# A Systematic Review of Circular Economy Literature in Healthcare: Transitioning from a 'Post-Waste' Approach to Sustainability

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**Abstract**

The healthcare sector generates significant waste and environmental challenges, making the adoption of circular economy principles increasingly urgent. While research on circular economy adoption in healthcare has grown, a critical gap exists in understanding how the field evolves and the primary themes driving this transformation. This study employs bibliometric and content analysis to systematically review the intellectual structure and current state of circular economy research in healthcare.

Analysing academic papers published between 2014 and 2024, this review identifies four key themes: healthcare waste management, sustainable product design, economic and policy frameworks, and education and stakeholder engagement. The findings highlight an imbalance in the research landscape, emphasising operational challenges strongly, while systemic enablers remain largely underexplored. Although Europe leads in adopting CE practices, significant research gaps persist in Asia and North America. Key barriers, including regulatory constraints, resistance to change, and concerns around patient safety, continue to impede the effective implementation of CE, particularly in the reuse and recycling of medical devices.

This study proposes research on three key areas: evaluating the impact of the existing economic and policy frameworks; sustainability education, aimed at embedding circular economy principles into healthcare training programs; and operationalising circular supply chains, focusing on reverse logistics for medical device recovery and recycling.

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This review contributes to Step 1 of circularity by addressing waste minimisation at the source. It also identifies gaps in research and geographic disparities to advance Step 2 of circularity, which is focused on resource recovery and reuse. Finally, it provides actionable recommendations for Step 3, which aims to build systemic resilience and reduce carbon footprints through circular supply chains and sustainable procurement.

**Keywords: Circular Economy in Healthcare, Sustainable Product Design, Healthcare Waste Management, Interdisciplinary Collaboration, Sustainability Education in Healthcare.**

List of Abbreviations

| | |
|---|---|
| CE | Circular Economy |
| HC | HC |
| I4.0 | Industry 4.0 |
| LSS | Lean Six Sigma |
| NHS-UK | National Health Service-United Kingdom |
| PRISMA | Preferred Reporting Items for Systematic literature review and Meta-Analyses |
| RQ | Research Question |
| SLR | Systematic Literature Review |

**Article Highlights**

This paper employs bibliometric and content analysis to systematically review CE research in healthcare between 2014 and 2024.

Healthcare waste management, sustainable product design, policy frameworks, and stakeholder engagement are essential pillars.

Europe leads in CE adoption, but research gaps persist in Asia and North America, highlighting regional disparities.

A proactive circular system needs future research on sustainability-oriented education, modular product design, and policy reforms.

**A Systematic Review of Circular Economy Literature in Healthcare: Transitioning from a 'Post-Waste' Approach to Sustainability.**

## 1. Introduction

Healthcare (HC), by its very nature, requires vast resources, resulting in considerable waste and pollution. The National Health Service (NHS), a cornerstone of the UK's healthcare system, generates around 156,000 tons of clinical waste yearly (NHS, 2023), an unavoidable consequence of contamination and infection control measures (Saha et al., 2024 a). Beyond the environmental toll, the financial burden is staggering, with operational costs soaring to £121 billion in 2022/23 alone (NHS, 2024). This resource-intensive, waste-heavy model has often been characterised as a 'post-waste' system, where efforts are centred on managing waste after its creation rather than addressing its root causes. Though practical in the short term, such an approach perpetuates structural inefficiencies and environmental harm. Traditionally dependent on single-use materials, the healthcare sector now stands at a critical juncture where implementing circular economy (CE) principles could transform its trajectory toward sustainability.

CE principles advocate for a shift towards proactive strategies—designing for durability, reusability, and recyclability—that tackle waste at its source. Therefore, Demir & Tekinarslan (2022), Hoveling et al. (2024) and MacNeill et al. (2020) highlight the need for recycling and resource reuse in healthcare. By reducing the risks associated with hazardous waste and improving disposal practices, CE offers a pathway to mitigate environmental damage and operational inefficiencies (Narang & Vij, 2021). For example, Scotland is taking tangible steps toward embedding CE principles using I4.0 technologies (e.g., AI, blockchain, big data, Internet of things) within its healthcare system to reduce single-use items, increase the re-use and remanufacturing of medical supplies, and utilise circular supply models that keep products within the economy longer (CivTech, 2024).

In the grand narrative of public health and environmental stewardship, effective waste management has long been recognised as essential (Assemu et al., 2020; Ibrahim et al., 2023). Recently, significant progress has been made in exploring CE practices in healthcare (189 peer-reviewed papers have been published in the last ten years, according to Scopus (2024). For instance, D'Alessandro et al. (2024) highlight the importance of identifying current CE practices and areas for improvement to support sustainable healthcare. Techniques such as Lean Six Sigma, when applied to healthcare, show promise in cutting down medical waste, further highlighting the sector's capacity for change (Saha et al., 2024a). Chauhan et al. (2021) and Kazançoğlu et al. (2021) explore how I4.0 technologies can address barriers and challenges in implementing CE strategies by transforming waste management systems in

healthcare. Sagha Zadeh et al. (2016) explore the importance of improving energy efficiency in hospitals, a critical but often undervalued element of sustainability in healthcare. While Molero et al. (2021) and Simwita et al. (2023) assess both the progress and ongoing challenges in driving sustainability within the sector by highlighting the gradual shift towards greener practices. However, Pereno and Eriksson (2020) stress the value of collaboration among multiple stakeholders and cross-sector partnerships, showing how these relationships can foster innovation and support sustainable development in healthcare. Further research by Jayasinghe et al. (2023), Obeidat et al. (2023), Priyadarshini et al. (2024), Syms et al. (2023), and Vishwakarma et al. (2024) focus on CE strategies to improve areas like supply chain management, green human resource management, and overall circularity in healthcare. Yet, despite these advances, the practical implementation of CE is still fraught with challenges as healthcare systems continue to face regulatory hurdles and the high costs involved in transitioning to more sustainable models (Ranjbari et al., 2022).

As the body of work grows, research remains fragmented, with studies focusing on isolated issues like waste management (Sagha Zadeh et al., 2016) or individual technological solutions (Kazançoğlu et al., 2021) or particular country (Dixit & Dutta, 2024), limiting broader applicability and necessitating further exploration of barriers, benefits, and the applicability of CE models in various healthcare contexts. The fragmented state of research on CE in healthcare presents a dual challenge: it reflects the growing interest in integrating CE principles into this critical sector while simultaneously exposing the limitations of the existing literature. On the other hand, the absence of a systematic literature review (SLR) consolidating these fragmented findings leaves critical gaps in our understanding, hindering the development of actionable and scalable frameworks. Therefore, it is necessary to systematically review this rapidly expanding literature to synthesise these disparate findings. Moreover, such a review is essential to identify empirical gaps, particularly around multi-stakeholder collaboration and supply chain integration (Obeidat et al., 2023; Pereno & Eriksson, 2020). To this end, our SLR seeks to address two fundamental questions to explore the current literature in order to pave the path for future research of CE in the HC sector:

**RQ1:** What is the intellectual structure of circular economy literature on the healthcare sector?

**RQ2:** What is the current state of research on circular economy practices in healthcare?

To address these research questions, we assess the CE in HC literature using a combination of bibliometric and content analysis. Beyond methodological triangulation, such a combination provides holistic understanding, uncovers hidden patterns, synergistically analyses the findings, and generates critical insights.

The HC sector has shown a growing interest in CE principles. Still, it remains entrenched in reactive waste management practices, which could either indicate incremental progress or a sign of stagnation. This review seeks to address these challenges by making three targeted contributions, each aligned with advancing the healthcare sector's shift from reactive waste management to genuine circularity. First, it delivers a systematic and integrative analysis of CE practices in healthcare, categorising key themes such as waste management, sustainable product design, policy frameworks, and stakeholder engagement. This approach reveals the sector's gradual move toward circularity and critically exposes enduring barriers, including regulatory complexities, resource constraints, and entrenched cultural norms. Doing so provides the foundational knowledge required for Step 1 (minimising waste at the source through informed decision-making and strategic interventions) of circularity—identifying and addressing inefficiencies in current waste management systems.

Second, the review advances the methodological discourse by scrutinising existing research approaches and geographic disparities, revealing a dearth of empirical studies and the gaps in CE adoption in Asia and North America. This gap highlights the need for more robust, data-driven research to substantiate and generalise findings to provide a stronger foundation for scaling CE practices across healthcare systems. This insight directly supports Step 2 of circularity (resource recovery and reuse), focusing on optimising resource utilisation and improving the design of healthcare products to align with CE principles.

Finally, this paper outlines actionable pathways for future research and practice, emphasising the importance of interdisciplinary collaboration, embedding sustainability education into healthcare training, and crafting dynamic policy frameworks. These recommendations are essential for Step 3 (building systemic resilience and reducing carbon footprints)—enabling decarbonisation through circular supply chains and sustainable procurement practices.

The remainder of this paper is structured as follows: first, we detail the methodological approaches for the review, and then, in section 3, we present the findings of the reviews. The discussion section highlights the broader meanings of our findings, explores future research agendas and acknowledges our limitations. Finally, we draw conclusion in section 5.

## 2. Methodological approach

This research conducts an SLR (Agostini et al., 2023) combined with bibliometric and content analysis. The epistemological position of the review is critical realism (Bhaskar, 1975), which embraces a mixed-method approach. Mixed-methods research integrates quantitative and qualitative approaches to address complex phenomena such as CE in HC holistically (Creswell & Plano Clark, 2017). Our approach

is inspired by the precedent set by Saha et al. (2024c), whose mixed-methods SLR on CE, published in the *Journal of Cleaner Production*, demonstrated the value of integrating quantitative and qualitative approaches to gain a nuanced understanding of complex systems. Our approach aligns with this framework since our bibliometric methods follow a deductive and quantitative approach while the content analysis uses an inductive qualitative (Zawacki-Richter et al., 2020) strategy. The deductive approach of bibliometric review identifies overarching trends, assesses the relative impact of different articles, and provides a comprehensive picture of the field's intellectual structure (RQ1). On the other hand, the content analysis introduces qualitative dimensions to unveil the current state of research on CE practices in healthcare (RQ2). This two-layered approach adheres to the principles of mixed-methods research (Tashakkori & Teddlie, 2010), providing both the breadth of quantitative bibliometric insights and the depth of qualitative thematic interpretation.

### 2.1. Identification and Quality Assessment of CE-Health Care Literature

We applied the PRISMA approach to conduct the SLR (Figure 1). The initial search was conducted through the Scopus database (Malanski et al., 2021) on 2 August 2024 based on keywords “circular economy,” AND “Health*,” OR “Healthcare;” OR “Medical” for searches within “the title, abstract, and keyword”. A total of 2589 documents were identified as the original sample. To refine the sample, we focused on topics relevant to healthcare, excluding papers not pertinent to the discussion and restricting the sample to English-language documents.

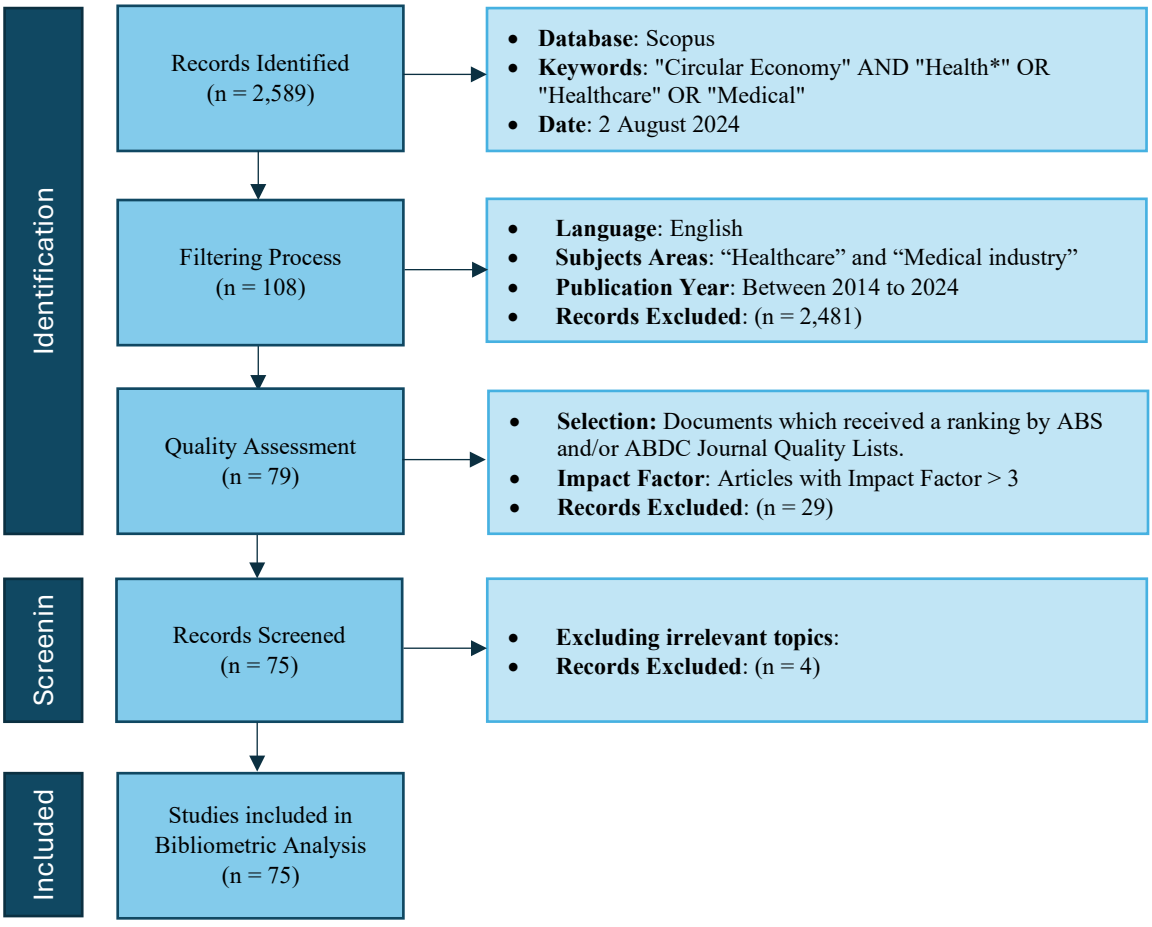

*Figure 1. Selection process based on PRISMA method*

The inclusion and exclusion criteria were carefully applied to ensure the selection of high-quality studies directly aligned with this systematic review's two RQs and methodological framework. Articles were included if they explicitly addressed CE practices in healthcare and provided theoretical, empirical, or practical insights. Additionally, only English-language studies were included to ensure consistency in analysis and accessibility. Exclusion criteria were similarly designed to refine the dataset and maintain relevance to the research questions. Grey literature, such as policy briefs and reports, was excluded to focus on peer-reviewed sources that meet established academic standards. Papers that lacked direct relevance to CE in healthcare, such as those addressing industrial applications or generic mentions of CE without detailed analysis, were omitted. Methodological considerations also played a role; studies with limited or unclear methodologies were excluded.

The HC sector has undergone significant changes over the past decade, driven by technological advancements, sustainability challenges, and evolving patient needs, particularly during the COVID-19 pandemic. The selected time frame of 2014–2024 reflects a strategic choice to capture a decade of significant evolution in CE research within the healthcare sector. This period marks the emergence of CE as a critical area of academic and policy focus, with early contributions from authors such as Viani et al. (2016), who investigated value recovery from medical instruments used in England and Italy. Furthermore, this time frame captures pivotal global sustainability initiatives (i.e., the European Green Deal and the United Nations' Sustainable Development Goals [SDGs]), which have driven the integration of CE practices into healthcare systems. While earlier studies are excluded, this 10-year time frame allows us to capture the most relevant and contemporary insights, notably how the pandemic accelerated innovations in healthcare delivery and sustainability practices.

To enhance credibility, we assessed the quality of the selected papers based on journal rankings from the Australian Business Deans Council (ABDC) (Hair et al., 2019) and the Chartered Association of Business Schools (CABS) (Walker et al., 2019) Journal Quality List. Since healthcare-focused articles are often published in non-ABDC and CABS journals, we also considered articles from journals outside the scope of ABDC and CABS. However, we only selected reputed journals using the citation reports (good impact factors >3.00 and above), similar to Saha et al. (2024c, p. 5) and the definition of a predatory journal presented in Oviedo-García (2021) for quality control purposes.

***Table 1. Selected literature (75), their relevance, thematic and geographic scopes and methodological approaches***

| ID | Articles for content analysis | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Geographic scope | Methodological approach |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Abhilash and Inamdar (2022) | 1 | 2 | 2 | 5 | Medium | Healthcare Waste Management | Not Specified | Qualitative |
| **2** | Ahkola et al. (2024) | 2 | 2 | 1 | 5 | Medium | Healthcare Waste Management | Europe | Qualitative |
| **3** | Alexaki et al. (2018) | 3 | 2 | 2 | 7 | High | Sustainable Product or Procedure Design | Europe | Theoretical |
| **4** | Ali and Geng (2018) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Asia | Qualitative |
| **5** | Ali and Kannan (2022) | 3 | 3 | 2 | 8 | High | Economic and Policy Frameworks | Not Specified | Theoretical |
| **6** | American Public Health Association (2023) | 3 | 2 | 2 | 7 | High | Healthcare Waste Management | North America | Theoretical |
| **7** | Benedettini (2022) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | North America | Qualitative |
| **8** | Best and Williams (2021) | 3 | 3 | 3 | 9 | High | Economic and Policy Frameworks | North America | Theoretical |
| **9** | Chau et al. (2022) | 1 | 2 | 1 | 4 | Medium | Healthcare Waste Management | Europe | Theoretical |
| **10** | Chauhan et al. (2021) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Not Specified | Qualitative |
| **11** | Chen et al. (2023) | 2 | 2 | 2 | 6 | Medium | Healthcare Waste Management | Not Specified | Qualitative |
| **12** | Chew et al. (2023) | 3 | 3 | 3 | 9 | High | Healthcare Waste Management | Asia | Qualitative |
| **13** | Chu et al. (2023) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Asia | Qualitative |

| ID | Articles for content analysis | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Geographic scope | Methodological approach |
|---|---|---|---|---|---|---|---|---|---|
| **14** | Cobra et al. (2023) | 3 | 2 | 3 | 8 | High | Sustainable Product or Procedure Design | South America | Qualitative |
| **15** | Cook et al. (2023) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Asia | Theoretical |
| **16** | Daú et al. (2019) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | South America | Qualitative |
| **17** | Dihan et al. (2023) | 3 | 3 | 3 | 9 | High | Healthcare Waste Management | Asia | Qualitative |
| **18** | Dolatabad et al. (2022) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Asia | Theoretical |
| **19** | Duane et al. (2020) | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Europe | Qualitative |
| **20** | Dukić et al. (2013) | 1 | 2 | 1 | 4 | Medium | Economic and Policy Frameworks | Europe | Theoretical |
| **21** | Ezeudu et al. (2022) | 3 | 3 | 2 | 8 | High | Economic and Policy Frameworks | Africa | Qualitative |
| **22** | Fanta et al. (2021) | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Not Specified | Theoretical |
| **23** | Ferronato et al. (2020) | 1 | 3 | 1 | 5 | Medium | Healthcare Waste Management | South America | Qualitative |
| **24** | Gaberščik et al. (2021) | 3 | 2 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Europe | Quantitative |
| **25** | Govindan et al. (2022) | 1 | 3 | 1 | 5 | Medium | Healthcare Waste Management | Not Specified | Qualitative |
| **26** | Haber and Fargnoli (2021) | 2 | 2 | 2 | 6 | Medium | Sustainable Product or Procedure Design | Europe | Qualitative |

| ID | Articles for content analysis | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Geographic scope | Methodological approach |
|---|---|---|---|---|---|---|---|---|---|
| **27** | Harding et al. (2021) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | North America | Qualitative |
| **28** | Hatzivasilis et al. (2019) | 3 | 3 | 3 | 9 | High | Economic and Policy Frameworks | Europe | Qualitative |
| **29** | Hunfeld et al. (2023) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Europe | Qualitative |
| **30** | Ishaq et al. (2024) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Europe | Qualitative |
| **31** | Jafarzadeh Ghoushchi et al. (2022) | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Asia | Qualitative |
| **32** | Kandasamy et al. (2022) | 3 | 3 | 2 | 8 | High | Economic and Policy Frameworks | Asia | Quantitative |
| **33** | Kane et al. (2018) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | North America | Qualitative |
| **34** | Kazançoğlu et al. (2021) | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Not Specified | Qualitative |
| **35** | Kheirabadi and Sheikhi (2022) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | North America | Qualitative |
| **36** | Kumar and Chhabra (2022) | 3 | 2 | 2 | 7 | High | Sustainable Product or Procedure Design | Asia | Theoretical |
| **37** | Kumar et al. (2021) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Not Specified | Qualitative |
| **38** | Leissner and Ryan-Fogarty (2019) | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Europe | Qualitative |
| **39** | MacNeill et al. (2020) | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | North America | Qualitative |

| ID | Articles for content analysis | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Geographic scope | Methodological approach |
|---|---|---|---|---|---|---|---|---|---|
| **40** | Mahjoob et al. (2023) | 3 | 3 | 3 | 9 | High | Economic and Policy Frameworks | Not Specified | Qualitative |
| **41** | Mallick et al. (2022) | 2 | 2 | 1 | 5 | Medium | Sustainable Product or Procedure Design | Europe | Qualitative |
| **42** | Mariampillai et al. (2023) | 3 | 2 | 2 | 7 | High | Healthcare Waste Management | North America | Qualitative |
| **43** | Martin et al. (2022) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Europe | Qualitative |
| **44** | Meissner et al. (2021) | 3 | 2 | 1 | 6 | Medium | Healthcare Waste Management | North America | Qualitative |
| **45** | Meister et al. (2022) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Europe | Qualitative |
| **46** | Mekonnen and Aragaw (2021) | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | North America | Theoretical |
| **47** | Najar et al. (2024) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Not Specified | Qualitative |
| **48** | Narang and Vij (2021) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Asia | Qualitative |
| **49** | Patil et al. (2022) | 2 | 3 | 2 | 7 | High | Economic and Policy Frameworks | Not Specified | Qualitative |
| **50** | Priyadarshini et al. (2024) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Not Specified | Qualitative |
| **51** | Ramos et al. (2023a) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Europe | Mixed |
| **52** | Ramos et al. (2023b) | 3 | 3 | 3 | 9 | High | Healthcare Waste Management | North America | Qualitative |

| ID | Articles for content analysis | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Geographic scope | Methodological approach |
|---|---|---|---|---|---|---|---|---|---|
| **53** | Ranjbari et al. (2022) | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Asia | Theoretical |
| **54** | Ranjbari et al. (2023) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Not Specified | Theoretical |
| **55** | Ritchie (2021) | 3 | 3 | 1 | 7 | High | Sustainable Product or Procedure Design | North America | Qualitative |
| **56** | Saber et al. (2022) | 1 | 2 | 1 | 4 | Medium | Healthcare Waste Management | North America | Qualitative |
| **57** | Sadhukhan and Sekar (2022) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Asia | Qualitative |
| **58** | Shabani et al. (2024) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Africa | Qualitative |
| **59** | Sharma et al. (2023) | 2 | 2 | 1 | 5 | Medium | Healthcare Waste Management | Asia | Qualitative |
| **60** | Singh et al. (2022) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Asia | Theoretical |
| **61** | Singh et al. (2023) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Not Specified | Theoretical |
| **62** | Sittig et al. (2022) | 3 | 2 | 2 | 7 | High | Sustainable Product or Procedure Design | North America | Theoretical |
| **63** | Soares et al. (2023 a) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Not Specified | Qualitative |
| **64** | Soares et al. (2023 b) | 3 | 3 | 3 | 9 | High | Education and Stakeholder Engagement | Europe | Quantitative |

| ID | Articles for content analysis | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Geographic scope | Methodological approach |
|---|---|---|---|---|---|---|---|---|---|
| **65** | Syms et al. (2023) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Africa | Qualitative |
| **66** | Ugandar et al. (2023) | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Asia | Qualitative |
| **67** | Van Boerdonk et al. (2021) | 3 | 2 | 2 | 7 | High | Economic and Policy Frameworks | Not Specified | Qualitative |
| **68** | Van Straten et al. (2021) | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Europe | Qualitative |
| **69** | Viani et al. (2016) | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Europe | Qualitative |
| **70** | Viegas et al. (2019) | 2 | 2 | 2 | 6 | Medium | Economic and Policy Frameworks | Europe | Qualitative |
| **71** | Vishwakarma et al. (2024) | 3 | 2 | 2 | 7 | High | Economic and Policy Frameworks | Asia | Theoretical |
| **72** | Voudrias (2018) | 3 | 3 | 1 | 7 | High | Sustainable Product or Procedure Design | Europe | Qualitative |
| **73** | Wandji et al. (2022) | 1 | 2 | 1 | 4 | Medium | Sustainable Product or Procedure Design | Not Specified | Theoretical |
| **74** | Wright et al. (2019) | 2 | 3 | 2 | 7 | High | Economic and Policy Frameworks | Africa | Qualitative |
| **75** | Zlaugotne et al. (2022) | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Europe | Theoretical |

*Source: Author's analysis of Scopus data.*

### 2.2. Bibliometric review process

We employ author co-citation analysis, keywords co-occurrence analysis and bibliographic coupling to uncover citation patterns and cluster-related documents within the field of CE in healthcare. Author co-citation analysis measures the frequency with which authors are cited together, achieving three

key objectives: (i) identifying influential scholars within CE in healthcare, (ii) uncovering connections between these scholars, and (iii) gaining insight into the main themes and directions within the research domain (Donthu et al., 2021). The keyword co-occurrence analysis, however, identifies the frequency with which specific terms appear together in the research on CE in healthcare. This technique helps uncover the key topics and themes frequently studied in conjunction with revealing the research focus areas and emerging trends within the field (Duong et al., 2024). Bibliographic coupling, on the other hand, examines the degree of similarity between reference lists of different academic articles, identifying those that share a conceptual foundation and revealing emerging areas in the field (Vogel et al., 2021). This bibliometric approach helps illuminate the intellectual structure (O'Donnell et al., 2024) of CE in healthcare, uncovering collaboration and communication networks among scholars. Using the VOSviewer (Van Eck & Waltman, 2017) software package, we generate visual maps and co-citation networks to understand the development and future research directions better.

**2.3. Content analysis process**

For this review, we established three relevance criteria (C1, 2 and 3) to systematically evaluate and select articles that would best support our analysis and address our research questions (Saha et al., 2024c; Vogel et al., 2021). These criteria ensured that selected articles provided substantive contributions to understanding both the intellectual structure and current state of CE practices in healthcare:

> C1. Articles should offer robust theoretical frameworks or concepts that provide insights into the core principles, sustainability models, or interdisciplinary approaches of CE in HC.
>
> C2. Articles that propose novel research areas or explore emerging themes, particularly those that push the boundaries of traditional CE applications in HC. This includes exploring innovative waste management techniques, resource efficiency models, or the integration of new technologies (e.g., AI, Industry 4.0) in healthcare contexts.
>
> C3. Articles that establish new frameworks or methodologies to advance CE practices in HC. These frameworks should focus on practical and scalable solutions for resource use, waste minimisation, and sustainability in healthcare, as well as provide replicable research designs for future studies.

The thematic relevance criteria (C1, C2, C3) were systematically applied to ensure that the selected articles directly aligned with the RQs of this review. C1 focused on identifying studies that explicitly

discussed CE practices within the healthcare sector to ensure that the analysis remained anchored in the specific context of healthcare, avoiding dilution by broader CE discussions in unrelated industries. C2 emphasised including studies that contributed to the understanding of methodological approaches and theoretical frameworks underpinning CE practices in healthcare. This criterion ensured a comprehensive exploration of the intellectual structure and current state of research, aligning with RQ1 and RQ2. Finally, C3 prioritised studies addressing practical challenges, solutions, and emerging trends related to CE adoption in healthcare. Two members of our research team independently reviewed each article in detail for relevance to the three criteria, with scores assigned 1 (low relevance), 2 (medium relevance), and 3 (high relevance) (Saha et al., 2024c; Vogel et al., 2021). Based on these scores, articles were categorised as high (scores 7 and above), medium (4-6), or low (3 and below). Appendices 1 and 2 present the relevant criteria application methods. We ultimately classified 75 articles, of which 49 were high relevance, and 26 were medium relevance, as detailed in Table 1. Such strict adherence to the review protocol ensured the reliability of our content analysis.

## 3. Results

This section represents the findings of our bibliometric review and content analysis.

### 3.1 Mapping the Intellectual Structure of Circular Economy in Healthcare (RQ1)

We identify the key research patterns through author co-citation, keyword co-occurrence, and bibliometric coupling, in this section. These tools provide a comprehensive mapping of the research landscape, highlighting core themes, influential authors, and emerging trends within the field.

#### Author Co-citation analysis

The main aim of author co-citation analysis has been to find the important researchers in a particular area of research, what relationships exist between authors, and what the core concepts and the evolution direction in the area of research are. For example, prominent scholars such as Alnoor A., Kumar A., and Boopathi S. have strongly influenced CE research in healthcare. Given that CE-HC research is a relatively new area, we applied a minimum citation threshold of 10 to ensure statistical robustness while accommodating the emerging nature of the field. However, adopting a higher threshold, such as 20 citations, would have significantly limited the pool of qualifying authors—yielding only 29 in this case—due to the relatively low citation counts typical of emerging fields. The adopted threshold enhances the reliability of co-citation analysis by excluding authors with minimal citations, thereby reducing the risk of chance associations and ensuring the identification of meaningful relationships (Van Eck & Waltman, 2017). Setting the threshold at 10 achieves a strategic

balance between inclusivity and statistical rigour, allowing us to include 71 authors (Van Eck & Waltman, 2014).

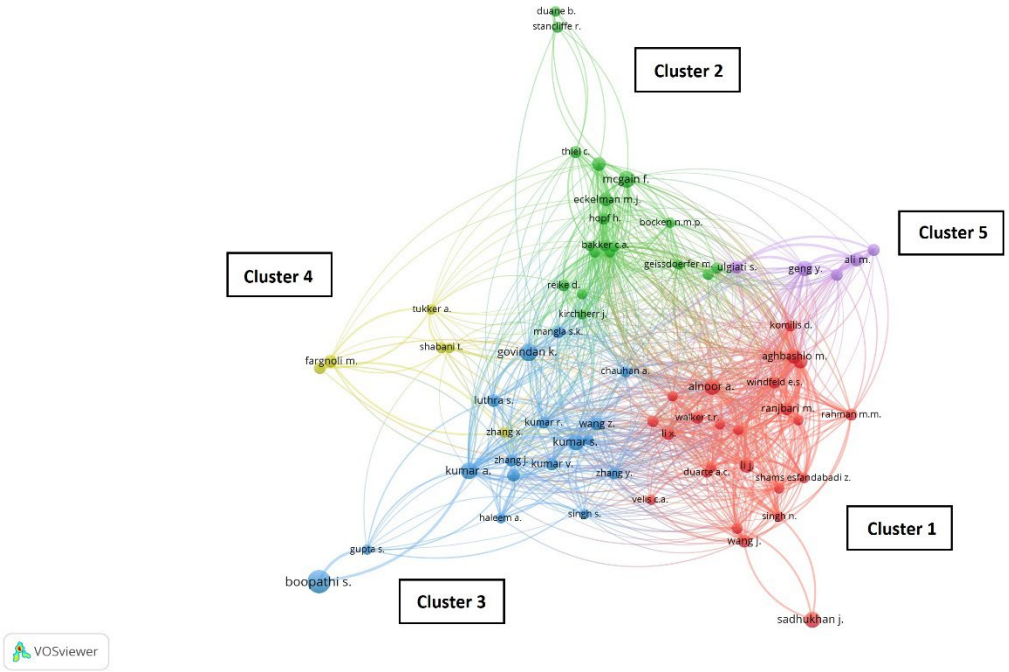


*Figure 2. Co-citation of authors [Minimum number of citation = 10] [Source: VOS Viewer analysis of literature].*

Figure 2 presents a visualisation of the co-citation network generated using VOSviewer. The network consists of 71 nodes representing individual authors and 1719 links, which reflect the strength of co-citation relationships between pairs of authors. The network is divided into five distinct clusters, each represented by different colours (Cluster 1 = red, Cluster 2 = green, Cluster 3 = blue, Cluster 4 = yellow, Cluster 5 = purple). The size of each node corresponds to the frequency with which an author is cited, and the thickness of the links between nodes indicates the strength of their co-citation, signifying the extent to which two authors are cited together in other works (Zhao & Strotmann, 2015). Table 2 presents the statistics for the co-citation analysis.

***Table 2. Co-citation analysis data.***

| Clusters | Paper Counts | Total Citations | Average Citation | Citation % | Highest cited paper [citations] |
|---|---|---|---|---|---|
| **Cluster 1** | 24 | 334 | 13.92 | 32 | Alnoor, a. [25]<br>Sadhukhan, j. [25] |
| **Cluster 2** | 19 | 246 | 12.95 | 23 | Mcgain, f. [27] |
| **Cluster 3** | 17 | 296 | 17.41 | 28 | Boopathi, s. [51] |
| **Cluster 4** | 6 | 73 | 12.17 | 7 | Fargnoli, m. [15] |

| Clusters | Paper Counts | Total Citations | Average Citation | Citation % | Highest cited paper [citations] |
|---|---|---|---|---|---|
| **Cluster 5** | 5 | 82 | 16.40 | 8 | Geng, y. [22] |
| **Total** | 71 | 1031 | | 100 | |

*Source: Author's analysis of VOS Viewer data.*

The network of citations and co-citations also reveals a concentration of academic influence within distinct clusters, each representing a specific area of focus within CE practices in HC. For example, Cluster 1 primarily discusses innovative waste treatment methods and design for circularity in medical products, exploring new approaches to managing medical waste and enhancing the sustainability of medical product design. Led by authors such as Alnoor A. and Sadhukhan J., this cluster contains the largest number of papers (24) and accounts for 32% of the total dataset citations, positioning it as a core body of literature on circular economy applications in healthcare. Cluster 2 centres on design for circularity in medical products, with a focus on developing sustainable medical products that reduce environmental impact through circular design principles. Dominated by McGain F., this cluster includes 19 papers and contributes 23% of total citations, underscoring its relevance and significant role in sustainable healthcare product design discussions.

Cluster 3 addresses both innovative waste treatment methods and circular economy business models, combining waste management advancements with economic models promoting circularity. Although it includes fewer papers (17), this cluster shows a high average citation count (17.41), with Boopathi S. as its most frequently cited author, signalling concentrated, high-impact influence within ongoing circular economy discussions. Cluster 4 also emphasizes design for circularity in medical products, reinforcing the importance of sustainable product design within healthcare. Scholars such as Fargnoli M. contribute to this area, though the cluster remains smaller in terms of paper count. Lastly, Cluster 5 focuses on resource recovery and recycling, examining strategies for reclaiming and reusing materials from healthcare waste streams. Researchers like Geng Y. are central to this cluster, which highlights a crucial area for reducing waste and resource dependency in healthcare.

**Keywords Co-occurrence analysis**

To better understand the current research trends and knowledge base, we conducted an overlay visualisation analysis, which helps highlight the evolution of topics over time. In this visualisation, darker nodes represent earlier research topics, while lighter nodes indicate more recent ones

(Alaminos et al., 2024). Of the 926 keywords identified, 42 met the threshold for analysis, with a minimum of five occurrences each.

In Figure 3, 'circular economy' emerges as the most frequently used keyword, appearing 51 times. Other frequently occurring terms include 'health care', 'human', and 'waste management', each appearing 26 times, indicating significant research interest in these areas. Newer topics, suggesting emerging trends in circular economy research within the healthcare sector, include 'single-use' (MacNeill et al., 2020; Narang & Vij, 2021), 'incineration' (Pikoń et al., 2021) and 'healthcare delivery' (Samenjo et al., 2023). For instance, the environmental impact of single-use products is a critical area of study, particularly in evaluating their role in waste generation within healthcare. The CE initiative of the Scottish NHS mentioned earlier in this paper focuses on reducing single-use items by promoting reuse, remanufacturing, and sustainable supply chain models. This initiative reflects a growing recognition of the environmental and economic costs associated with single-use products, making it a critical area of emerging research. While 'incineration' plays an important role in converting hazardous healthcare waste into energy and reducing landfill usage, it also generates harmful emissions. Reducing single-use items, as promoted by the Scottish NHS initiative mentioned earlier, will lower the volume of waste requiring incineration. This connection is reflected in the co-occurrence of these keywords. On the other hand, 'healthcare delivery' research focuses on how resource reuse and waste reduction align with green practices throughout the patient care process.

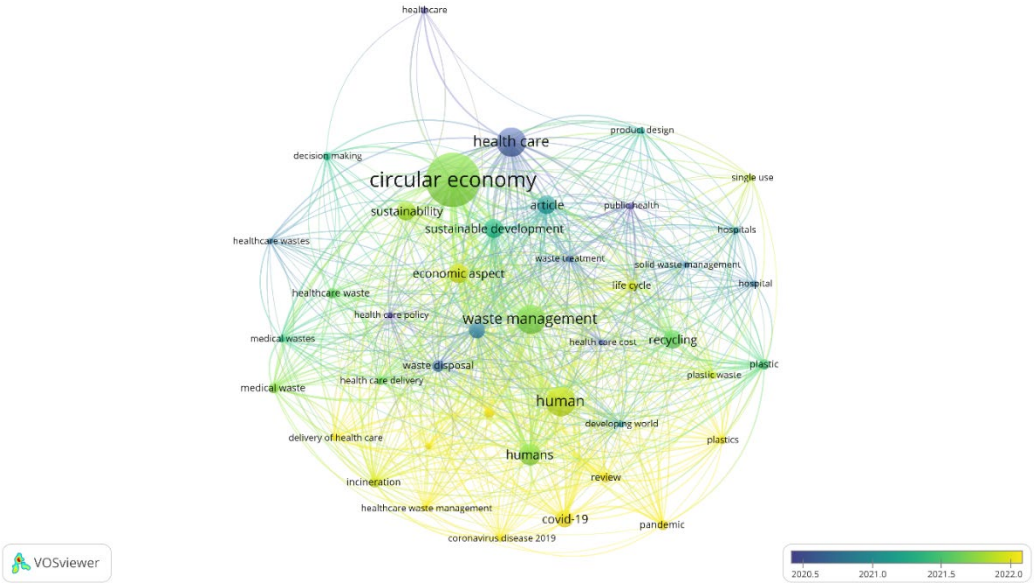


*Figure 3. Overlay representation of keywords co-occurrence [Minimum number of occurrences of a keyword = 5]* [Source: VOS Viewer analysis of literature].

**Bibliometric review: Bibliometric Coupling**

A bibliometric analysis was conducted to visualise the relationships among relevant scholarly works. The visual representation generated from this analysis provides a comprehensive map of academic influence, revealing intricate co-citation relationships among 463 distinct links.

The bibliometric map, depicted in Figure 4, demonstrates the interconnectedness of various papers and authors, organising them into nine distinct clusters based on the strength of their bibliometric coupling. These nine clusters reflect a diverse and complex body of literature, totalling 1,780 citations.

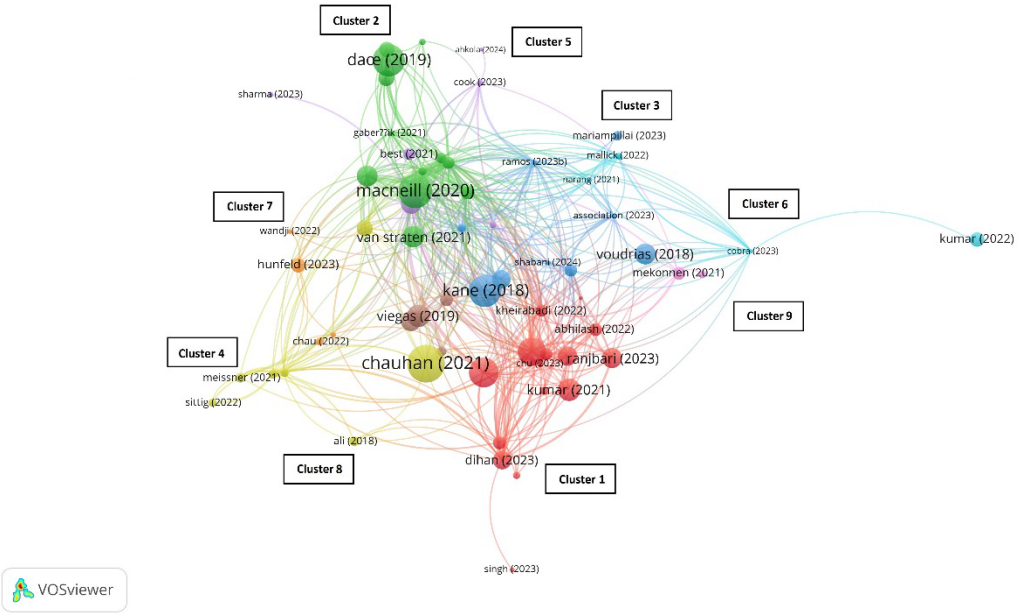


*Figure 4. Bibliometric Coupling (UoA: documents).* [Source: VOS Viewer analysis of literature].

The distribution of citations across these clusters presents the varied yet interconnected nature of research within this domain. Some clusters are centred around high-impact, widely cited papers (i.e., MacNeill et al.,2020) that serve as critical reference points, while others represent emerging scholarly dialogues that are still developing momentum (e.g., Cluster 9). Each cluster is represented by a different colour, signifying a group of closely related papers. Table 3 presents the statistics for the Bibliometric Coupling analysis.

The bibliometric clustering of CE research in HC unveils a landscape of overlapping priorities and emerging scholarships – an indication of both progress and fragmentation within the field. Cluster 1, grounded in healthcare waste management, represents a vital but reactive approach, capturing the current practice of dealing with waste post-creation rather than preventing it. This focus on downstream management suggests a somewhat limited vision for the healthcare sector, which fails to embrace CE's transformative potential fully. Cluster 2, however, with its emphasis on sustainable

product design and economic policy, begins to move towards a more forward-thinking model, where policy frameworks and sustainable design are seen as mechanisms to reshape the healthcare system from within. The high citation counts here reflect an academic awakening to the systemic shifts needed to embed CE principles effectively.

***Table 3. Bibliometric cluster data.***

| Cluster | Number of Papers | Total Citations | Most Cited Paper (Citations) | Focus Area |
|---|---|---|---|---|
| **Cluster 1 (Red)** | 15 | 455 | Singh et al. (2022) (95 citations) | HC waste management for efficient waste management |
| **Cluster 2 (Green)** | 12 | 525 | MacNeill et al. (2020) (121 citations) | Sustainable product/procedure design and economic & policy frameworks |
| **Cluster 3 (Blue)** | 10 | 250 | Kane et al. (2018) (109 citations) | HC waste management and sustainable product/procedure design |
| **Cluster 4 (Yellow)** | 7 | 231 | Chauhan et al. (2021) (152 citations) | Education & Stakeholder engagement for sustainable product/procedure design |
| **Cluster 5 (Purple)** | 6 | 80 | Chew et al. (2023) (48 citations) | Economic & regulatory frameworks for HC waste management |
| **Cluster 6 (Light Blue)** | 6 | 40 | Kumar and Chhabra (2022) (24 citations) | Sustainable product/procedure innovation for HC practice |
| **Cluster 7 (Orange)** | 4 | 40 | Hunfeld et al. (2023) (25 citations) | Sustainable design innovations in HC waste management practices |
| **Cluster 8 (Brown)** | 4 | 131 | Viegas et al. (2019) (55 citations) | Policy interventions for circular economy in HC. |
| **Cluster 9 (Pink)** | 2 | 28 | Mekonnen and Aragaw (2021) (19 citations) | Integration of sustainability and waste management in HC. |

*Source: Author's analysis of VOS Viewer data.*

In Clusters 3 and 4, we see the beginnings of a more integrative approach. Cluster 3's merger of waste management with sustainable design suggests that scholars are inching towards a vision where waste is minimised by design rather than managed post facto. Cluster 4, with its focus on education and stakeholder engagement, addresses the nuanced, often overlooked dimensions of CE—those that require a cultural and behavioural shift alongside structural reform. However, the comparatively lower citation counts in these clusters highlight that, while foundational, these areas are yet to receive the academic attention they deserve.

The smaller clusters (6-9) focused narrowly on sustainable design or in conjunction with waste management. These clusters, though valuable, indicate a fragmented field, with research interests spread across narrow avenues rather than converging towards a cohesive, unified CE framework.

Thus, while the academic growth in CE research for HC is evident, there remains a critical need for synthesis—a bridging of themes and clusters to achieve a robust, system-wide CE model with practical and preventative strategies.

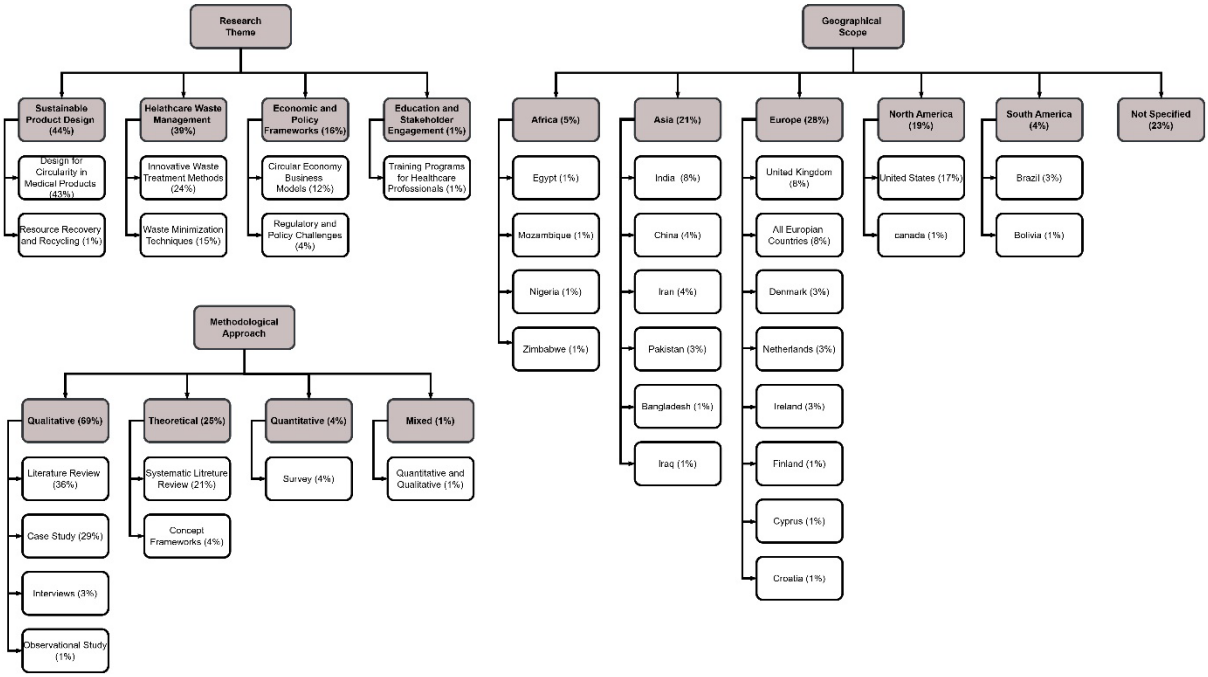


*Figure 5. Main research themes and subthemes, geographic scope, and methodology with their frequency* [Source: Authors' analysis of literature].

### 3.2 Current state of research on circular economy practices in healthcare (RQ2)

We conducted a detailed thematic analysis of selected articles (75) to identify their thematic focus (to reflect both the practical demands of the HC industry and the overarching goals of global CE frameworks), methodological approaches (to evaluate the research's depth and applicability), and geographical scopes (to examine regional variations in CE adoption). We coded all articles based on three predefined thematic criteria: waste reduction, resource efficiency, and cross-sector collaboration. These themes are derived from our bibliometric insights, capturing both the intellectual structure and the current state of CE practices in HC. They also align with global sustainability objectives (e.g., European Green Deal, SDGs), contributions of CE thinktanks (e.g., EllenMacarthurFoundation.org), and existing CE reviews (e.g., D'Alessandro et al., 2024; Duong et al., 2024; Dzhengiz et al., 2023 and Saha et al., 2024c). Thus, we identified and presented four key themes in Table 1: sustainable product design (Syms et al., 2023), healthcare waste management (Soares et al., 2023a), economic and policy frameworks (Ali & Kannan, 2022), and education and stakeholder engagement (Soares et al., 2023b). We have included the detailed coding schema in Appendix 2. Table 1 and Figure 5 illustrate the mapping of the papers based on primary themes and subthemes.

When a subtheme was addressed by multiple studies within a cluster, the most cited article was selected to represent that subtopic.

**Core research themes in circular economy adoption within healthcare: pathways to sustainability**

By analysing the key areas of focus in Table 1 and Figure 5, our content analysis reveals product design, waste management, policy and stakeholder engagement as the core themes of CE in HC literature.

Sustainable product design (44%) emerges as the most prominent theme and represents a forward-looking approach to healthcare, challenging the current 'post-waste' model by prioritising durability and recyclability from the outset. Unlike traditional practices that manage waste after it has been generated, this model aims to minimise waste creation entirely by designing products intended to last longer and be reused. This proactive approach supports a more sustainable healthcare system that aligns with environmental goals, reducing resource consumption while upholding clinical efficacy.

Closely following, healthcare waste management (39%) remains a key focus, addressing the sector's current reactive stance of managing waste post-creation. This theme includes strategies for reducing medical waste, promoting recycling, green procurement, and safely handling hazardous materials. While essential for mitigating the environmental impact of healthcare, waste management's reactive nature highlights the need to link it with sustainable product design. Such integration would reduce reliance on resource-intensive disposal and recycling practices.

While waste management remains a central pillar within the current 'post-waste' structure of the healthcare industry, extending beyond basic disposal to integrate recycling, green procurement, and the safe handling of end-of-life products. This approach reflects a growing emphasis on balancing patient safety with environmental sustainability. However, linking waste management with sustainable product design could reduce the need for extensive disposal protocols and resource-intensive recycling.

On the other hand, research into economic and policy frameworks (16%) plays a central role in promoting circular economy practices within healthcare, especially in the context of single-use products. Studies in this area explore how regulatory and financial mechanisms can support sustainable business practices, encouraging repair, reuse, and recycling as standard operations. Well-designed policies have the potential to shift healthcare from a predominantly disposable model towards one that prioritises resource conservation, aligning environmental goals with operational needs.

Despite being the least explored theme, education and stakeholder engagement (1%) hold strategic importance for systemic CE adoption in healthcare. Research highlights the need to cultivate a deeper understanding among healthcare professionals about the environmental and economic consequences

of their choices in product use. Additionally, engaging stakeholders, from manufacturers to policymakers, can create a collaborative environment where shared knowledge influences regulation.

The emphasis (combinedly 83% of articles in our sample) on sustainable product design and healthcare waste management reflects a predominant focus on operational challenges within the sector, rooted in a 'post-waste' mindset that prioritises waste management over prevention. In contrast, the comparatively limited attention to economic and policy frameworks and education and stakeholder engagement highlights a critical gap, as these enabling mechanisms are vital for the transition of the healthcare sector to CE. Table 4 also offers a structured view of how these research areas are advancing the adoption of CE principles within the healthcare sector.

**Global disparities in the adoption of circular economy practices in healthcare: Socioeconomic and political influences**

Socioeconomic and political factors play a significant role in influencing the adoption of CE practices in healthcare across different regions. As presented in Table 1 and Figure 5, 28% of the geographic focus in the reviewed literature is centred in Europe (the UK accounting for 8%, and Denmark, Ireland, and the Netherlands each representing 3%) (e.g., Alexaki et al., 2018; Duane et al., 2020; Hatzivasilis et al., 2019; Van Straten et al., 2021). In Europe, a strong political commitment to environmental sustainability, supported by comprehensive policies like the European Green Deal, drives the integration of CE practices. Wealthier economies with advanced healthcare infrastructure, like the UK and Denmark, have the resources to invest in CE innovations, aligning with regulatory frameworks. Interestingly, North America lags behind (19%) (e.g., Best &Williams, 2021; Kane et al., 2018; Kheirabadi & Sheikhi, 2022; MacNeill et al., 2020) due to its lack of cohesive federal regulations (mainly in the United States) and decentralised (fragmented and often privatised) health care system that focus on cost control over long-term sustainability slow progress in this area.

Asia contributes 21% of the geographical focus (e.g., Chew et al., 2023; Ranjbari et al., 2022; Singh et al., 2022;). Environmental pressures, government policies, and technological advancements drive Asia's strong performance in CE healthcare research. Rapid industrialisation and population growth have spurred the need for sustainable solutions, leading countries like China and India to integrate CE into national agendas. Additionally, the region's adoption of I4.0 technologies enhances resource optimisation and waste reduction in healthcare. Taiwan's Chi Mei Medical Centre, for example, uses AI copilots to reduce waste and streamline patient care, highlighting how CE practices are being effectively applied to address healthcare challenges such as worker shortages and rising patient demands (Yee, 2024). Asia's varying levels of healthcare infrastructure provide fertile ground for research addressing region-specific challenges and innovative CE practices in healthcare systems.

In contrast, countries in South America (mainly Brazil, which represents 4%, e.g., Cobra et al., 2023; Daú et al., 2019; Ferronato et al., 2020) face socioeconomic and political challenges that hinder the widespread adoption of CE. Here, governments may prioritise immediate healthcare needs over long-term sustainability goals, resulting in slower implementation of CE practices. The 23% of studies without a specific geographic focus (e.g., Ali &Kannan, 2022; Chauhan et al., 2021; Kumar et al., 2021) is indicative of the global relevance of CE but also highlights the need for more regionally focused research to understand how local regulations and infrastructure influence the successful implementation of CE in healthcare systems.

**Challenges and opportunities in implementing circular economy practices in healthcare**

The content analysis reveals both positive developments and areas of concern. Healthcare waste management accounts for 39% of the focus (Chew et al., 2023; Dihan et al., 2023; Singh et al., 2023), while treatment strategies cover 24% (Kheirabadi & Sheikhi, 2022; Kumar et al., 2021; Ugandar et al., 2023), compared to waste prevention strategies, which only represent 15% (Ferronato et al., 2020; Ranjbari et al., 2023). This imbalance indicates that healthcare remains a 'post-waste' industry, where more attention is placed on managing waste after its creation rather than preventing it from being generated in the first place—a pattern that the bibliometric coupling analysis identified as well. This reactive approach reveals a lingering gap in the HC industry's structural thinking. This was also reflected in our keywords analysis in section 3.1 as the reduction of single-use care items and optimised delivery emerged as dominant research themes.

Healthcare providers' use of risk-free disposable healthcare materials (e.g., syringes, gloves, and sterile wraps) instead of reusable ones (Saha, 2024 a; Ünal et al., 2019) conflicts with the CE principles due to the excessive consumption of these fleeting articles (Leissner & Ryan-Fogarty, 2019; Ramos et al., 2023b). Additionally, this non-recyclable and hazardous medical waste needs advanced, efficient and expensive disposal systems (Kandasamy et al., 2022; Singh et al., 2022) unavailable to many. Although sustainable healthcare product design (again to reduce single-use culture) still captures the most share of research output at 44% (Chauhan et al., 2021; Hunfeld et al., 2023; MacNeill et al., 2020), there is a significant difference between designing a product to fit in the circular economy (43%) (Ranjbari et al., 2022; Van Straten et al., 2021; Voudrias, 2018) and reclaiming or recycling a product's resources (1%) (Ali &Geng, 2018). This indicates an underdeveloped focus on the post-consumer phase of medical devices, which is crucial for achieving a fully circular model.

Healthcare delivery could improve by prioritising upstream strategies, such as adopting new technologies or materials to eliminate waste at its source. While new treatment techniques and waste minimisation strategies are emerging, much of the research still needs to be connected to broader CE

frameworks, particularly regarding resource recovery and closed-loop systems. Therefore, adopting more circular models in this industry is often considered impractical or unsuitable due to its results-driven nature (Ayanaw et al., 2023). Moreover, significant investment is required to address systemic and supply chain issues that arise with the introduction of CE practices (Bressanelli et al., 2019; Vishwakarma et al., 2024).

Furthermore, the limited research on economic and policy frameworks (16%) (Hatzivasilis et al., 2019; Van Boerdonk et al., 2021; Viegas et al., 2019), especially regulatory challenges (4%) (Best and Williams, 2021; Dukić et al., 2013; Ezeudu et al., 2022), suggests that the CE paradigm in healthcare remains less feasible without stronger regulatory backing. Among the practical issues, such regulatory challenges are the most critical (Kandasamy et al., 2022). Medical devices, medicines, and other health-related products are produced under strict safety and efficacy requirements. This makes reusing, reconfiguring or recycling these products more difficult than in other industries (Kane et al., 2018). The lack of emphasis on education and stakeholder engagement (1%) (Soares et al., 2023b) raises questions about the practical effectiveness of CE frameworks in this sector. This gap was similarly highlighted in the bibliometric coupling analysis, particularly within Cluster 4. Without targeted educational initiatives, healthcare workers' willingness to adopt environmentally friendly practices may remain theoretical, hindering the systemic change necessary for meaningful CE adoption in healthcare.

***Table 4. Core areas of future research in circular economy in the healthcare industry***

| Core Research themes | Key Contributions |
|---|---|
| **Sustainable Product Design**<br><br>Benedettini, 2022; Gaberščik et al., 2021; Ishaq et al., 2024; MacNeill et al., 2020; Syms et al., 2023 | Authors have focused on integrating CE principles into HC by advancing the design of reusable and recyclable medical devices. This research highlights the importance of extending product lifecycles to reduce waste and conserve raw materials, reducing HC's environmental footprint, and implementing circular strategies while maintaining safety standards. |
| **Healthcare Waste Management**<br><br>Kheirabadi and Sheikhi, 2022; Singh et al., 2022; Soares et al., 2023a; Ugandar et al., 2023; Zlaugotne et al., 2022) | Researchers in this field focus on reducing medical waste, promoting recycling and material reuse, and encouraging green purchasing. This body of work explores strategies for safely handling hazardous waste from end-of-life healthcare products, paving the way for innovative and regulatory frameworks. |
| **Economic and Policy Frameworks**<br><br>Ali and Kannan, 2022; Dukić et al., 2013; Van Boerdonk et al., 2021; Viegas et al., 2019 | Research on economic and policy frameworks shapes the operationalisation of CE principles within HC by addressing laws, incentives, and cost structures. This strand of research offers guidance to policymakers on implementing financial and regulatory measures that encourage the repair, reuse, and recycling of medical devices. |
| **Education and Stakeholder Engagement**<br><br>Saif-Ur-Rahman et al., 2019; Soares et al., 2023b | This area of research highlights the importance of stakeholder collaboration in fostering awareness and building the capacity of healthcare providers and other key actors to make informed decisions and adopt improved practices. Targeted educational efforts help stakeholders understand the principles of CE, including waste reduction, resource efficiency, and product stewardship. |

*Source: Author's analysis of reviewed literature*

A methodological critique of the reviewed literature reveals several limitations that undermine the reliability, generalizability, and comprehensiveness of current research. The predominance of qualitative approaches, which account for 69% of the studies (Figure 4), largely relies on case studies (Daú et al., 2019; Govindan et al., 2022; Ugandar et al., 2023; Van Boerdonk et al., 2021; Van Straten et al., 2021) and literature reviews (Chauhan et al., 2021; Kumar et al., 2021; MacNeill et al., 2020; Hatzivasilis et al., 2019; Kane et al., 2018; Viegas et al., 2019). While these methods provide valuable insights into specific contexts, they often lack the empirical validation required to apply their conclusions across diverse healthcare settings.

Furthermore, only 4% of the research employed quantitative survey-based methods (Gaberščik et al., 2021; Kandasamy et al., 2022; Soares et al., 2023b), which restricts the ability to derive statistically significant conclusions about CE practices in healthcare. This lack of methodological diversity hinders the development of robust theoretical models that could guide the large-scale implementation of CE practices. As a result, the practical application of these findings is constrained, making it difficult for policymakers and practitioners to adopt CE strategies confidently across varied healthcare systems. Without more generalisable and reliable research, the transition to CE in healthcare may face obstacles due to uncertainty in its broad effectiveness.

## 4. Discussion

Healthcare largely remains a 'post-waste' industry, although significant growth in CE research has taken place over the last ten years. In this section, we synthesise our findings on the present research landscape and inform future directions in CE adoption within healthcare.

Our SLR has established that prominent scholars such as Alnoor A., Kumar A., Govindan K., McGain F., and Boopathi S. are among the most cited authors in the field of circular economy practices within the healthcare sector. These authors have consistently focused on two critical domains: enhancing waste treatment methods and promoting the circularity of medical product design. Their work digs into strategies that support sustainable healthcare systems by reducing waste, improving material efficiency, and reimagining the lifecycle of medical products. Notably, their contributions are not limited to theoretical frameworks but also involve practical interventions that align healthcare operations with CE principles. This citation pattern reflects the growing scholarly consensus around the importance of integrating circular economy principles in healthcare to address environmental sustainability, cost efficiency, and resource optimisation.

In addition to identifying key authors, our bibliometric analysis also highlights a predominant geographical focus on Europe, particularly in the UK, Denmark, and the Netherlands. These countries

have shown a pronounced interest in exploring the barriers, enablers, and challenges associated with promoting a circular economy in healthcare systems. Research originating from these regions tends to concentrate on two primary themes: advanced waste treatment methods and the design for circularity in medical devices. These European countries are at the forefront of developing and implementing policy frameworks that incentivise circular practices within healthcare, often driven by stringent environmental regulations and a cultural commitment to sustainability. The focus on medical device circularity, for instance, is particularly relevant given the growing demand for high-performance, reusable medical technologies that can withstand rigorous sterilisation processes without compromising safety or functionality. Furthermore, the interest in advanced waste treatment indicates a recognition of the significant environmental footprint of healthcare waste, prompting efforts to not only reduce waste generation but also improve waste segregation, recycling, and energy recovery processes.

The results show that while 2021 publications focused on waste management to support CE, 2020 studies centred on healthcare policy. In 2022, the focus shifted to how the COVID-19 pandemic has influenced circular economy strategies. This progression highlights the evolving focus on practical CE applications in healthcare research, i.e. CE business models. The critical features of CE business models and various relevant players (e.g., providers of healthcare services, manufacturers of pharmaceuticals and medical devices, regulating authorities, waste management entities, suppliers of healthcare goods), and even patients and consumers. Such actors are essential to how CE is constructed in the context of the healthcare industry.

There are three common limitations, according to Snyder (2019), in review studies: (1) lack of methodological transparency, (2) restrictive literature searches, and (3) underutilisation of data. We meticulously documented each step of our review process to address these, enhancing clarity, replicability, and comprehensibility (Fan et al., 2022). We also expanded our literature search to include a more comprehensive range of reputable journals and focused on materials published in the last ten years to ensure that our review remains highly applicable to the current healthcare landscape and addresses the sector's immediate challenges and opportunities.

Our methodology combined bibliometric and content analysis. The bibliometric phase mapped key themes and influential authors, informing the content analysis and allowing for a deeper qualitative interpretation of theoretical and practical implications. This iterative process between methods ensured transparency and reinforced the reliability of our findings. For example, the identification of four critical areas: (1) sustainable product design, (2) healthcare waste management, (3) economic and policy frameworks, and (4) education and stakeholder engagement as emerging research themes

is broadly convergent with recent publications in CE and healthcare (e.g., Ranjbari et al., 2022, 2023; Saha et al. 2024a, b, c).

**Translating CE Research Themes into Practice**

**Sustainable product design** has the potential to transform the healthcare sector from its current reliance on reactive waste management to a proactive model focused on waste prevention, directly addressing Step 1. For instance, companies like Philips have pioneered modular and reusable medical devices, such as MRI systems for refurbishment and extended lifecycles. In developing countries like India, companies such as Sahajanand Medical Technologies[2] have started manufacturing reusable stents and other medical devices to improve affordability and sustainability. For healthcare practitioners, adopting reusable devices hinges on establishing clear regulatory frameworks to address patient safety concerns and compatibility with existing health systems. Collaborative efforts between local manufacturers, healthcare providers, and policymakers are essential to create certification systems for circular medical products, ensuring safety, affordability, and environmental impact mitigation.

In **healthcare waste management**, there is a need for more advanced techniques to reduce, reuse, and recycle complex medical waste, particularly hazardous materials, to align with Step 2: resource recovery and reuse. For instance, adopting advanced waste treatment technologies, such as pyrolysis or plasma arc systems (Kaldas et al., 2006), could help healthcare systems align with CE principles while mitigating environmental risks. To support widespread adoption, regulators and health services should build on existing frameworks, such as the EU's Waste Framework Directive[3] or NHS UK's circular procurement initiative (NHS, 2024) for standardised guidelines for hazardous waste recycling. These guidelines could include clear protocols for material recovery, safe handling procedures, and integrating sustainability criteria into procurement contracts, further incentivised through tax benefits or subsidies.

**Economic and policy frameworks** (e.g., circular procurement guidelines and economic incentives) address the regulatory and financial mechanisms necessary to act as enablers for Step 3: building systemic resilience. However, the relative underrepresentation of this theme in the literature accentuates the need for more robust institutional and policy-driven interventions to advance CE practices. A compelling example of such an intervention is Scotland's implementation of CE principles within its health services, leveraging I4.0 technologies (CivTech, 2024). Scotland's efforts focus on

[2] https://smtpl.com/carbon_reduction_plan
[3] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

reducing single-use items, increasing the reuse and remanufacturing of medical supplies, and adopting circular supply chain models to keep products in use for longer.

To replicate Scotland's success in other regions, tailored policies are essential to address localised challenges. Within the UK, adopting a unified strategy across devolved healthcare systems could deliver consistency and innovation. Internationally, regions with varying levels of regulatory development or technological infrastructure, as highlighted in our findings on geographic skewness, could adapt Scotland's approach to fit their unique contexts to leverage locally available resources and tailored policy frameworks. For example, high-income nations (e.g., the USA and Canada) could prioritise investment in advanced technologies, while resource-constrained regions (e.g., Latin America and Africa) might focus on low-cost modular designs and resource recovery systems.

Lastly, **education and stakeholder engagement** require further investigation. Corresponding to our findings, the importance of education and training in advancing environmentally sustainable practices in healthcare is evident across various sectors, such as clinical pharmacy (Saha et al., 2024a) and animal health (Saha et al., 2024b). Healthcare professionals (e.g., doctors, nurses, paramedics) are at the forefront of patient care. They can determine the judicious use of single-use items and other resources in healthcare settings, making them key players in adopting CE practices.

However, the integration of sustainability education into healthcare curricula remains inadequate. This is primarily due to the comprehensive nature of healthcare training, which often leaves limited room for the inclusion of topics like sustainability and CE. Junior healthcare staff, in particular, often lack early exposure to such sustainability methodologies, which creates a knowledge gap that hinders the practical implementation of waste reduction and CE practices. Even experienced professionals, despite formal training, face challenges in applying these principles due to limited resources and competing clinical priorities. The integration of sustainability education into healthcare training is essential to successfully implement Step 3.

**Exploring Pathways for Future Research in CE Healthcare**

Despite the evolution of research in CE practices, significant obstacles to their adoption remain, including challenges in product design, the complexity of waste management, cultural and behavioural resistance, and concerns around safety and hygiene. Furthermore, our methodological critique highlights how a lack of empirical validation and statistically significant findings limits the development of comprehensive theoretical models. This gap in evidence-based research constrains the practical application of CE practices, making it difficult for policymakers and practitioners to implement these strategies confidently across diverse healthcare systems.

Notably, research on economic and policy frameworks remains limited, with a focus primarily on business models and regulatory challenges, while the Education and Stakeholder Engagement theme is narrowly addressed, covering only training programmes. Future research on economic and policy frameworks should investigate the impact of policies such as the NHS's circular procurement initiative on supplier behaviour and waste management practices, with comparative analyses across countries to identify scalable policy models.

In this regard, two other promising areas are (1) the development of economic mechanisms—such as subsidies, tax incentives, and grants—that reduce cost barriers for small and medium-sized healthcare providers and (2) the examination of global regulatory harmonisation efforts, especially within the European Union, to standardise CE practices across borders for greater scalability and alignment in circular healthcare systems. Such harmonisation would provide a consistent framework that facilitates the operationalisation of circular supply chains, including reverse logistics systems for recovering and recycling medical devices. By aligning regulations and practices across regions, these efforts could be further supported by feasibility studies and cost-benefit analyses, ensuring that circular supply chains are not only circular but also economically viable and adaptable to diverse healthcare contexts.

For healthcare education programs, future research must focus on how sustainability concepts can be embedded into existing ones. Education researchers may develop pedagogical frameworks integrating sustainability education into healthcare curricula at all levels. This could include (1) designing targeted programs for early-career healthcare professionals to expose them to CE principles and environmentally sustainable practices from the outset of their training and (2) embedding continuous professional development in sustainability for experienced healthcare professionals to address the challenges they face in applying CE practices due to resource constraints and clinical priorities.

Furthermore, studies could assess the effectiveness and replicability of multi-stakeholder collaborations (e.g., Scotland's CivTech initiative) involving healthcare providers, policymakers, manufacturers, and NGOs in advancing CE practices. Patient and public engagement initiatives could complement such collaborations, as educational campaigns are crucial in shaping the acceptance of sustainable medical devices and other CE-oriented practices.

## 5. Conclusion

The intellectual structure of circular economy literature on the healthcare sector reveals a fragmented yet evolving field. This systematic review identified four dominant themes: healthcare waste management, sustainable product design, economic and policy frameworks, and education and

stakeholder engagement. While waste management and product design dominate the research landscape, reflecting the sector's focus on operational and technical challenges, economic and policy frameworks, education, and stakeholder engagement remain critically underexplored. This imbalance illuminates the need for a more integrative research and operational approach that bridges technical solutions (waste management and product design) with systemic enablers (policy, education and engagement) to drive genuine circularity in healthcare.

The current state of circular economy research in healthcare highlights a reliance on reactive waste management strategies, indicative of a 'post-waste' model. While advancements in recycling and green procurement reflect progress, proactive measures, such as modular product design and circular supply chains, are still in their infancy. Geographic skewness further complicates the landscape, with most research concentrated in Europe, particularly the UK, Denmark, and the Netherlands, while contributions from developing regions remain sparse. This regional disparity limits the global applicability of CE principles and calls for a more inclusive research agenda.

The healthcare sector is clearly ready to embrace CE initiatives, as evidenced by Scotland's NHS supply chain circularity initiatives and Taiwan's AI-driven healthcare innovations mentioned in this paper. These initiatives demonstrate that the healthcare sector is not only capable of adopting CE principles but is actively transitioning toward more sustainable practices. Policymakers can leverage these examples to establish region-specific policies, such as standardised waste management protocols and financial incentives for adopting modular and reusable medical devices. Embedding sustainability into healthcare pedagogy can further accelerate this progress by equipping future healthcare professionals with the knowledge and skills to implement CE principles effectively.

Our paper serves as a guide for this transition, as we hope.

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## Appendices

Appendix 1: Initial Sample Including 75 Documents from Scopus Database

| ID | Authors | Year | Source Title | Cited by | DOI | Language | Document Type | Publication Stage |
|---|---|---|---|---|---|---|---|---|
| 1 | Najar I.N.; Sharma P.; Das R.; Tamang S.; Mondal K.; Thakur N.; Gandhi S.G.; Kumar V. | 2024 | Journal of Environmental Management | 1 | 10.1016/j.jenvman.2024.121136 | English | Review | Final |
| 2 | Ahkola H.; Junttila V.; Kauppi S. | 2024 | Journal of Environmental Management | 0 | 10.1016/j.jenvman.2024.121362 | English | Article | Final |
| 3 | Vishwakarma A.; Dangayach G.S.; Meena M.L.; Gupta S.; Joshi D.; Jagtap S. | 2024 | Journal of Global Operations and Strategic Sourcing | 4 | 10.1108/JGOSS-07-2022-0084 | English | Article | Final |
| 4 | Ishaq S.; Hoang T.G.; Tanveer U.; Hoang T.-H.; Truong H.Q. | 2024 | Journal of Cleaner Production | 0 | 10.1016/j.jclepro.2024.141370 | English | Article | Final |
| 5 | Priyadarshini J.; Singh R.K.; Mishra R.; He Q.; Braganza A. | 2024 | Information Systems Frontiers | 1 | 10.1007/s10796-024-10482-1 | English | Article | Article in press |
| 6 | Cobra R.; Moroni I.T.; Rodrigues V.P.; Fradinho J.M.S.; Mascarenhas J. | 2023 | Health Policy and Technology | 2 | 10.1016/j.hlpt.2023.100778 | English | Article | Final |
| 7 | Ramos T.; Christensen T.B.; Oturai N.; Syberg K. | 2023 | Journal of Cleaner Production | 10 | 10.1016/j.jclepro.2022.135379 | English | Article | Final |
| 8 | Sittig D.F.; Sherman J.D.; Eckelman M.J.; Draper A.; Singh H. | 2022 | Journal of the American Medical Informatics Association | 8 | 10.1093/jamia/ocac137 | English | Review | Final |
| 9 | Ali I.; Kannan D. | 2022 | Annals of Operations Research | 44 | 10.1007/s10479-022-04596-5 | English | Article | Final |
| 10 | van Boerdonk P.J.M.; Krikke H.R.; Lambrechts W. | 2021 | Journal of Cleaner Production | 48 | 10.1016/j.jclepro.2020.125375 | English | Article | Final |

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|---|---|---|---|---|---|---|---|---|
| 11 | Chauhan A.; Jakhar S.K.; Chauhan C. | 2021 | Journal of Cleaner Production | 150 | 10.1016/j.jclepro.2020.123854 | English | Article | Final |
| 12 | Narang S.; Vij D. | 2021 | Asia Pacific Journal of Health Management | 2 | 10.24083/apjhm.v16i4.1305 | English | Article | Final |
| 13 | Shabani T.; Mutekwa V.T.; Shabani T. | 2024 | Circular Economy and Sustainability | 3 | 10.1007/s43615-023-00313-x | English | Article | Final |
| 14 | Ramos T.M.; Christensen T.B.; Bour A.; Almroth B.C.; Kristensen D.M.; Selck H.; Syberg K. | 2023 | TrAC - Trends in Analytical Chemistry | 3 | 10.1016/j.trac.2023.117191 | English | Review | Final |
| 15 | Association A.P.H. | 2023 | New Solutions | 3 | 10.1177/10482911231167166 | English | Article | Final |
| 16 | Mahjoob A.; Alfadhli Y.; Omachonu V. | 2023 | Sustainability (Switzerland) | 7 | 10.3390/su15107788 | English | Article | Final |
| 17 | Cook E.; Derks M.; Velis C.A. | 2023 | Science of the Total Environment | 4 | 10.1016/j.scitotenv.2022.160385 | English | Review | Final |
| 18 | Chen W.; Yang H.; Peng C.; Wu T. | 2023 | Environmental Science and Pollution Research | 9 | 10.1007/s11356-023-25167-6 | English | Article | Final |
| 19 | Soares A.L.; Buttigieg S.C.; Bak B.; McFadden S.; Hughes C.; McClure P.; Couto J.G.; Bravo I. | 2023 | International Journal of Health Policy and Management | 9 | 10.34172/ijhpm.2023.6947 | English | Review | Final |
| 20 | Ezeudu O.B.; Ezeudu T.S.; Ugochukwu U.C.; Tenebe I.T.; Ajogu A.P.; Nwadi U.V.; Ajaero C.C. | 2022 | Recycling | 7 | 10.3390/recycling7060087 | English | Review | Final |
| 21 | Syms R.; Taylor-Robinson S.D.; Trovato G. | 2023 | Risk Management and Healthcare Policy | 4 | 10.2147/RMHP.S396667 | English | Note | Final |
| 22 | Zlaugotne B.; Pubule J.; Gusca J.; Kalnins S.N. | 2022 | Environmental and Climate Technologies | 9 | 10.2478/rtuect-2022-0006 | English | Article | Final |
| 23 | Gaberščik C.; Mitchell S.; Fayne A. | 2021 | Smart Innovation, Systems and Technologies | 3 | 10.1007/978-981-15-8131-1_19 | English | Conference paper | Final |
| 24 | Fanta G.B.; Pretorius L.; Nunes B. | 2021 | Proceedings of the 30th International | 5 | 10.52202/060557-0085 | English | Conference paper | Final |

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| | | | Conference of the International Association for Management of Technology, IAMOT 2021 - MOT for the World of the Future | | | | | |
| 25 | Mariampillai J.; Rockall A. | 2023 | Radiologie | 10 | 10.1007/s00117-023-01189-6 | English | Review | Final |
| 26 | Ugandar R.E.; Rahamathunnisa U.; Sajithra S.; Christiana M.B.V.; Palai B.K.; Boopathi S. | 2023 | Applications of Synthetic Biology in Health, Energy, and Environment | 42 | 10.4018/978-1-6684-6577-6.ch015 | English | Book chapter | Final |
| 27 | Chu Y.T.; Zhou J.; Wang Y.; Liu Y.; Ren J. | 2023 | Energies | 4 | 10.3390/en16031074 | English | Review | Final |
| 28 | Soares A.L.; Buttigieg S.C.; Couto J.G.; Bak B.; McFadden S.; Hughes C.; McClure P.; Rodrigues J.; Bravo I. | 2023 | Radiography | 8 | 10.1016/j.radi.2022.12.006 | English | Article | Final |
| 29 | Ranjbari M.; Shams Esfandabadi Z.; Gautam S.; Ferraris A.; Scagnelli S.D. | 2023 | Gondwana Research | 47 | 10.1016/j.gr.2021.12.015 | English | Article | Final |
| 30 | Singh S.; Yadav R.; Singh A.N. | 2023 | Waste Management and Resource Recycling in the Developing World | 3 | 10.1016/B978-0-323-90463-6.00010-5 | English | Book chapter | Final |
| 31 | Sadhukhan J.; Sekar K. | 2022 | Energies | 3 | 10.3390/en15238974 | English | Article | Final |
| 32 | Hunfeld N.; Diehl J.C.; Timmermann M.; van Exter P.; Bouwens J.; Browne-Wilkinson S.; de Planque N.; Gommers D. | 2023 | Intensive Care Medicine | 23 | 10.1007/s00134-022-06940-6 | English | Article | Final |
| 33 | Kheirabadi S.; Sheikhi A. | 2022 | Current Opinion in Green and Sustainable Chemistry | 18 | 10.1016/j.cogsc.2022.100695 | English | Review | Final |

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|---|---|---|---|---|---|---|---|---|
| 34 | Sharma M.; Jain N.L.; Purohit J.K. | 2023 | Lecture Notes in Mechanical Engineering | 4 | 10.1007/978-981-19-6107-6_12 | English | Conference paper | Final |
| 35 | Abhilash; Inamdar I. | 2022 | Science of the Total Environment | 19 | 10.1016/j.scitotenv.2022.155895 | English | Review | Final |
| 36 | Chau C.; Paulillo A.; Ho J.; Bowen R.; La Porta A.; Lettieri P. | 2022 | Sustainable Production and Consumption | 8 | 10.1016/j.spc.2022.07.005 | English | Article | Final |
| 37 | Kumar A.; Chhabra D. | 2022 | Cleaner Engineering and Technology | 23 | 10.1016/j.clet.2022.100559 | English | Review | Final |
| 38 | Benedettini O. | 2022 | Sustainability (Switzerland) | 13 | 10.3390/su141912670 | English | Article | Final |
| 39 | Mallick P.K.; Salling K.B.; Pigosso D.C.A.; McAloone T.C. | 2022 | Journal of Diabetes Science and Technology | 6 | 10.1177/19322968221088329 | English | Article | Final |
| 40 | Patil A.; Madaan J.; Shardeo V.; Charan P.; Dwivedi A. | 2022 | International Journal of Logistics Management | 12 | 10.1108/IJLM-11-2020-0425 | English | Article | Final |
| 41 | Best S.; Williams S.J. | 2021 | Frontiers in Public Health | 17 | 10.3389/fpubh.2021.765501 | English | Review | Final |
| 42 | Singh N.; Ogunseitan O.A.; Tang Y. | 2022 | Critical Reviews in Environmental Science and Technology | 93 | 10.1080/10643389.2021.1885325 | English | Review | Final |
| 43 | Wandji C.; Rejeb H.B.; Zwolinski P. | 2022 | Procedia CIRP | 3 | 10.1016/j.procir.2022.02.009 | English | Conference paper | Final |
| 44 | Ritchie N.H. | 2021 | Healthcare Management Forum | 5 | 10.1177/08404704211003610 | English | Article | Final |
| 45 | Kumar N.M.; Mohammed M.A.; Abdulkareem K.H.; Damasevicius R.; Mostafa S.A.; Maashi M.S.; Chopra S.S. | 2021 | Process Safety and Environmental Protection | 55 | 10.1016/j.psep.2021.06.026 | English | Article | Final |
| 46 | Harding C.; Van Loon J.; Moons I.; De Win G.; Bois E.D. | 2021 | Sustainability (Switzerland) | 20 | 10.3390/su13042207 | English | Article | Final |
| 47 | Mekonnen B.A.; Aragaw T.A. | 2021 | Environmental Footprints and Eco-Design of | 19 | 10.1007/978-981-16-3860-2_5 | English | Book chapter | Final |

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| | | | Products and Processes | | | | | |
| 48 | Meissner M.; Lichtnegger S.; Gibson S.; Saunders R. | 2021 | Risk Management and Healthcare Policy | 11 | 10.2147/RMHP.S325017 | English | Article | Final |
| 49 | Duane B.; Stancliffe R.; Miller F.A.; Sherman J.; Pasdeki-Clewer E. | 2020 | Journal of Dental Research | 30 | 10.1177/0022034520919391 | English | Article | Final |
| 50 | Macneill A.J.; Hopf H.; Khanuja A.; Alizamir S.; Bilec M.; Eckelman M.J.; Hernandez L.; McGain F.; Simonsen K.; Thiel C.; Young S.; Lagasse R.; Sherman J.D. | 2020 | Health Affairs | 121 | 10.1377/hlthaff.2020.01118 | English | Article | Final |
| 51 | Hatzivasilis G.; Soultatos O.; Ioannidis S.; Verikoukis C.; Demetriou G.; Tsatsoulis C. | 2019 | Proceedings - 15th Annual International Conference on Distributed Computing in Sensor Systems, DCOSS 2019 | 129 | 10.1109/DCOSS.2019.00091 | English | Conference paper | Final |
| 52 | Viegas C.V.; Bond A.; Vaz C.R.; Bertolo R.J. | 2019 | Journal of Cleaner Production | 54 | 10.1016/j.jclepro.2019.117719 | English | Review | Final |
| 53 | Daú G.; Scavarda A.; Scavarda L.F.; Portugal V.J.T. | 2019 | Sustainability (Switzerland) | 109 | 10.3390/su11123259 | English | Article | Final |
| 54 | Kane G.M.; Bakker C.A.; Balkenende A.R. | 2018 | Resources, Conservation and Recycling | 109 | 10.1016/j.resconrec.2017.07.030 | English | Article | Final |
| 55 | Ali M.; Geng Y. | 2018 | Environmental Monitoring and Assessment | 12 | 10.1007/s10661-018-7063-y | English | Article | Final |
| 56 | Alexaki S.; Alexandris G.; Katos V.; Nikolaos Petroulakis E. | 2018 | IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and | 29 | 10.1109/CAMAD.2018.8514954 | English | Conference paper | Final |

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|---|---|---|---|---|---|---|---|---|
| | | | Networks, CAMAD | | | | | |
| 57 | Viani C.; Vaccari M.; Tudor T. | 2016 | Resources, Conservation and Recycling | 18 | 10.1016/j.resconrec.2016.03.025 | English | Article | Final |
| 58 | Govindan, K., Nosrati-Abarghooee, S., Nasiri, M.M. and Jolai, F. | 2022 | Journal of Environmental Management | 37 | 10.1016/j.jenvman.2022.115888 | English | Article | Final |
| 59 | Haber, N. and Fargnoli, M. | 2021 | Sustainability | 27 | 10.3390/su13126624 | English | Article | Final |
| 60 | Jafarzadeh Ghoushchi, S., Memarpour Ghiaci, A., Rahnamay Bonab, S. and Ranjbarzadeh, R | 2022 | Environmental science and pollution research | 26 | 10.1007/s11356-022-19018-z | English | Article | Final |
| 61 | Kandasamy, J., Kinare, Y.P., Pawar, M.T., Majumdar, A., KEK, V. and Agrawal, R. | 2022 | Sustainable Development | 16 | 10.1002/sd.2293 | English | Article | Final |
| 62 | Dolatabad A.H.; Mahdiraji H.A.; Babgohari A.Z.; Garza-Reyes J.A.; Ai A. | 2022 | Environment, Development and Sustainability | 18 | 10.1007/s10668-022-02535-9 | English | Article | Article in press |
| 63 | Dukić N.; Blecich A.A.; Cerović L. | 2013 | Economic Research-Ekonomska Istrazivanja | 9 | 10.1080/1331677X.2013.11517643 | English | Article | Final |
| 64 | Martin N.; Mulligan S.; Fuzesi P.; Hatton P.V. | 2022 | Journal of Dentistry | 9 | 10.1016/j.jdent.2022.103948 | English | Article | Final |
| 65 | Saber D.A.; Aziza R.; Dreyer S.; Sanford D.; Nadeau H. | 2022 | Online Journal of Issues in Nursing | 6 | 10.3912/OJIN.Vol27No02PPT33 | English | Article | Final |
| 66 | Meister J.A.; Sharp J.; Wang Y.; Nguyen K.A. | 2023 | Processes | 4 | 10.3390/pr11010036 | English | Article | Final |
| 67 | Chew X.Y.; Khaw K.W.; Alnoor A.; Ferasso M.; Al Halbusi H.; Muhsen Y.R. | 2023 | Environmental Science and Pollution Research | 47 | 10.1007/s11356-023-26677-z | English | Article | Final |

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|---|---|---|---|---|---|---|---|---|
| 68 | Dihan M.R.; Abu Nayeem S.M.; Roy H.; Islam M.S.; Islam A.; Alsukaibi A.K.D.; Awual M.R. | 2023 | Science of the Total Environment | 37 | 10.1016/j.scitotenv.2023.162083 | English | Review | Final |
| 69 | Ranjbari M.; Shams Esfandabadi Z.; Shevchenko T.; Chassagnon-Haned N.; Peng W.; Tabatabaei M.; Aghbashlo M. | 2022 | Journal of Hazardous Materials | 84 | 10.1016/j.jhazmat.2021.126724 | English | Article | Final |
| 70 | Kazançoğlu Y.; Sağnak M.; Lafcı Ç.; Luthra S.; Kumar A.; Taçoğlu C. | 2021 | International Journal of Environmental Research and Public Health | 22 | 10.3390/ijerph18147513 | English | Article | Final |
| 71 | van Straten B.; Dankelman J.; van der Eijk A.; Horeman T. | 2021 | Sustainable Production and Consumption | 51 | 10.1016/j.spc.2020.10.030 | English | Article | Final |
| 72 | Wright C.Y.; Godfrey L.; Armiento G.; Haywood L.K.; Inglesi-Lotz R.; Lyne K.; Schwerdtle P.N. | 2019 | Globalization and Health | 38 | 10.1186/s12992-019-0501-y | English | Review | Final |
| 73 | Leissner S.; Ryan-Fogarty Y. | 2019 | Resources, Conservation and Recycling | 38 | 10.1016/j.resconrec.2019.104462 | English | Article | Final |
| 74 | Ferronato N.; Ragazzi M.; Torrez Elias M.S.; Gorritty Portillo M.A.; Guisbert Lizarazu E.G.; Torretta V. | 2020 | Waste Management and Research | 20 | 10.1177/0734242X19883690 | English | Article | Final |
| 75 | Voudrias E.A. | 2018 | Waste Management | 50 | 10.1016/j.wasman.2018.04.020 | English | Editorial | Final |
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## Appendix 2 Article Relevance Criteria and coding schema for content analysis

Categorisation process:

[Score: Low=1, Medium=2, High=3 for each RQs]; Agreed Total Score: High ≥ 7, Medium= 4-6, Low < 4

| ID | Articles for content analysis | Preliminary Assessment (abstract reading) | Detailed Review | C1 Score | C2 Score | C3 Score | Total Score | Relevance Category | Thematic scope | Subthematic scope | Geographic scope | Geographic scope (Country) | Methodological approach | Sub-methodological approach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Abhilash and Inamdar (2022) | Pass, conduct detailed review | Conduct scoring | 1 | 2 | 2 | 5 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Not Specified | Not Specified | Qualitative | literature review |
| 2 | Ahkola et al. (2024) | Pass, conduct detailed review | Conduct scoring | 2 | 2 | 1 | 5 | Medium | Healthcare Waste Management | Waste Minimization Techniques | Europe | Finland | Qualitative | literature review |
| 3 | Alexaki et al. (2018) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | Cyprus | Theoretical | conceptframeworks |
| 4 | Ali and Geng (2018) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Resource Recovery and Recycling | Asia | Pakistan | Qualitative | case studies |
| 5 | Ali and Kannan (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Economic and Policy Frameworks | Circular Economy Business Models | Not Specified | Not Specified | Theoretical | systematic literature review |
| 6 | American Public Health Association (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Healthcare Waste Management | Waste Minimization Techniques | North America | United States | Theoretical | systematic literature review |
| 7 | Benedettini (2022) | Pass, conduct | Conduct | 3 | 3 | 3 | 9 | High | Sustainable Produ | Design for Circula | North America | United States | Qualitative | interviews |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | detailed review | scoring | | | | | | ct or Procedure Design | rity in Medical Products | | | | |
| 8 | Best and Williams (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Economic and Policy Frameworks | Regulatory and Policy Challenges | North America | United States | Theoretical | systematic literature review |
| 9 | Chau et al. (2022) | Pass, conduct detailed review | Conduct scoring | 1 | 2 | 1 | 4 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Europe | United Kingdom | Theoretical | systematic literature review |
| 10 | Chauhan et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Not Specified | Not Specified | Qualitative | literature review |
| 11 | Chen et al. (2023) | Pass, conduct detailed review | Conduct scoring | 2 | 2 | 2 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Not Specified | Not Specified | Qualitative | literature review |
| 12 | Chew et al. (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | Iraq | Qualitative | literature review |
| 13 | Chu et al. (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | China | Qualitative | literature review |
| 14 | Cobra et al. (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 3 | 8 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | South America | Brazil | Qualitative | case studies |
| 15 | Cook et al. (2023) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | China | Theoretical | systematic literature review |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Daú et al. (2019) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | South America | Brazil | Qualitative | case studies |
| 17 | Dihan et al. (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | Bangladesh | Qualitative | literature review |
| 18 | Dolatabad et al. (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Asia | Iran | Theoretical | systematic literature review |
| 19 | Duane et al. (2020) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | United Kingdom | Qualitative | literature review |
| 20 | Dukić et al. (2013) | Pass, conduct detailed review | Conduct scoring | 1 | 2 | 1 | 4 | Medium | Economic and Policy Frameworks | Regulatory and Policy Challenges | Europe | Croatia | Theoretical | systematic literature review |
| 21 | Ezeudu et al. (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Economic and Policy Frameworks | Regulatory and Policy Challenges | Africa | Nigeria | Qualitative | literature review |
| 22 | Fanta et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Not Specified | Not Specified | Theoretical | systematic literature review |
| 23 | Ferronato et al. (2020) | Pass, conduct detailed review | Conduct scoring | 1 | 3 | 1 | 5 | Medium | Healthcare Waste Management | Waste Minimization Techniques | South America | Bolivia | Qualitative | case studies |
| 24 | Gaberščik et | Pass, conduct | Conduct | 3 | 2 | 1 | 6 | Medium | Sustainable Produ | Design for Circula | Europe | Ireland | Quantitative | Survey |

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| | al. (2021) | detailed review | scoring | | | | | | ct or Procedure Design | rity in Medical Products | | | | |
| 25 | Govindan et al. (2022) | Pass, conduct detailed review | Conduct scoring | 1 | 3 | 1 | 5 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Not Specified | Not Specified | Qualitative | case studies |
| 26 | Haber and Fargnoli (2021) | Pass, conduct detailed review | Conduct scoring | 2 | 2 | 2 | 6 | Medium | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | European Countries | Qualitative | case studies |
| 27 | Harding et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Waste Minimization Techniques | North America | United States | Qualitative | case studies |
| 28 | Hatzivasilis et al. (2019) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Economic and Policy Frameworks | Circular Economy Business Models | Europe | European Countries | Qualitative | literature review |
| 29 | Hunfeld et al. (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | Netherlands | Qualitative | case studies |
| 30 | Ishaq et al. (2024) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | European Countries | Qualitative | case studies |
| 31 | Jafarzadeh Ghoushchi et al. (2022) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Asia | Iran | Qualitative | case studies |
| 32 | Kandasamy et al. (2022) | Pass, conduct detail | Conduct | 3 | 3 | 2 | 8 | High | Economic and Policy | Circular Economy | Asia | India | Quantitative | Survey |

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| | | ed review | scoring | | | | | | Frameworks | Business Models | | | | |
| 33 | Kane et al. (2018) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | North America | United States | Qualitative | literature review |
| 34 | Kazançoğlu et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Not Specified | Not Specified | Qualitative | literature review |
| 35 | Kheirabadi and Sheikhi (2022) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | North America | United States | Qualitative | literature review |
| 36 | Kumar and Chhabra (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Asia | India | Theoretical | systematic literature review |
| 37 | Kumar et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | Not Specified | Not Specified | Qualitative | literature review |
| 38 | Leissner and Ryan-Fogarty (2019) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | Irland | Qualitative | case studies |
| 39 | MacNeill et al. (2020) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | North America | United States | Qualitative | literature review |
| 40 | Mahjoob et al. (2023) | Pass, conduct detailed | Conduct scoring | 3 | 3 | 3 | 9 | High | Economic and Policy | Circular Economy Busine | Not Specified | Not Specified | Qualitative | literature review |

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| | | review | | | | | | | Frameworks | ss Models | | | | |
| 41 | Mallick et al. (2022) | Pass, conduct detailed review | Conduct scoring | 2 | 2 | 1 | 5 | Medium | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | Denmark | Qualitative | case studies |
| 42 | Mariampillai et al. (2023) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | North America | United States | Qualitative | literature review |
| 43 | Martin et al. (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Waste Minimization Techniques | Europe | United Kingdom | Qualitative | observational study approach |
| 44 | Meissner et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 1 | 6 | Medium | Healthcare Waste Management | Waste Minimization Techniques | North America | United States | Qualitative | case studies |
| 45 | Meister et al. (2022) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Europe | United Kingdom | Qualitative | case studies |
| 46 | Mekonnen and Aragaw (2021) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | North America | United States | Theoretical | systematic literature review |
| 47 | Najar et al. (2024) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | Not Specified | Not Specified | Qualitative | Literature Review |
| 48 | Narang and Vij (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Asia | India | Qualitative | literature review |

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| 49 | Patil et al. (2022) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 2 | 7 | High | Economic and Policy Frameworks | Circular Economy Business Models | Not Specified | Not Specified | Qualitative | case studies |
| 50 | Priyadarshini et al. (2024) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Not Specified | Not Specified | Qualitative | case studies |
| 51 | Ramos et al. (2023a) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | Denmark | Mixed | Qualitative and quantitative |
| 52 | Ramos et al. (2023b) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Healthcare Waste Management | Waste Minimization Techniques | North America | United States | Qualitative | literature review |
| 53 | Ranjbari et al. (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Asia | Iran | Theoretical | systematic litreture review |
| 54 | Ranjbari et al. (2023) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Waste Minimization Techniques | Not Specified | Not Specified | Theoretical | systematic literature review |
| 55 | Ritchie (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 1 | 7 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | North America | Canada | Qualitative | literature review |
| 56 | Saber et al. (2022) | Pass, conduct detailed review | Conduct scoring | 1 | 2 | 1 | 4 | Medium | Healthcare Waste Management | Waste Minimization Techniques | North America | United States | Qualitative | case studies |

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| 57 | Sadhukhan and Sekar (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Asia | China | Qualitative | literature review |
| 58 | Shabani et al. (2024) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Waste Minimization Techniques | Africa | Zimbabwe | Qualitative | case studies |
| 59 | Sharma et al. (2023) | Pass, conduct detailed review | Conduct scoring | 2 | 2 | 1 | 5 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | India | Qualitative | case studies |
| 60 | Singh et al. (2022) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | Pakistan | Theoretical | systematic literature review |
| 61 | Singh et al. (2023) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Not Specified | Not Specified | Theoretical | conceptframeworks |
| 62 | Sittig et al. (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | North America | United States | Theoretical | conceptframeworks |
| 63 | Soares et al. (2023a) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Waste Minimization Techniques | Not Specified | Not Specified | Qualitative | literature review |
| 64 | Soares et al. (2023b) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Education and Stakeholder Engagement | Training Programs for Healthcare Professionals | Europe | European Countries | Quantitative | Survey |
| 65 | Syms et al. (2023) | Pass, conduct detail | Conduct | 3 | 3 | 3 | 9 | High | Sustainable Product or | Design for Circularity in | Africa | Egypt | Qualitative | literature review |

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| | | ed review | scoring | | | | | | Procedure Design | Medical Products | | | | |
| 66 | Ugandar et al. (2023) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Healthcare Waste Management | Innovative Waste Treatment Methods | Asia | India | Qualitative | case studies |
| 67 | Van Boerdonk et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Economic and Policy Frameworks | Circular Economy Business Models | Not Specified | Not Specified | Qualitative | case studies |
| 68 | Van Straten et al. (2021) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 3 | 9 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | Netherlands | Qualitative | case studies |
| 69 | Viani et al. (2016) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 1 | 6 | Medium | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | United Kingdom | Qualitative | interviews |
| 70 | Viegas et al. (2019) | Pass, conduct detailed review | Conduct scoring | 2 | 2 | 2 | 6 | Medium | Economic and Policy Frameworks | Circular Economy Business Models | Europe | United Kingdom | Qualitative | literature review |
| 71 | Vishwakarma et al. (2024) | Pass, conduct detailed review | Conduct scoring | 3 | 2 | 2 | 7 | High | Economic and Policy Frameworks | Circular Economy Business Models | Asia | India | Theoretical | systematic literature review |
| 72 | Voudrias (2018) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 1 | 7 | High | Sustainable Product or Procedure Design | Design for Circularity in Medical Products | Europe | European Countries | Qualitative | literature review |
| 73 | Wandji et al. (2022) | Pass, conduct detail | Conduct | 1 | 2 | 1 | 4 | Medium | Sustainable Product or | Design for Circularity in | Not Specified | Not Specified | Theoretical | systematic literatu |

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| | | ed review | scoring | | | | | | Procedure Design | Medical Products | | | | re review |
| 74 | Wright et al. (2019) | Pass, conduct detailed review | Conduct scoring | 2 | 3 | 2 | 7 | High | Economic and Policy Frameworks | Circular Economy Business Models | Africa | Mozambique | Qualitative | literature review |
| 75 | Zlaugotne et al. (2022) | Pass, conduct detailed review | Conduct scoring | 3 | 3 | 2 | 8 | High | Healthcare Waste Management | Innovative Waste Treatment Methods | Europe | European Countries | Theoretical | systematic literature review |