hospitals can improve throughput and material quality by using load-forecasting techniques like ARIMA and machine-learning regressors to schedule sterilisation and shredding batches, predict waste surges, and maintain stable recycling operations [15, 16]. Under demand uncertainty, it has been shown that reverse-logistics systems with secure transfer hubs and intermediate storage nodes improve material recovery and reduce empty-route cycles [17]. Integration of RFID or QR tagging and also IoT sensors with AI dashboards can strengthen traceability, allowing real-time rerouting and contamination control [18]. Process-level optimization-including predictive maintenance, batch-sterilization planning, and efficient melt-cycle control-has demonstrated improvements in energy use and greenhouse-gas performance compared with incineration [19]. However, operational barriers remain, including workflow disruption, space limitations for sorting and pre-processing infrastructure, and alignment with clinical sterilization workflows, and the ability to address these constraints through hospital-level planning and regulatory coordination remains critical for scalable circular recovery of medical thermoplastics [20]. As illustrated in Figure 1, the closed-loop system supports waste reduction, resource recovery, and sustainable hospital waste management.

Environmental & Economic Assessment

Life-cycle assessment (LCA) studies increasingly quantify the environmental trade-offs of diverting hospital thermoplastic waste from incineration toward recycling, finding that well-implemented recycling routes typically lower cradle-to-grave greenhouse-gas emissions but can incur higher on-site energy use depending on sterilization and processing requirements [20]. Comparative LCAs report that advanced mechanical and chemical recycling can reduce CO_2-eq relative to incineration with energy recovery—especially as grid electricity decarbonizes—yet energy-intensive steps (sterilization, shredding, depolymerization) create important trade-offs that must be modelled explicitly [19]. In hospital thermoplastic waste management, material optimisation promotes greener, more circular recovery pathways. Recent work on natural fiber–metal systems further confirms that combination with eco-friendly reinforcements can improve structural performance without compromising sustainability goals.[35].Economically, circular pathways yield dual benefits: lower disposal and incineration fees and potential revenue from recycle sales or in-house reuse[21].Nevertheless, hospital-based LCA studies remain limited, with few assessments capturing the full chain from point-of-generation through sterilization, AI-enabled sorting energy demands, and downstream product substitution [22. Emerging research also flags the often-overlooked energy footprint of AI and sensor systems used for sorting and logistics, arguing for "green-AI" design and inclusion of AI electricity use within LCA boundaries [23]. With emerging circular-economy principles, these sustainable fibre-based laminates also offer enhanced potential for end-of-life recovery and recycling compared to conventional synthetic FMLs, reducing overall environmental impact [31]. The natural-fiber also reinforced polymer composites may significantly improve tensile and flexural performance while maintaining biodegradability [32].

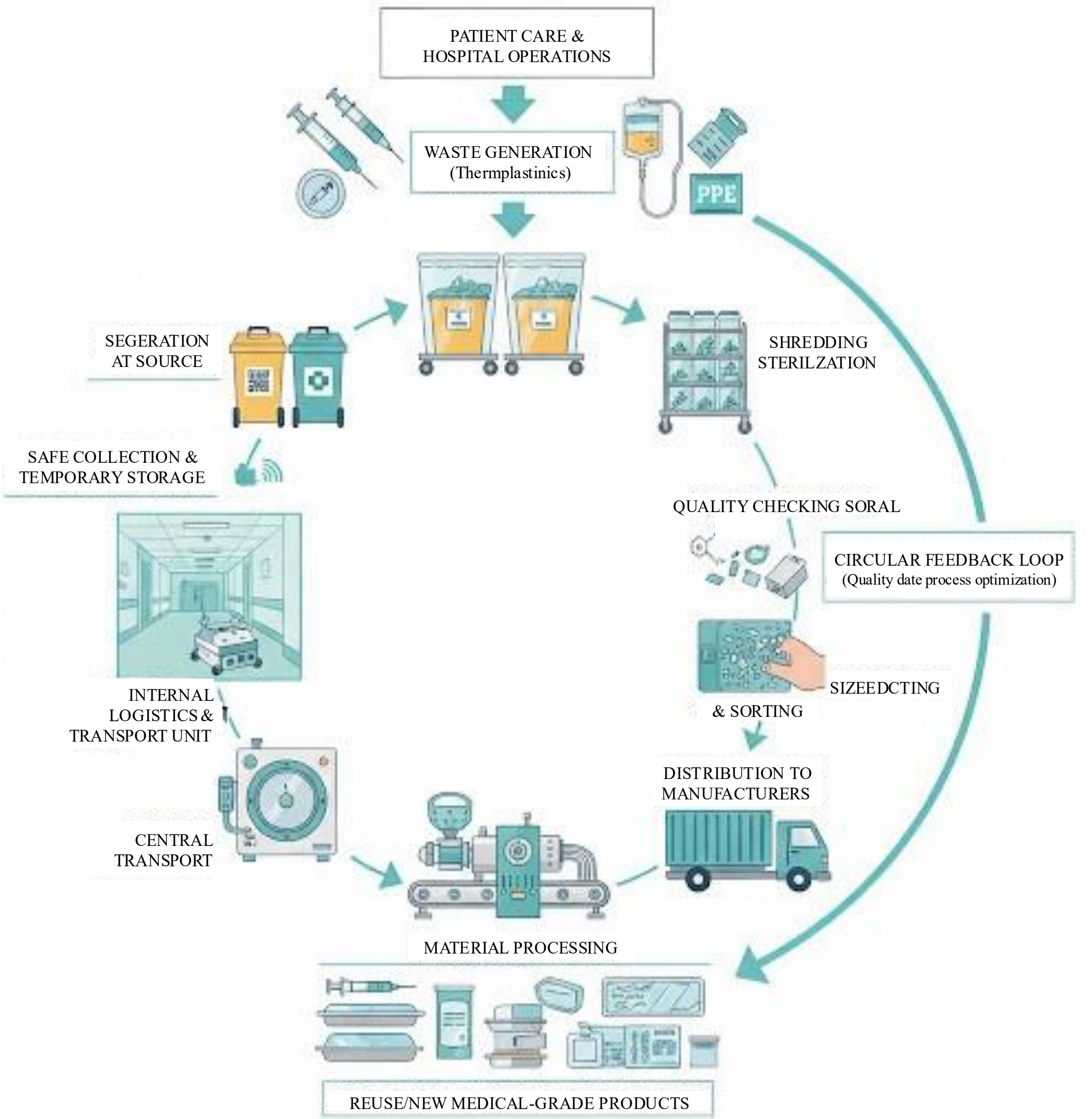
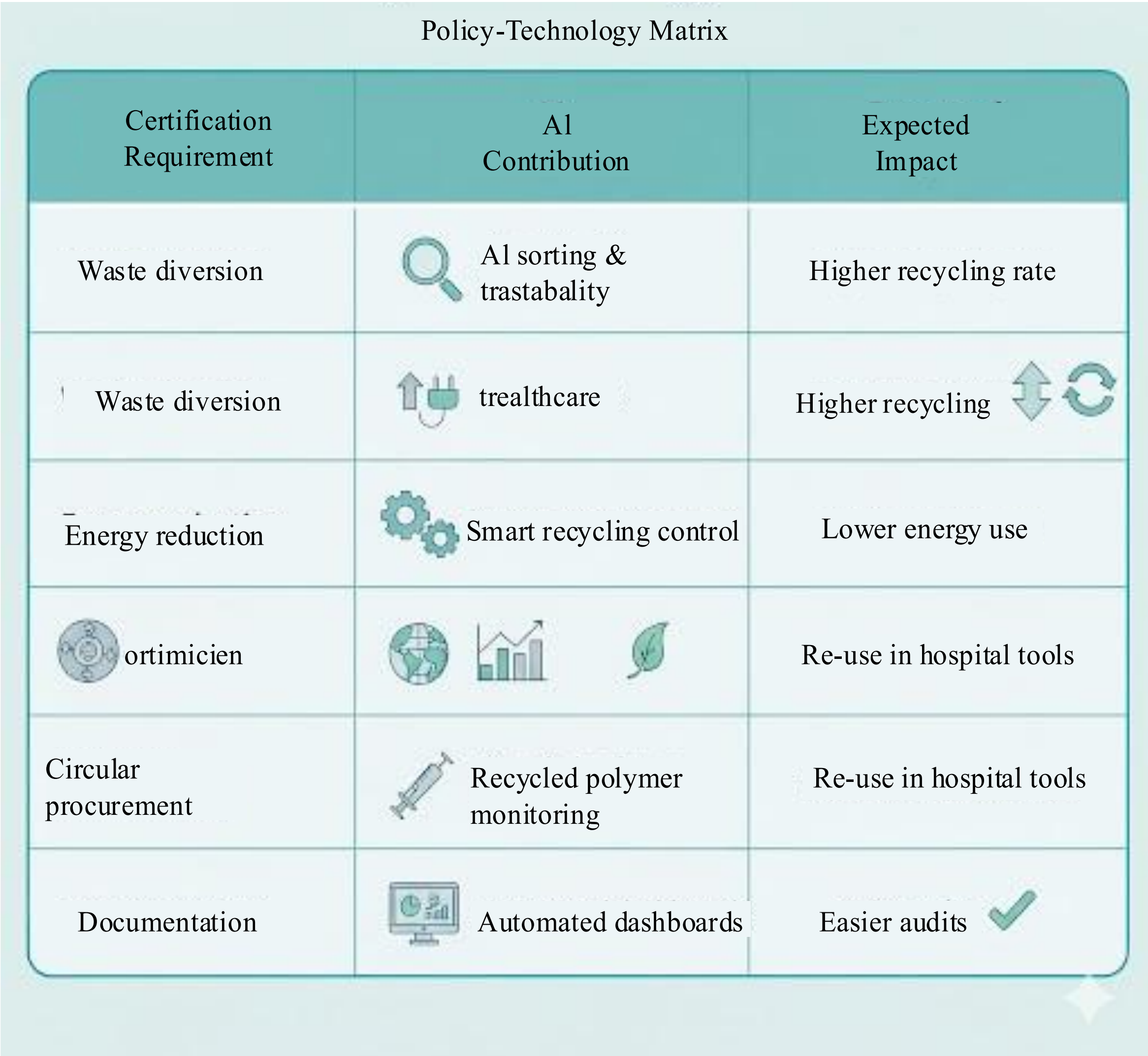


Figure 1. Visual representation of the circular economy for thermoplastic waste in hospitals

Certification & Policy Linkages

Healthcare facilities are increasingly seeking green certification, which recognise practices such as waste diversion, energy reduction and circular procurement. However, while waste-diversion and procurement credits are present in many frameworks, the explicit role of data-driven tools and AI systems in achieving these credits remains underdeveloped. A recent comparative study of green certification systems for healthcare facilities found that although waste management and materials reuse appear as categories, the criteria rarely include advanced real-time monitoring or AI-based performance documentation [24]. Another paper shows how AI-driven decision-support tools can help hospitals track waste flows and environmental performance—but it also notes that certification frameworks do not specify requirements for such systems [25]. Policy reviews highlight a gap in healthcare regulation: while hospitals are required to meet waste-management and energy-efficiency standards, few policies mandate or guide the use of AI or digital monitoring tools tailored for certification compliance [23]. Because of this, many hospitals find it to difficult their technological investments like AI-enabled recycling systems directly to certification credits or policy incentives and this situation suggests a clear need for certification and policy updates to explicitly integrate and reward AI-enabled sustainability monitoring and circular-economy efforts in hospital settings. As shown in Figure 2, the framework highlights the progressive improvement in efficiency, sustainability, and automation in hospital thermoplastic waste management.


Policy-Technology Matrix

Certification Requirement	AI Contribution	Expected Impact
Waste diversion	AI sorting & trastabality	Higher recycling rate
Waste diversion	trealthcare	Higher recycling
Energy reduction	Smart recycling control	Lower energy use
ortimicien		Re-use in hospital tools
Circular procurement	Recycled polymer monitoring	Re-use in hospital tools
Documentation	Automated dashboards	Easier audits

Figure 2. AI-enabled circular hospital waste management maturity framework

Although AI-enabled thermoplastic recycling shows strong potential in healthcare, key gaps remain. Most studies demonstrate computer-vision sorting, predictive logistics, and contamination-safe recycling in laboratory or pilot environments, with very limited real-world hospital deployment. Evidence integrating cost-benefit evaluation with life-cycle assessment (LCA) is scarce, restricting understanding of economic and environmental returns. There is also no standardized metric framework for assessing recycling efficiency, contamination reduction, or recovered-material quality, making comparisons across studies difficult.

Furthermore, there is a policy and compliance gap as there aren't numerous studies that specifically connect AI-driven waste systems to green hospital certification pathways like LEED-Healthcare and NABH Green. Despite being crucial for hospital adoption, operational aspects such as staff workflow integration, infection-control procedures, space requirements, and behaviour modification are rarely studied. Implementing AI-enabled circular waste systems in hospitals requires standard performance metrics, certification-aligned implementation models, and practical validation, despite the literature's generally encouraging conceptual and technological advances.

METHODOLOGY

Search Strategy

This study adopted a systematic narrative review approach, as AI-enabled recycling in hospital context is still an emerging field with limited available research. This method enabled the inclusion of both empirical studies and conceptual or ethical discussions relevant to healthcare setting. This study focused on research examining the use of AI or smart technologies for recycling thermoplastic medical plastics, assessing outcomes related to material recovery, recycling efficiency, cost-effectiveness, and environmental impact. Studies published between 2010 and 2025 were considered. We included studies Only English-language studies from the available period were considered, and non-AI studies or those not related to thermoplastic medical waste were excluded. Literature was searched in PubMed, Scopus, Web of Science, and Google Scholar, along with grey sources like WHO and UNEP reports. Keywords related to hospital waste, thermoplastics, and AI recycling methods were used, and only studies that focused on hospitals, plastic waste recycling, and the use of AI or smart technology were selected. Full papers were read in detail, and those not relevant were excluded. Information from final selected studies was recorded, such as the type of AI used, results of recycling, environmental impact, and challenges. The quality of each study was checked. Finally, results were summarized to show what current research says, and a PRISMA chart was used to show how many studies were found, filtered, and included.

Selection Strategy

An initially search has been identified 103 records and after removing 31 duplicates, 72 articles were eligible to undergo screening. A two-tier approach was used for the screening of the articles. Figure 3 illustrates the search strategy used in this review, including the database selection, keyword combinations, and the inclusion and exclusion criteria applied for screening the studies.

Firstly, titles and abstracts were screened for studies that were not related to AI, unrelated to healthcare-generated waste, conceptual or editorial in nature, or not specific to thermoplastic medical waste from a general waste-management perspective. At this stage, 48 articles were found eligible for full-text screening. Secondly, full texts were screened based on predefined inclusion criteria: only those that presented empirical evidence or technical evaluation of AI-based systems for thermoplastic waste management, segregation, recycling, or circular-economy practices in healthcare facilities. Moreover, such studies needed to be peer-reviewed, published in the English language, free, and available to all. Studies lacking clarity in methodology and having no measurable outcomes were not considered. After eligibility assessment, 32 studies were finalised that were included for synthesis. Findings were narratively analysed and visualized in structured tables and a PRISMA flow diagram to ensure transparency in article identification, screening, and inclusion.

Criteria Category	Inclusion Criteria	Exclusion Criteria
Study Focus	Studies on AI, ML, computer vision, robotics, or smart sensing technologies for hospital/medical waste recycling	Studies unrelated to AI or digital technologies; general waste studies not linked to healthcare
Setting	Hospital, clinic, or healthcare waste-management systems	Municipal, industrial, or household waste systems
Waste Type	Thermoplastic medical waste (PPE, syringe plastics, IV tubing, plastic consumables)	Non-plastic biomedical waste, chemical waste, liquid waste, pharmaceutical waste
Study Design	Empirical research, pilot trials, experimental studies, technical evaluations, case studies	Narrative papers, editorials, reviews without data, commentaries, conceptual papers only
Publication Type	Peer-reviewed journal articles	Conference abstracts without full text, non academic reports, blogs, web articles
Language	English	Non-English publications
Availability	Full-text accessible	Full-text not accessible
Outcome Measures	Reports measurable outcomes: segregation accuracy, recycling efficiency, contamination reduction, cost-benefits, LCA/environmental impact	Studies lacking measurable data, unclear methodology, or insufficient detail

Figure 3. Search strategy with inclusion and exclusion criteria

RESULT OF FINDING

AI for Segregation and Detection of Thermoplastic Waste

Artificial intelligence demonstrated a high level of skill in the automatic classification and sorting of hospital thermoplastic waste. Deep learning models, including CNNs, Efficient Net, and YOLO variants, had consistent performances above 90% on plastics such as PP, PE, PVC, PET, and PPE-derived components [26]. Sensor-fusion techniques incorporating Near-Infrared, hyperspectral vision, and machine learning enhanced the accuracy of polymer differentiation in complex healthcare waste streams [27]. Vision-guided robotic sorting systems realized picking accuracy rates higher than 85%, at the same time reducing time devoted to manual handling and contamination exposure considerably [11]. The throughput was lower compared to industrial systems; however, pilot projects on smart-sensor waste bins equipped with AI recognition and IoT monitoring reported higher classification accuracy and automatic bin-level sorting. A reduction in contamination by 30-50% was observed in early healthcare pilots [29]. Figure 4 shows the use of artificial intelligence in waste segregation, where AI-based systems such as image recognition, sensors, and automated sorting mechanisms are applied to identify and separate thermoplastic waste accurately.

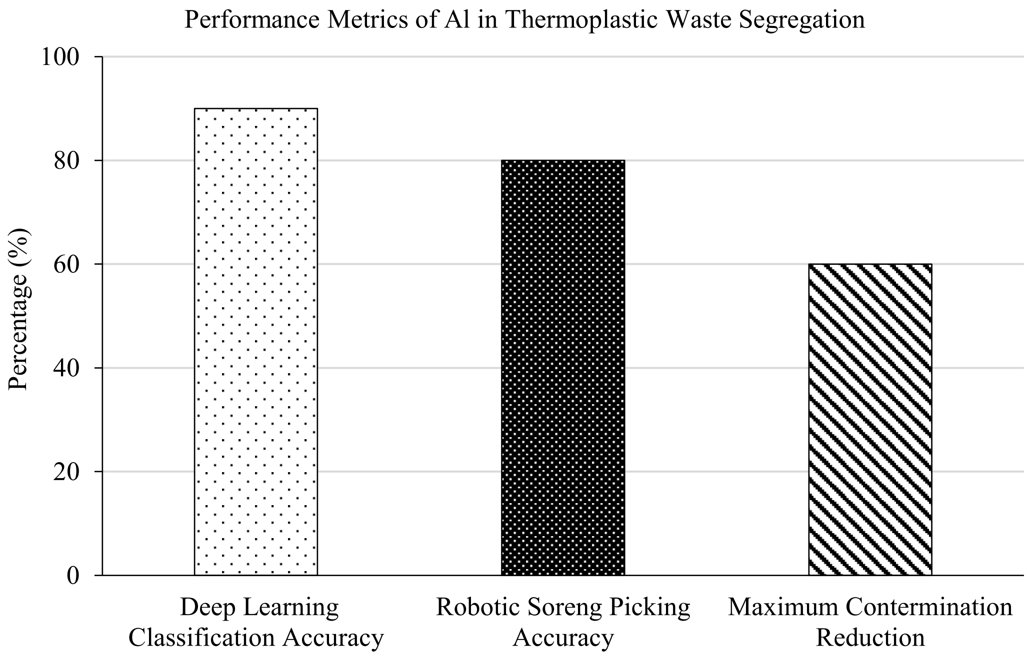


Figure 4. Using AI for waste segregation

AI for Operational Optimization and Logistics

AI streamlined such operational waste workflows by improving forecasting, route planning, and scheduling. Research using predictive models such as Random Forest, ARIMA, and neural networks has illustrated that more accurate forecasts of hospital waste volumes could be achieved, thus enabling better planning for sterilization and shredding. [28]. AI-enabled logistics systems reduced transport distance, idle routes, and overall cycle time, thereby improving efficiency by a range of 12-25% in trial settings [14]. Automated dashboards and real-time sensor data improved traceability, resource allocation, and compliance reporting [2]. However, while improvements in throughput and cost-reduction potential were indicated, comprehensive cost-benefit validation remains limited to pilot-scale studies [10].

AI for Circularity and Life-Cycle Assessment

Life-cycle assessment and circular economy studies showed favourable environmental performance for the AI-supported recycling systems. AI-enabled segregation increased recyclate purity by 20-25%

vs manual sorting, increasing reuse potential [2]. Comparative LCA showed reduced greenhouse-gas emissions for recycling vs incineration when sterile and clean polymer fractions were recovered [30]. AI-driven sustainability tools showed further evidence for improvements in waste traceability and material-recovery KPIs [11]. However, few of the studies have quantified energy consumption of AI equipment or long-term decarbonization impacts, and thus, extended monitoring and more empirical evidence at the hospital level is needed [4].

Integration into Hospital Workflows

Integration challenges, such as infrastructure, infection-control compliance, and staff training, were noted in hospital pilots. Implementation of robotic or automated sorting required dedicated space, sterilization units, and secure waste-feeding systems beforehand [8]. Adoption success was favoured by both behavioural and organisational readiness - a limited awareness among the staff and a lack of technical capacity constituted a limitation to implementation [11,10]. Major barriers were workflow disruption, infection control protocols, and lack of integrated waste-IT systems. Critical pre-processing needs were pointed out, example bio-contaminated plastics, as critical steps affecting feasibility [20]. As shown in Figure 5, the use of AI improves operational efficiency, reduces human error, and supports sustainable and circular waste management practices in hospitals.

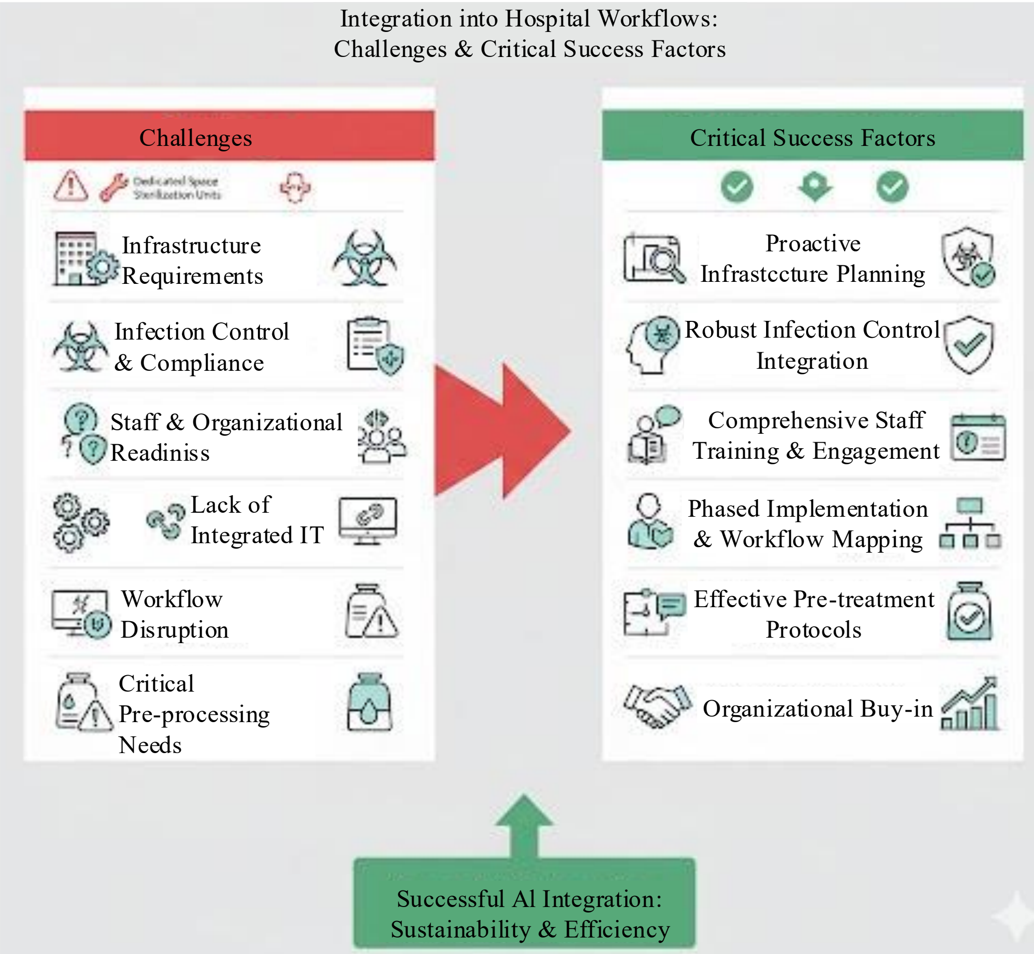


Figure 5. AI-driven waste segregation in hospital workflows

Link to Certification and Sustainability Indicators

Explicit linkage to the green-hospital certification standard remains limited, though AI-enabled waste systems align with sustainability and circular economy goals. There were reports of improved sorting efficiency and the quality of recycle traceability and documentation from AI pilots, combining green-procurement and waste-diversion goals [11]. Certification systems such as LEED-Healthcare, NABH Green, and global frameworks do not currently provide AI-specific credits; hence, digital waste optimisation investments remain under-recognised [25]. Quality appraisal across reviewed studies indicated that algorithm testing showed high rigour, applied pilots had medium quality, and there is low representation of real evidence on full-scale hospital deployment. The general weaknesses are the lack of standardised metrics, narrow economic evaluation, and brief timelines for the pilots. From the results obtained, the synthesis of evidence from past studies shows that AI significantly enhances sorting accuracy, contamination reduction, waste logistics optimisation, and strengthens the circularity outcomes in the healthcare industry. While there is technological maturity, the current development of integration within the hospital, calibration of standards relevant to certification, and economic validation require the scaling up of larger pilots and standardized performance framework

DISCUSSION

The rapid growth of AI technologies has created meaningful opportunities to improve hospital waste management, in particular for thermoplastic materials widely used in medical packaging, syringes, IV bottles, gloves, and protection equipment. This review demonstrated how AI could significantly enhance the accuracy and efficiency of waste sorting and reduce contamination while supporting the recycling of plastics otherwise commonly incinerated. Studies have shown that AI-vision systems and smart classification tools are able to achieve accuracy above 90% in controlled environments, hence promising to support cleaner waste segregation and a reduction of human error. Despite these promising results, real hospitals have still seen limited adoption. Many of the projects remain in their piloting or experimental phases, and the practical evidence from routine operations remains to emerge. Initial cost of investment, lack of staff trained in AI, and limited technical infrastructure in health-care facilities are some of the key barriers, along with a general lack of specific operational guidelines regarding AI-assisted waste segregation. Moreover, hygiene concerns related to infection control and safe handling of biomedical wastes, at times, slow down the shifting to automated systems from traditional manual methods.

These findings also suggest that AI can benefit the waste management chain as a whole. It can recognize different kinds of materials, provide real-time guidance for proper disposal, and produce accurate data that can help in reporting and planning. In addition to improving recycling, this aids hospitals in achieving sustainability objectives and pursuing green-hospital certification. Additionally, AI-enabled tracking systems can forecast waste generation, track waste patterns, and more effectively integrate hospitals with recycling partners. Transparent and accurate waste data promotes better decision-making, which enhances operational and environmental results. For hospitals to successfully implement AI-driven waste systems in the future, more practical examples, government incentives, industry standards, and training initiatives are required. With these technologies, partnership between healthcare organizations, technology developers, policymakers, and the recycling sector will be essential.

LIMITATIONS

Today, in using of these type of AI technologies several challenges can be faced. First, real-world adoptions are minimal. Very few large-scale implementations in hospitals dealing with routine clinical wastes have occurred; most were done in controlled laboratory studies or small pilots. Second, there is considerable variation in the methods used for the research: different AI models are used, as well as types of plastic wastes being assessed, and metrics such as contamination reduction, cost benefits, and sorting accuracy. Inconsistent methods limit the generalizability of findings and make it difficult to compare the results of different studies. Third, there are no standardized metrics that describe performance. Fewer studies report valuable outcomes such as the amount of pollution reduced, purity of recycled materials, greenhouse gas savings, or overall economic benefit-even though accuracy is more commonly reported. This review does not account for publications written in other languages. Internal hospital reports and grey literature, which may provide insight into practice from experiences in the real world, were under captured due to issues with indexing. Lastly, due to the specific time limit of this search, it might miss recently published data and implementations. Long-term confirmation of AI-enabled circular waste systems in healthcare requires further and more comprehensive well-structured, practice-focused research.

IMPLICATIONS

These findings have significant impact for those who develop technology, make policies, and oversee healthcare. According to the review's findings, hospital management can implement AI-based waste segregation and monitoring pilots to greatly increase recycling efficiency and get closer to achieving sustainable waste management objectives. By integrating the circular economy with procurement practices, such as sourcing recyclable materials and collaborating with certified recyclers, the circular economy will be further reinforced. Policymakers and accrediting bodies must create particular guidelines and certification credits that acknowledge and reward AI-enabled waste-management techniques if environmental reporting frameworks are to keep up with technological developments.

Future Research Directions

Future research efforts should focus and thorough investigations required in the generation of real-world evidence for AI-driven thermoplastic waste management in hospitals. This calls for large-scale, multi-hospital pilot studies to demonstrate that AI systems, which perform well in controlled or laboratory settings, can also be similarly accurate and efficient in real clinical environments across diverse healthcare contexts. It is also required that researchers establish standardised performance metrics, such as contamination-reduction rates, recycle purity, cost savings, energy consumption of AI systems, and life-cycle environmental benefits, to enable cross-study comparison and benchmarking. Longitudinal studies are needed to investigate long-term environmental and economic outcomes, including payback periods, carbon-footprint reduction, and resource-recovery efficiency in conditions that reflect standard hospital routines. Policy-oriented studies need to consider how AI-driven material-recovery systems can be integrated into green-hospital accreditation frameworks, procurement policies, and national biomedical waste regulations. Importantly, future work should also look into sociotechnical factors such as staff acceptance, behaviour change, requirements for digital training, infection-control integration, ethics of AI, data security, and system interoperability with hospital information systems, among others, and circular value-chain partnerships to further support safe and scalable adoption.

CONCLUSION

This review study illustrates how artificial intelligence can improve the performance of a circular economy, logistics optimization, and segregation of thermoplastic waste within hospitals. There is evidence that AI technologies, in the form of computer-vision systems, robotics, and sensor-fusion models, can dramatically increase plastic sorting accuracy, reduce contamination, and track waste in real time-all contributing to safer, more efficient routes for recycling. Excellent technical performance has been widely reported under controlled conditions; however, real-world implementation in healthcare is lacking. Differences in methodology, lack of standardized metrics, and lack of economic and life-cycle evidence mean policy adoption is constrained, along with certification alignment. On the whole, AI applied within hospitals in relation to circular-economy principles offers a promising side for reducing environmental burdens, increasing resource recovery, and moving toward green healthcare certification and climate-resilient waste management.

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