



ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

GREEN TECHNOLOGIES IN HEALTHCARE: A BIBLIOMETRIC ANALYSIS

SAĞLIK HİZMETLERİNDE YEŞİL TEKNOLOJİLER: BİBLİYOMETRİK BİR ANALİZ

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ABSTRACT

Green technologies in the health care sector offer the potential to improve the environmental sustainability and the quality of patient care. This study presents a bibliometric analysis of research on green technologies in healthcare. It aims to identify trends in the literature, key researchers and influential publications. The analysis included articles published between 2000 and 2023. The data was collected using the Web of Science and Scopus databases. The bibliometric analysis provides an important resource for understanding the current state of the literature and future research directions in the field of green technologies in health. It is of particular interest that green technologies have little relation to artificial intelligence, which is a popular research topic today. The spread of more sustainable and environmentally friendly practices in the health sector will benefit from increased interest and research activity in this area.

Keywords: Green-tech, Healthcare, Bibliometric Analysis

JEL Classification Codes: J1, I10, J11

ÖZ

Sağlık sektöründeki yeşil teknolojiler, çevresel sürdürülebilirliği ve hasta bakım kalitesini artırma potansiyeli sunmaktadır. Bu çalışma, sağlık hizmetlerinde yeşil teknolojiler üzerine yapılan araştırmaların bibliyometrik bir analizini sunmaktadır. Literatürdeki eğilimleri, kilit araştırmacıları ve etkili yayınları belirlemeyi amaçlamaktadır. Analiz, 2000 ile 2023 yılları arasında yayınlanan makaleleri içermektedir. Veriler Web of Science ve Scopus veri tabanları kullanılarak toplanmıştır. Bibliyometrik analiz, literatürün mevcut durumunu ve sağlıkta yeşil teknolojiler alanında gelecekteki araştırma yönlerini anlamak için önemli bir kaynak sağlamaktadır. Yeşil teknolojilerin günümüzde popüler bir araştırma konusu olan yapay zeka ile çok az ilişkisi olması özellikle ilgi çekicidir. Sağlık sektöründe daha sürdürülebilir ve çevre dostu uygulamaların yaygınlaşması, bu alanda artan ilgi ve araştırma faaliyetlerinden fayda sağlayacaktır.

Anahtar Kelimeler: Yeşil Teknoloji, Sağlık Hizmeti, Bibliyometrik Analiz

JEL Sınıflandırma Kodları: J1, I10, J11.

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GENİŞLETİLMİŞ ÖZET

Amaç ve Kapsam:

Bu çalışmanın amacı sağlık sektöründe yeşil teknolojilerin mevcut durumunu, uygulamalarını ve potansiyel faydalarını kapsamlı bir şekilde analiz etmektir. Sağlık sektörü, yüksek enerji tüketimi, atık üretimi ve kaynak yoğunluğu nedeniyle önemli bir çevresel etkiye sahiptir. Bu nedenle, sektörün çevresel ayak izini azaltmak için sürdürülebilir uygulamalara doğru ilerleme ihtiyacı artmaktadır. Yeşil teknolojilerin benimsenmesi, sağlık sektörünün karbon ayak izini azaltmak, enerji verimliliğini artırmak ve kaynak kullanımını optimize etmek için önemli bir potansiyele sahiptir. Bu çalışma, bu teknolojilerin sağlık sektöründe nasıl kullanılabileceğini ve sağlık hizmetleri üzerinde olabilecek olumlu etkileri göstermeyi amaçlamaktadır. Ayrıca, yeşil teknolojilerin yayılmasını engelleyen mevcut zorlukları ele almak ve bu engellerin üstesinden gelmek için çözümler önermektedir. Bu çalışma, 2000 ile 2023 yılları arasında yayınlanmış bilimsel yayınları inceleyerek sağlık sektöründe yeşil teknolojiler hakkındaki literatürün kapsamlı bir bibliyometrik analizini sunmaktadır. Web of Science ve Scopus gibi kapsamlı akademik veri tabanlarındaki yayınlara odaklanarak, çalışma sağlık sektöründe sürdürülebilir teknoloji uygulamaları, enerji verimliliği, atık yönetimi, yeşil bina standartları gibi konularda öne çıkan araştırma temalarını, kilit araştırmacıları ve etkili yayınları belirlemektedir. Ayrıca yeşil sağlık teknolojilerinin en yoğun şekilde araştırıldığı ülkeler ve bu ülkelerdeki bilimsel iş birliği ağları da incelendi. Çalışma, sağlık sektöründe yeşil teknolojilerin benimsenmesini destekleyen faktörlerin yanı sıra bunların yaygınlaşmasının önündeki engellere odaklanıyor.

Yöntem:

Bu çalışmada, sağlık sektörü ve yeşil teknoloji ile ilgili bilimsel yayınlar Web of Science (WoS) ve Scopus veri tabanları kullanılarak derinlemesine analiz edilmiştir. Bu veri tabanları kapsamlı içerikleri ve güvenilir atıf indekslemesi sayesinde bibliyometrik çalışmalarda sıklıkla tercih edilmektedir. Yayınlar “yeşil teknoloji”, “sürdürülebilir teknoloji”, “sağlık”, “tıbbi teknoloji” ve “çevre sağlığı” gibi anahtar kelimeler kullanılarak filtrelenmiştir. Dahil edilen yayınların İngilizce olması ve sağlık sektöründe yeşil teknolojilerin uygulanmasını ele alması gerekiyordu. Veri işleme sırasında öncelikle WoS ve Scopus veri tabanlarının yerleşik fonksiyonları kullanılarak tekrarlanan kayıtlar elenmiştir. Ardından seçilen yayınların başlıkları ve özetleri incelenmiş ve araştırma konusu ile uyumlu olanlar belirlenmiştir. Bu filtreleme işleminin ardından yazar adları, yayın yılı, dergi adı, anahtar kelimeler ve atıf sayıları gibi bibliyometrik veriler standart bir formatta dışarı aktarılmıştır. Bibliyometrik analizde bilimsel haritalama çalışmaları 'Bibliometrix' R paketi kullanılarak gerçekleştirilmiştir. Bu yazılım, yayın sayısı, en çok atıf alan yazarlar ve en etkili dergiler gibi temel bibliyometrik göstergeleri hesaplayarak araştırma alanına genel bir bakış sağlar. Yazarlar ve kurumlar arasındaki iş birliği ağlarını analiz ederek, çalışma sağlık sektöründe yeşil teknoloji üzerine araştırma yapan temel aktörleri ve iş birliği kümelerini ortaya koymaktadır. Ayrıca, anahtar kelime ilişkilerini görselleştirmek için anahtar kelime analizi ve tematik analiz yürütülmüştür. Bu analiz, temel konuların sıklığını ve aralarındaki bağlantıları anlamak için veri sağlamıştır. Atıf analizi, h-indeksi, toplam atıf sayısı ve makale başına ortalama atıf gibi metrikleri hesaba katarak yayınların etkisini değerlendirmek için kullanılmıştır. Çalışma yalnızca kamuya açık bilimsel literatüre dayandığından etik onay gerekmemiştir. Hiçbir insan denek veya kişisel veri kullanılmadığından, çalışma tamamen bilimsel yayınların analizine dayanmaktadır.

Bulgular:

Bu çalışmanın bulguları, 2000-2023 yılları arasında sağlık sektöründe yeşil teknoloji üzerine yapılan araştırmaların eğilimlerini ve temel temalarını kapsamlı bir şekilde ortaya koymaktadır. Analiz edilen verilere göre son yirmi üç yılda yeşil teknoloji alanında sağlık sektörü ile ilgili çalışma sayısında önemli bir artış olmuştur. Özellikle 2020 yılından itibaren bu alanda yayın sayısında önemli bir artış olmuş olup, COVID-19 pandemisinden sonra çevresel sürdürülebilirliğe olan ilginin bu artışa katkıda bulunduğu anlaşılmaktadır. Bu durum, çevresel sürdürülebilirlik ve enerji verimliliği gibi konuların sağlık sektöründe giderek daha önemli hale geldiğini göstermektedir. Çalışmada analiz edilen yayınlarda en sık kullanılan anahtar kelimeler arasında “enerji verimliliği”, “sürdürülebilir sağlık yönetimi”, “yeşil bina teknolojileri” ve “atık yönetimi” yer almaktadır. Anahtar kelime analizine göre enerji verimli veri merkezlerinin kullanımı, hastanelerde çevre dostu malzemelerin tercih edilmesi ve yeşil binaların sağlık tesislerine entegrasyonu gibi temalar ön plana çıkmaktadır. Bu temalar, sağlık hizmetlerinin çevre üzerindeki olumsuz etkisini azaltmak için yenilikçi girişimlerin önemini vurgulamakta ve sağlık sektöründe sürdürülebilir çözümler sunmak için yeşil teknolojilerin potansiyelini göstermektedir.

Sonuç ve Tartışma:

Bu çalışma, bibliyometrik analiz yoluyla sağlık sektöründeki yeşil teknolojilerin çevresel sürdürülebilirliği ve hasta bakımının kalitesini iyileştirme potansiyelini incelemektedir. Bulgular, son yıllarda yeşil teknolojilere olan ilginin hızla arttığını, enerji verimliliği, atık yönetimi ve yeşil bina standartlarının önemli araştırma konuları olarak ortaya çıktığını göstermektedir. Araştırma ayrıca ABD, Çin, İtalya ve Avrupa ülkelerinin yeşil sağlık teknolojileri alanında güçlü işbirlikleri geliştirdiğini ve bu işbirliklerinin küresel düzeyde sürdürülebilir çözümler üretmede kritik bir role sahip olduğunu ortaya koymaktadır. Bu bulgular sağlık sektöründe yeşil teknolojilerin benimsenmesinin önemini vurgularken, yeşil uygulamaların yapay zeka gibi yenilikçi teknolojilerle entegrasyonunun sınırlı olduğunu göstermektedir. Bu, yeşil sağlık teknolojilerinde inovasyonu artırmak ve çevresel etkileri en aza indirmek için yapay zeka ve büyük veri gibi alanlarda daha fazla araştırma yapılması gerektiğine işaret etmektedir. Çalışma, politika yapıcılar ve sağlık sektörü yöneticileri için sağlıkta yeşil teknolojinin kullanımı için stratejik bir yol haritası sunarken, gelecekteki araştırmalar için yeni fırsatları ve araştırma boşluklarını aydınlatmaktadır.

1. INTRODUCTION

The term ‘green Information and Communication Technologies (ICTs) in health’ refers to the utilization of cutting-edge, environmentally-friendly technologies and applications with the objective of enhancing health and well-being (Jiang, Chang & Shahzad, 2022). This concept is more than just an abstract definition; rather, it is an analytical construct that can be more readily comprehended through the use of tangible examples. For instance, telemedicine, which enables patients to receive remote medical care via video conferencing, telephone calls, or messaging, not only reduces the necessity for in-person visits but also reduces carbon emissions from transportation (Purohit, Smith & Hibble, 2021). Another illustrative example is the utilisation of renewable energy sources, such as solar or wind energy, to provide the energy requirements for healthcare facilities. The utilisation of renewable energy sources not only reduces carbon emissions but also results in a reduction in energy costs. Moreover, green buildings constructed with energy-efficient designs can improve indoor air quality and reduce energy consumption in healthcare facilities (Karimi et al., 2023).

The healthcare sector represents a substantial contributor to greenhouse gas emissions. In light of this and the growing need to implement green technologies in order to reduce the sector's carbon footprint, it has become increasingly important to adopt these technologies. The adoption of green technologies in healthcare plays a crucial role in achieving sustainable development goals and reducing the environmental impact of the healthcare sector (Eckelman et al., 2020; Malik et. al., 2018; Pichler et al., 2019).

The utilisation of green technology in healthcare has the potential to significantly reduce the environmental impact of the sector while simultaneously improving patient outcomes (Sherman et al. 2020). Previous research has examined the utilisation of green technology in various facets of healthcare, encompassing energy efficiency, waste reduction, and sustainable building design (Hafez et al. 2023). In summary, green technologies in healthcare have the potential to promote sustainability while improving patient outcomes (McGain & Naylor, 2014; Dion, Evans & Farrell, 2023; Doulabi, 2024).

The application of environmentally friendly techniques to healthcare could have a significant effect on reducing the environmental impact of the sector while improving patient outcomes (Eckelman & Sherman, 2016). However, there is a necessity for further investigation to fully comprehend the advantages and drawbacks of implementation (Holmner, Rocklöv & Nilsson, 2012). Despite a growing interest in green technology in healthcare, a lack of comprehensive research remains. In particular, there is a paucity of bibliometric analysis studies in this field. This study aims to address the existing knowledge gap by conducting a bibliometric analysis of the extant research on green technology in healthcare. Additionally, it aims to provide a detailed examination of the existing body of knowledge in the field of green technology in healthcare, with a view to identifying promising avenues for further inquiry

Theoretical background

The healthcare sector is a significant contributor to environmental degradation, largely due to its high energy consumption, extensive waste generation, and reliance on resource-intensive practices (Tee et al., 2024). As the healthcare sector continues to evolve, the potential of Green ICTs to reduce the environmental impact of healthcare operations has become increasingly evident. Previous research has investigated the utilization of green technology in various facets of healthcare, including energy efficiency, waste reduction and sustainable building design (Cimprich et al., 2019). Nevertheless, a comprehensive understanding of the current state of research in this area remains challenging.

The utilization of green technology in healthcare has the potential to significantly reduce the environmental impact of the sector while simultaneously improving patient outcomes (Taiwo et al., 2019). It has been observed that certain healthcare organizations have been able to significantly reduce their environmental footprint by implementing a range of straightforward, intelligent and sustainable measures. Conversely, the construction of green hospitals is a challenging endeavor due to the influence of local conditions and the rising expectations of patients. Furthermore, the energy- and resource-intensive utilization of increasingly sophisticated medical procedures, equipment and technologies has contributed to an intensification of the environmental footprint of healthcare. In-depth research in this area reveals that the following results are worthy of further analysis.

The number of academic publications on green technologies in health has risen dramatically in recent years. China, the United States of America and Italy have been identified as the countries that have made the most notable

contributions to this field. Nevertheless, global collaboration in this field remains constrained (Tan et al., 2021). The primary research foci encompass energy efficiency, sustainable healthcare management, and green building technologies. The research is concentrated on topics such as the reduction of greenhouse gas emissions, the implementation of energy-efficient data centers in hospitals, and the utilization of information and communication technologies to enhance sustainability (Godbole and Lamb, 2015).

It is evident that collaboration between researchers and institutions is crucial, yet there is still a need to strengthen this aspect. Institutions such as Universiti Teknologi Malaysia and the University of California System are expected to play a leading role in green technology research (Purnomo et al., 2022; Yin et al., 2018).

Recent research has concentrated on the integration of big data analytics, cloud computing and green innovation in healthcare. Future research is anticipated to delve more deeply into these areas, exploring innovative designs and technologies with the objective of further enhancing sustainability in healthcare systems (Wu & Junior, 2023), (Berniak-Woźny & Rataj, 2023). Significant obstacles include the necessity for enhanced international collaboration and the formulation of comprehensive policy frameworks to facilitate the implementation of sustainable practices. There is an opportunity to utilize emerging technologies and to build robust data-driven strategies with the aim of reducing the environmental impact of healthcare.

Revealed technology advantage (RTA)

The OECD Science, Technology and Industry Outlook (OECD, 2012) presents the main characteristics, strengths and weaknesses of national Science, Technology and Innovation (STI) systems and recent major changes in national STI policy in a series of country profiles. The statistical dimension of the country profiles has benefited from studies and empirical research conducted by the OECD on the development of internationally comparable STI indicators for the measurement of innovation and policy analysis. This multifaceted report presents an index of Revealed Technology Advantage (RTA) indicators, which are of great value for the study.

The RTA index serves as an indicator of a given country's relative specialization in selected technological fields. It is based on patent applications filed under the Patent Cooperation Treaty. The index is calculated as a country's share of patents in a particular technological field divided by that country's share in all patent fields. The index is equal to zero when the country has no patents in a given sector; equal to 1 when the country's share in the sector is equal to its share in all fields (no specialization); and above 1 when a positive specialization is observed. Only economies with more than 500 patents in the period under analysis are included. The data were sourced from the OECD Patent Database. The RTA ratios of OECD countries can be used to project the prevalence of green technologies in relation to green technologies in general and, indirectly, in relation to healthcare, which is heavily influenced by technological developments. Table 1 provides an indirect understanding of the capacities and importance of countries in relation to green ICTs.

Table 1. Environment-Related Technologies

	RTA in environment-related technologies		Share of patents filed by PRIs in environment-related technologies
	1997-1999	2007-2009	2005-2009
Australia	1,26	1,14	8,50
Austria	1,53	1,30	2,21
Belgium	0,75	0,79	5,60
Brazil	..	1,02	6,11
Canada	1,49	1,12	8,38
China	0,87	0,59	5,02
Czechia	..	1,27	9,09
Denmark	1,28	1,65	5,61
Finland	0,58	0,70	1,18
France	0,96	1,08	13,95
Germany	1,56	1,34	1,47

Hungary	..	1,45	0,38
India	..	0,70	11,19
Ireland	..	0,79	7,33
Israel	0,59	0,71	14,47
Italy	0,71	0,93	4,79
Japan	1,36	1,38	2,87
Korea	1,17	0,90	8,84
Mexico	..	0,88	6,67
Netherlands	1,10	0,97	2,18
New Zealand	0,84	0,90	0,00
Norway	1,24	1,48	1,99
Poland	..	1,35	6,57
Russian Federation	1,51	1,08	0,39
South Africa	1,06	0,85	11,76
Spain	1,06	1,20	12,60
Sweden	0,90	0,85	0,00
Switzerland	0,73	0,71	3,46
Türkiye	..	0,61	1,35
United Kingdom	0,82	0,84	6,76
United States	0,74	0,74	9,17
European Union (27 countries)	1,16	1,12	4,57
OECD sample median	1,01	0,95	5,60
BRICs economies**	1,10	0,67	..

* Data are obtained from the OECD database.

**BRICs economies -Brazil, Russia, India, Indonesia, China and South Africa

2. METHOD

Research design

In this study, a bibliometric analysis was employed to investigate the evolution and impact of green technologies in the healthcare sector. A bibliometric analysis is a quantitative method used to measure and analyse scientific literature, providing insights into publication trends, authorship patterns, collaboration networks and research impact (see figure 1). This method is well suited to the identification of key research themes and emerging trends within a particular field (Donthu et al., 2021).

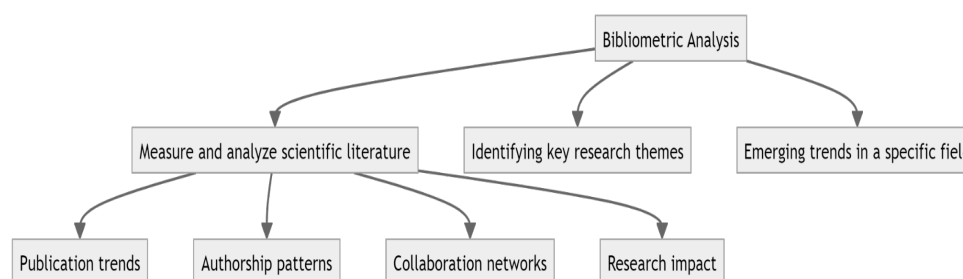


Figure 1. A Diagrammatic Representation of the Research Workflow

Data collection

The data for this analysis were sourced from the Web of Science (WoS) Core Collection, which is renowned for its comprehensive and high-quality citation indexing. The Web of Science (WoS) was selected for this analysis

due to its comprehensive coverage of peer-reviewed literature and its reputation as a reliable source for bibliometric studies;

- A search query was designed to capture articles related to "green technologies" and "health" using a combination of relevant keywords and Boolean operators. The search terms included those related to "green technology", "sustainable technology", "healthcare", "medical technology" and "environmental health".
- In order to ensure that only the most relevant and recent work was included in the search, the publication date limit was set between 2000 and 2023.
- The analysis was conducted on a diverse range of research outputs, including articles, reviews and conference proceedings.
- In order to ensure consistency and to reflect the dominance of English in scientific publishing, only publications in English were included in the analysis. The articles were required to have a clear focus on the application or impact of green technologies in the health sector.

Data processing

The initial search yielded a substantial corpus of documents. The following steps were taken to refine and process the data: (a) Duplicate records were identified and removed using the built-in functions of the WoS database, (b) Titles and abstracts were screened to ensure relevance to the research topic. The relevant bibliometric data, including authors, titles, publication years, journal names, keywords and citations, were exported from WoS in a standardised format for further analysis.

Analytical Techniques

The bibliometric analysis was performed using the Bibliometrix R package, a comprehensive tool for science mapping analysis. Key bibliometric indicators such as number of publications per year, leading authors and most influential journals were calculated to provide an overview of the research landscape. Network analysis was performed to map patterns of collaboration between authors and institutions. Bibliometrix facilitated the visualisation of co-authorship networks, highlighting key researchers and collaborative clusters.

These analyses were conducted to identify the intellectual structure and thematic development of the field. Highly cited articles and clusters of related articles were identified using Bibliometrix to discern major research themes and influential studies. Thematic analysis of keywords was conducted to identify emerging trends and research points. The frequency and co-occurrence of keywords were analysed using Bibliometrix to visualise the main topics and their relationships. Citation analysis was performed to assess the influence and impact of publications. Metrics such as h-index, total citations and average citations per article were calculated for the dataset using Bibliometrix.

Ethical Statement and Permissions

As this study did not involve human subjects or personal data, ethical approval was not required. The analysis was based solely on published scientific literature, and adherence to ethical standards was ensured.

3. RESULTS

In accordance with the parameters established within the research framework, data were gathered and bibliometric analyses were conducted. The evaluations yielded the following findings. Firstly, when the contents of the studies conducted between 2000 and 2023 are examined in general, the word cloud in Figure 2 is obtained. Upon analysis of the figure, it becomes evident that certain words, such as "nanoparticles," "performance," "management," "design," "health," and "in-vitro," stand out.

The utilization of green technologies in the field of health management, or the generation of green technologies as an outcome of health management, represents another intriguing area of inquiry. Figure 3 illustrates the interrelationships between green health technologies at the level of the entire field and at the level of specific subfields.

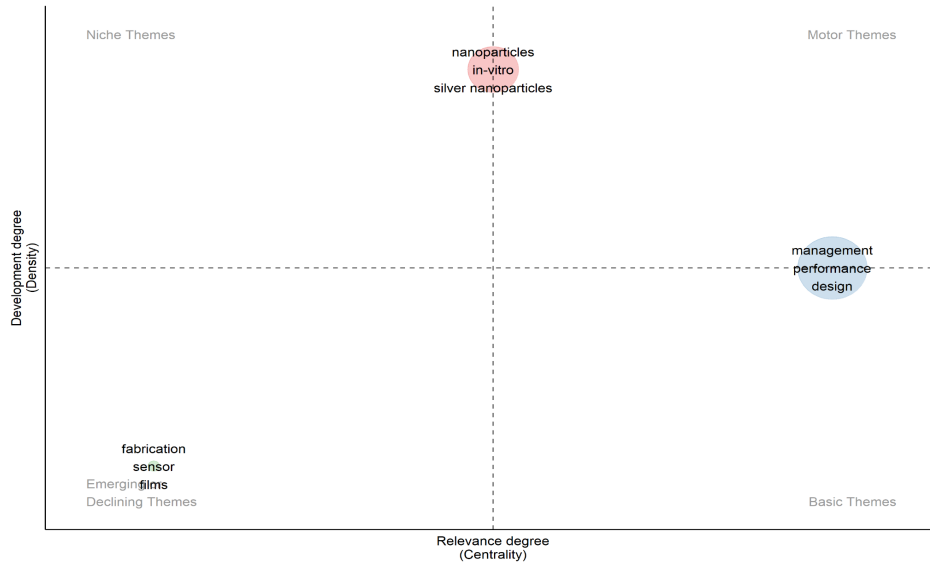


Figure 4. Co-Occurrence Network Map

Figure 4 illustrates the countries and links associated with keywords related to green technologies and health.

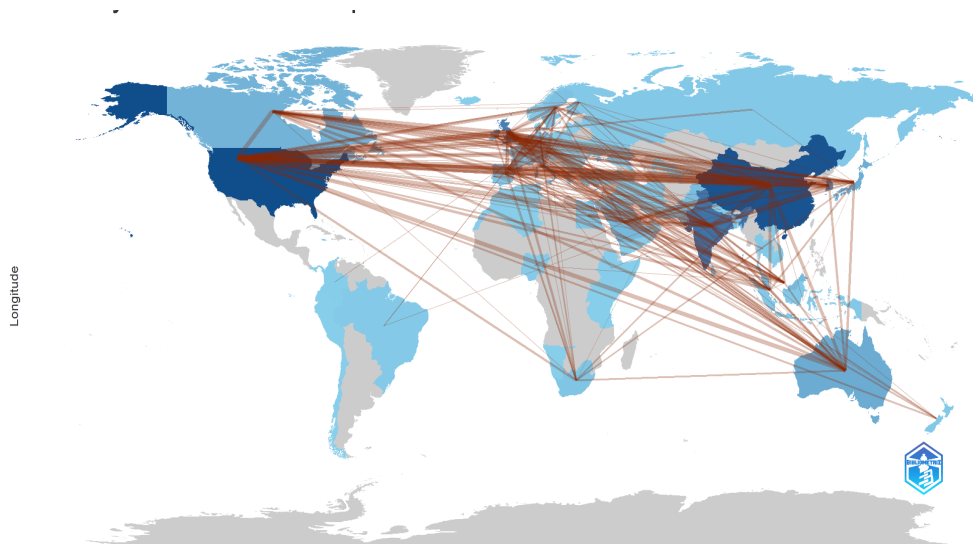


Figure 5. This Section Presents the Relationships between Green Health Technology Research and Country

Upon analysis of Figure 5, it becomes apparent that it is to be expected that countries belonging to the EU, the USA, and Australia possess a connected structure. Upon examination of the literature, it becomes evident that research centers in these countries are primarily responsible for conducting studies on green technology and health services. As evidenced by the figure, researchers and research centres based in South America are notably enthusiastic about the field of Green Health Technologies.

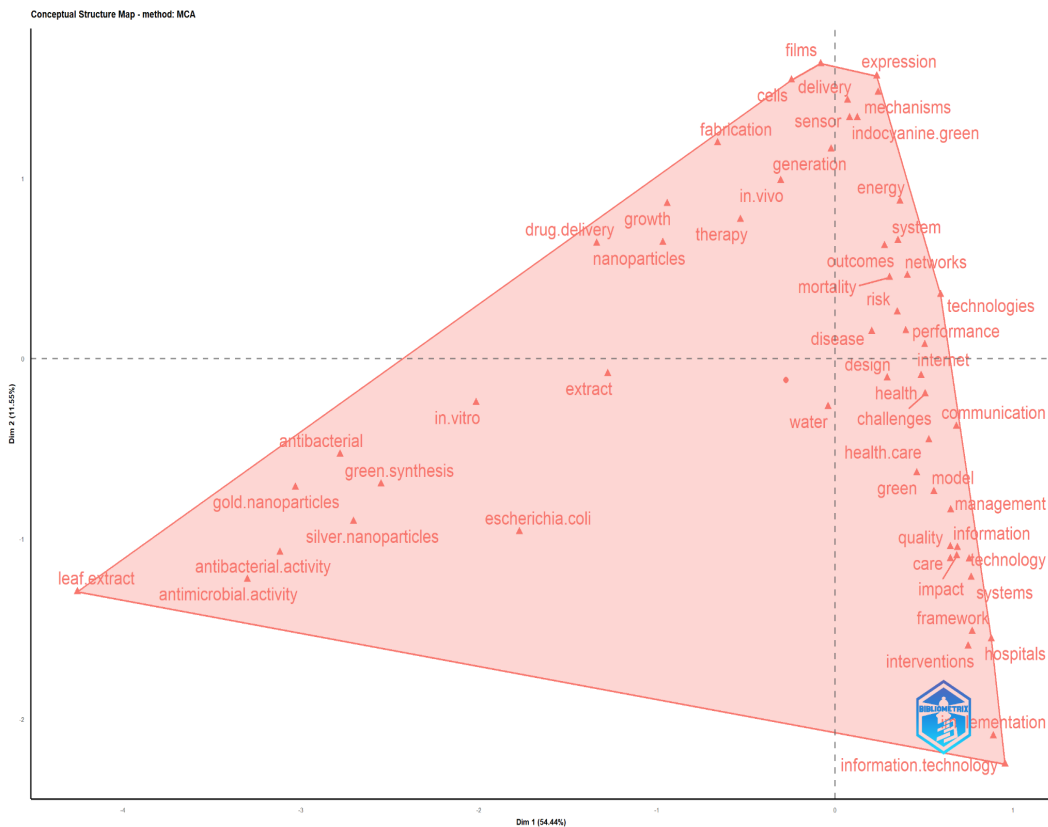


Figure 6. Fractional Map

Figure 6 provides a detailed analysis of the areas in which the keywords present in the literature are concentrated. Keywords such as "antibacterial, Escherichia coli, nanoparticles, in vitro" represent a significant proportion of the literature on green healthcare in the field of biological sciences. Conversely, keywords such as "management, mortality, disease, healthcare" may indicate the intensity of research in areas such as health management.

There is no evidence of a direct correlation between the field of green technologies in health services and the field of artificial intelligence. This situation indicates a significant potential for research on a crucial subject such as artificial intelligence, which is becoming increasingly prevalent and influencing everyday life

4. DISCUSSION AND CONCLUSION

The objective of this study is to provide a comprehensive overview of green technology in healthcare. The healthcare sector is a significant contributor to greenhouse gas emissions, and there is an increasing necessity for the adoption of green technologies to reduce its environmental footprint. The significance of this subject matter lies in the potential of green technologies to enhance the sustainability of the healthcare sector while simultaneously reducing its environmental impact.

This study compares the environmental impacts of adopting green technologies with traditional healthcare practices. Despite the potential benefits of green technologies in healthcare, there are still some challenges and barriers to their widespread adoption. The study provides data on the status of green technology in healthcare and its potential impact on the environment. This study is important in that it provides a comprehensive overview of the status of green technology in healthcare and its potential impact on the environment. The findings of this study have significant implications for policymakers, healthcare providers, and researchers in the development and implementation of green technologies in healthcare. The study highlights the necessity for further research to address the challenges and barriers to the widespread adoption of green technologies in healthcare. This study provides a distinctive perspective on the potential impact of green technologies on the healthcare sector and the environment. The study is constrained by the availability of data on the status of green technology in healthcare and the challenges and barriers to its widespread adoption.

A significant drawback of this bibliometric analysis is that it is dependent on databases such as Web of Science and Scopus, which may not encompass all pertinent publications. This limitation implies that crucial research published in other databases or grey literature may be overlooked, potentially leading to an incomplete understanding of the field. A further limitation is that the majority of indexed publications are in English and originate from Western countries, which introduces a language and regional bias. This bias may result in an underrepresentation of research and innovation in non-English-speaking and developing regions, thereby limiting the global applicability of the findings.

The limitation of the timeframe, which focuses on articles published between 2000 and 2023, may not capture earlier baseline studies or the latest developments and emerging trends in real time. This may result in a lack of insight into the historical evolution and contemporary status of green technologies in healthcare. Citation analysis, which is often an important component of bibliometric studies, tends to emphasise highly cited studies. Nevertheless, citation counts may be influenced by factors that are not directly related to the quality of the research, such as the publication in high-impact journals or self-citations. This focus may result in the overlooking of important but less cited research, which could potentially skew the perception of impactful work in the field.

The interdisciplinary nature of green technologies in healthcare, which intersects with fields such as engineering, environmental science and medical science, presents a challenge in classifying and analysing relevant studies. This complexity can result in an oversimplified view of the multifaceted nature of the research field.

To address these limitations, future research should include a wider range of databases and sources, such as Google Scholar, PubMed and grey literature. This will help to capture a more comprehensive set of relevant publications and reduce bias. The inclusion of a broader range of studies will facilitate the identification of a more diverse set of influential works.

Conducting multilingual bibliometric analyses can assist in the identification of research conducted in non-English-speaking countries. Moreover, focusing on regional studies can enhance the global validity of findings by providing insights into geographically specific challenges and innovations in green health technologies. An analysis that extends the time frame both backwards and forwards can help to understand the historical development of green technologies in healthcare and capture the latest trends and breakthroughs. This longitudinal approach can provide a more comprehensive understanding of the evolution of the field. The integration of qualitative assessments of research impact and innovation potential could serve as a valuable complement to citation-based metrics.

This approach could provide a more nuanced understanding of the field by helping to identify influential but less cited studies and highlight important research that might otherwise be overlooked. It is of the utmost importance to foster interdisciplinary research and collaboration if the advancement of green technologies in healthcare is to be achieved. Future research should investigate the integration of different fields, with a view to determining the extent to which interdisciplinary approaches can stimulate innovation and lead to more effective solutions.

An examination of the impact of new technologies such as artificial intelligence, blockchain and the Internet of Things (IoT) on the development of green technologies in healthcare may provide avenues for new research and practical applications. These technologies have the potential to significantly enhance the sustainability and efficiency of healthcare practices. An examination of the impact of existing policies on the adoption and effectiveness of green technologies in healthcare can offer valuable insights. This can inform the development of more effective and supportive policy frameworks that facilitate the wider implementation of sustainable practices.

The documentation and analysis of case studies of successful implementations of green technologies in healthcare settings can provide practical information and guidelines for the wider adoption of such technologies. The identification of optimal practices can facilitate the replication of success across diverse regions and organisations, thereby contributing to the mainstreaming of sustainable health solutions.

This study presents a bibliometric analysis of the literature on the adoption of green technologies in healthcare, demonstrating their potential to improve environmental sustainability and the quality of patient care. A review of articles published between 2000 and 2023 reveals a clear upward trend in research on green technologies in healthcare. There is a growing interest and activity in this field. The utilisation of databases such as Web of Science and Scopus proved instrumental in the identification of pivotal researchers, impactful publications, and prevailing trends within this field.

The analysis demonstrated that the implementation of green technologies in healthcare has the potential to enhance environmental sustainability, optimise energy efficiency, streamline waste management, and elevate the quality of patient care. The integration of these technologies into strategic planning by hospital managers and health services directors can result in more efficient resource utilisation and cost savings. Moreover, the implementation of green building standards and sustainable waste management practices can facilitate the transformation of existing health facilities into environmentally sustainable entities.

The information derived from this analysis can be utilised by policy makers to develop regulations and guidelines that facilitate the adoption of green technologies in healthcare. An understanding of current trends and influential research enables the formulation of policies that align with the latest developments and best practices. By identifying key research areas and impactful studies, funding agencies can better allocate resources to projects with environmental and healthcare impacts.

The implementation of green technologies enables healthcare providers to adopt more sustainable practices, including the utilisation of energy-efficient medical devices, the reduction of waste and the preference for environmentally friendly materials. Such alterations can facilitate a healthier environment for both patients and healthcare professionals, with the potential to enhance patient outcomes and satisfaction. The bibliometric analysis identifies gaps in the literature and emerging trends, thereby providing a roadmap for future research and encouraging the development of innovative green technologies.

By integrating the insights from this analysis into their curricula, educational institutions can ensure that future healthcare professionals are trained in sustainable practices and the utilisation of green technologies. Furthermore, continuing education programmes for existing healthcare professionals can be updated to include the latest developments in green technologies, thereby encouraging continuous improvement in sustainability practices

AUTHORS' STATEMENT

Contribution Statement: The authors have contributed equally to the article.

Acknowledgement: The study did not receive support from any institution or organization.

Conflict of Interest Statement: There is no potential for conflict of interest in the study.

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