Power System Technology
ISSN:1000-3673

Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

Sustainable Management of Construction and Demolition Waste: A Bibliometric Analysis and Technological Innovations During 2001-2023

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Abstract: - The rapid pace of urbanization has escalated the production of Construction and Demolition Waste (CDW), reaching approximately 10 billion tons annually. CDW, comprising diverse materials such as concrete, bricks, asphalt, wood, glass, metals, and plastics, poses significant environmental challenges due to the presence of hazardous substances like asbestos and mercury. Effective management and recycling of CDW can transform waste into valuable resources for new construction, thereby reducing the need for raw material extraction and processing. This study employs bibliometric analysis to explore global research trends in sustainable CDW management from 2001 to 2023, utilizing data from the Scopus database. The analysis reveals a significant increase in publications and citations over time, with a predominant focus on environmental science and engineering. China, India, and the United Kingdom are identified as the leading contributors to this field. Key research themes include greenhouse gas emissions, carbon footprint, and human factors influencing waste management. The study underscores the importance of integrating advanced technologies such as Building Information Modelling (BIM) and 3D printing in promoting sustainable practices. The findings highlight the necessity for continued innovation and international collaboration to address the global challenge of CDW.

Keywords: *Construction and demolition waste (CDW), Waste Management, Sustainability.*

1. Introduction

Construction and Demolition Waste (CDW), encompassing waste generated during construction, maintenance, demolition, and deconstruction of buildings and civil structures [1], [2], [3], consists of diverse materials like concrete, bricks, asphalt, wood, glass, metals, and plastics, as outlined by the European Commission (2022) [4]. These materials stem from various sources, including building and infrastructure demolition, as well as road construction and maintenance. While CDW contains substantial renewable resources like steel, concrete, and glass, it also harbors hazardous substances such as asbestos and mercury, contributing to soil and water pollution [5], [6]. Alarmingly, global CDW production amounts to nearly 10 billion tons annually [7], necessitating immediate action to mitigate its adverse environmental

Power System Technology
ISSN:1000-3673
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impacts [8]. Embracing a circular perspective, CDW can serve as commodities in new construction projects, obviating the need for raw material mining and processing [9]. Consequently, sustainable CDW management offers myriad societal, economic, and environmental benefits, directly or indirectly contributing to SDG advancement. These benefits include greenhouse gas emissions reduction, creation of local job opportunities, economic prosperity, and poverty alleviation [10].

The reduction and recycling of construction and demolition (C&D) waste play a pivotal role in human society, profoundly impacting sustainable development. Initially, the management of C&D waste and the sustainable development of the ecological environment were primarily the concerns of local governments. However, they now pose threats to regional and global development [11]. With the world experiencing rapid urbanization, addressing the escalating conflict between increasing C&D waste and environmental protection becomes imperative. Exploring economically viable and sustainable solutions for the reduction and recycling of C&D waste is crucial [12]. The current era witnesses profound global changes unseen in a century, emphasizing the urgent need to address the substantial waste generated by human construction activities and to advance research on resource sustainability.

A substantial portion, roughly 35%, of CDWs globally finds its way to landfills [13], persisting as the primary disposal method across many regions [14], often exacerbated by unauthorized dumping practices [15]. Studies consistently underscore the significant annual output of CDWs [16]. For instance, in 2016, the European Union alone generated about 2.538 billion tons of waste, with the construction sector contributing a significant 36.4% [17]. Similarly, this industry dominates landfill inputs in various countries, accounting for 44% in the United Kingdom, 40% in Brazil, 29% in the United States, 44% in Australia [18], 23% in Hong Kong [19], and 27% in Canada [20].

Existing research indicates that the pace of construction waste recycling is accelerating in certain developing nations, while a shift in recycling trends is observed in developed countries [21]. Recent investigations have seen rapid development in the study of greenhouse gas emissions [22], [23], [24], carbon footprint [25], [26], human factors [27], [28], and waste management policies [29], [30], [31] related to recycling construction waste. Notably, human factors feature prominently in construction waste research, underscoring their importance in effective C&D waste management. Li et al. conducted a quantitative analysis of the impact of construction waste reduction behavior using the theory of planned behavior [32]. Udawtt highlighted both technical and human-made barriers to waste management in Australian construction projects, with human factors being predominant [33]. Social motivation and policies are identified as driving forces for the development and progress of construction waste management [30]. Updates to laws and regulations concerning construction waste treatment reflect changes in research focus on the topic. Reduction of construction waste remains a

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

prominent research theme, with scholars exploring effective methods from construction technology [34] to management strategies [35]. As environmental concerns mount, research on the environmental benefits of waste reduction management has intensified [36].

Treatment methods are evolving toward resource sustainability, focusing on recycling means and reducing construction waste to minimize harmful resource impacts. This includes the comprehensive adoption of BIM technology [37], [38], [39], 3D printing technology [40], [41], and other information technologies, as well as the implementation of circular economy principles and other management strategies throughout the construction waste lifecycle [42].

Drawing from the extensive literature discussed above, both academic and industrial stakeholders have made considerable strides toward fostering a sustainable future for Construction and Demolition Waste Management (CDWM). Nonetheless, CDWM remains a significant global challenge [43].

2. Objectives

Bibliometric analysis is utilized to explore and organize research trends and classify issues by examining the history of publications across different attributes of literature [44], [45], [46], [47]. Systematic literature review in the form of bibliometric analyses is valuable as it allows for the analysis of quantitative data and highlights the role of active contributors through co-occurrence and co-citation analyses [48]. This approach is instrumental in tracking global advancements in distinct academic fields [49]. Necessary bibliometric information is typically extracted from a range of databases [50]. For the purposes of this study, Scopus was selected due to its widespread adoption and its status as the most comprehensive database for abstracts and citations, which facilitates the research and data extraction process [51], [52], [53]. Social Network Analysis (SNA) maps were also employed to effectively display the bibliometric data obtained [54]. Additionally, the VOSviewer software was applied to produce maps of bibliometric data, providing detailed graphical representations [55]. This software, developed by Van Eck and Waltman from Leiden University in the Netherlands, is notable for its ability to handle extensive datasets, a feature not commonly found in most bibliographic visualization tools [56], [57]. Available at no cost to bibliometric researchers (www.vosviewer.com), it supports various mapping styles such as network, overlay, and density visualizations, which illustrate the relationships among publication elements, the timing of published research, and the volume and intensity of the elements analyzed [58].

Despite numerous studies conducted in the field of sustainable construction and demolition waste management, bibliometric analysis in this area has been very limited. Therefore, all parts of this systematic analysis of sustainable C&D waste management were conducted at K. N. Toosi University of Technology from March 2024 to May 2024.

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

3. Methods

This study utilized Scopus as a primary data source, recognized for its extensive statistical resources and widespread application in scholarly research [59]. The ability to export data in comma-separated values (CSV) format from Scopus was particularly advantageous, as it facilitated a systematic evaluation of data across various categories. The research focused on analyzing publications that included the terms (((“construction and demolition waste" OR "C&D waste" OR "CDW") AND "management" AND ("sustainability" OR "sustainable development" OR "sustainable"))) within their titles, abstracts, and keywords, spanning the years 2001 to 2023. Various parameters such as language, source type, subject area, document type, affiliation, country, and keywords were examined during this period. It was found that over 98.1% (623) of the publications were in English, with Portuguese (0.6%, 4), Spanish (2.3%, 4), Chinese (0.3%, 2) and German (0.3%, 2) also represented. A comprehensive range of document types was considered, including journal articles, conference papers, book series, trade journals, and books.

To delineate the connections among different bibliometric nodes, such as countries or author keywords within the network, Social Network Analysis (SNA) was employed [60]. For the visualization of these bibliometric networks, VOSviewer 1.6.20 was used, known for its efficacy in performing SNA. This software facilitated the creation of maps analyzing cooperation among countries and the distribution of author keywords. Additionally, key journal metrics such as the impact factor (IF), h-index, subject area, country, and publisher information were assessed using data from Scopus and SCImago Journal Rank (SJR), enhancing the depth of the bibliometric analysis [61], [62].

4. Results

Chronological trends and source types

Figure 1 illustrates the annual number of publications and citations in the years 2001 to 2023 within the realm of sustainable construction and demolition waste management research. There has been a notable increase in the volume of studies, rising from 1 publication in 2001 to 113 in 2023. This represents a significant growth in scholarly output. The majority of these publications, comprising 82.15%, consist of journal articles and conference papers. In total, the 633 publications reviewed encompass 388 journal articles (61.3%), 132 conference papers (20.85%), 61 review papers (9.64%), 38 book chapters (6%), 9 conference review papers (1.42%), 2 books (0.32%), 2 editorials (0.32%) and 1 erratum (0.16%). Additionally, the number of citations for articles has exhibited a range from zero in 2001 to a peak of 2,714, with a generally increasing trend over time. The highest citation counts up to 2023 corresponds to articles published in 2020. It is noteworthy that citations for articles from 2021 to 2023 have shown a decline, which can be attributed to their recent publication dates.

Power System Technology
ISSN:1000-3673

Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

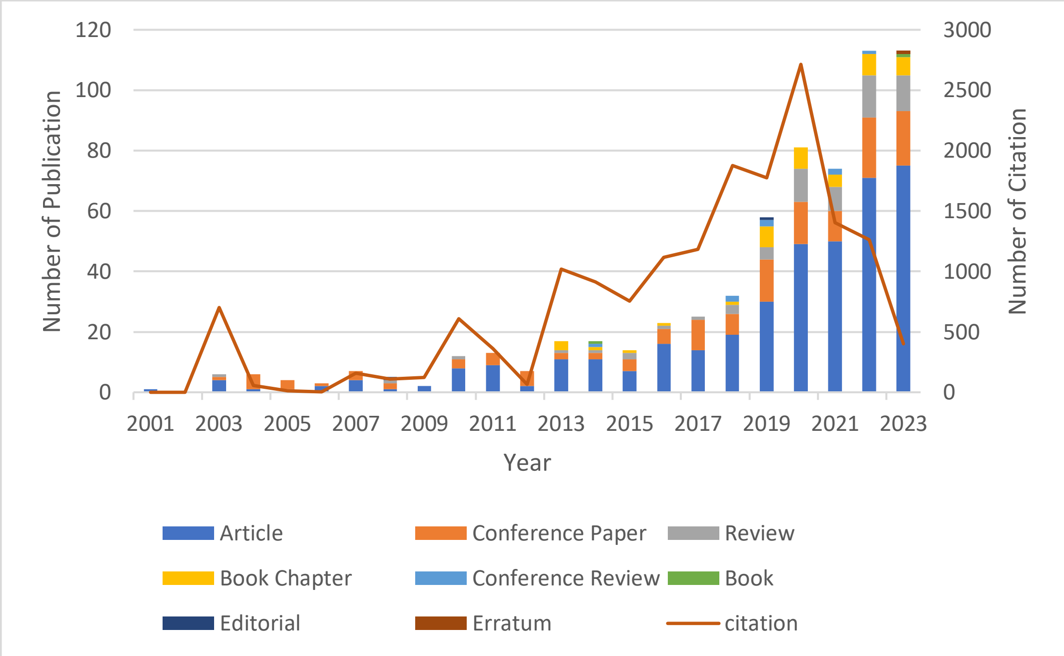

Fig. 1 A cumulative number of publications and citations by year

Subject categories

Publications on sustainable construction and demolition (C&D) waste management are extensively distributed across 21 distinct areas. Most of these publications fall into multiple subject categories. For instance, the study titled "On the Path towards Sustainable Construction—The Case of the United Arab Emirates: A Review" [63] is categorized under environmental science, engineering, energy, social sciences, business, management, and accounting. C&D waste management encompasses numerous environmental and technical facets, while sustainability also significantly intersects with economic and social sciences. According to Figure 2, the most prominent divisions are environmental science (29.8%) and engineering (23.2%). Energy and social sciences account for 9.2% and 7.1% respectively. Other areas include business, management, and accounting (5.4%), materials science (5%), computer science (4.6%), economics, econometrics, and finance (4.5%), and earth and planetary sciences (4%). The remaining fields—medicine, agricultural and biological sciences, physics and astronomy, chemical engineering, decision sciences, mathematics, arts and humanities, chemistry, multidisciplinary studies, biochemistry, genetics and molecular biology, pharmacology, toxicology and pharmaceutics, and psychology—collectively contribute 7.3%. Given that this study is a general review utilizing the default Scopus settings (search keywords and applied period) without additional filters, it is expected that some studies may not directly relate to the primary objective of the article.

Power System Technology
ISSN:1000-3673

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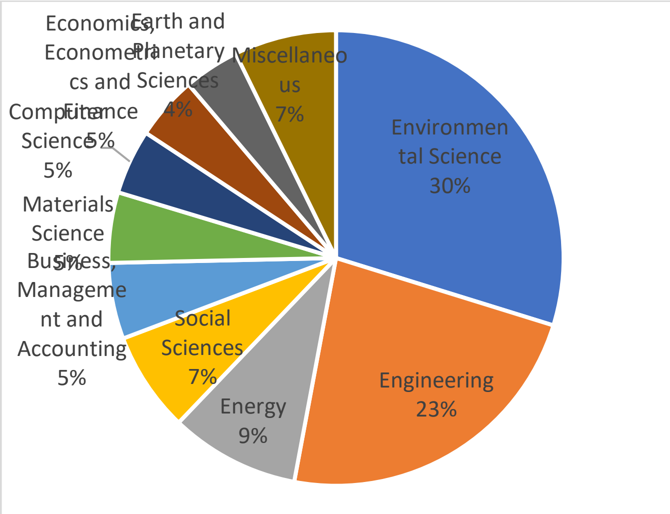

Fig. 2 The most major disciplines

Countries

The studies analyzed during the studied period were published across 78 countries. Among these, fifteen countries produced only one publication each, eleven countries had two publications, and fourteen publications lacked information regarding the author's country. Table 1 lists the top ten most prolific countries in the domain of sustainable construction and demolition (C&D) waste management. China leads with 101 publications, followed by India with 79 and the United Kingdom with 52. Notably, two of the top three countries in sustainable C&D waste management (China and the United Kingdom) are also among the top ten in sustainable construction studies, as highlighted by Amornrut Det Udomsap and Philip Hallinger (2020)[64]. Additionally, China holds the top rank in the field of construction and demolition waste, according to Huanyu Wu, Jian Zuo, and George Zillante (2019) [65]. These ten countries collectively contribute over 58% (511 publications) of the research in sustainable C&D waste management.

Publications were categorized as either independent or collaborative. Independent publications are those where all authors are from the same country, whereas collaborative publications involve authors from multiple countries. Figure 3 illustrates a network visualization where nodes represent countries[66]. The size of each node indicates the country's activity level, and each link denotes a relationship between two countries[58]. The United Kingdom, USA, and China have made significant contributions to this field, with the United Kingdom and USA having the highest number of international collaborations, evidenced by 36 and 28 links, respectively.

China is the most influential country in this field based on citation counts (4493), followed by Hong Kong (1993), the United Kingdom (1911), Spain (1747), Italy (1640), the USA (1471), and Australia (1449). Furthermore, in terms of "total link strength" analysis, China (76), the

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United Kingdom (69), and the USA (47) have the highest number of publications in sustainable C&D waste management.

Table 1 Top ten most productive countries

#	Country	Number of Publications
1	China	102
2	India	79
3	United Kingdom	52
4	Italy	51
5	Spain	51
6	Australia	50
7	United States	36
8	Portugal	34
9	Hong Kong	31
10	Brazil	26

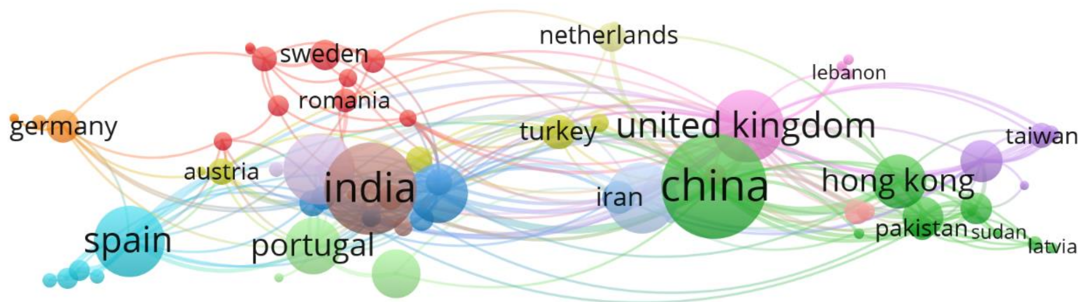

Fig. 3 Cooperation of the countries

Source titles

Table 2 presents the ten most prolific sources in the field of sustainable construction and demolition (C&D) waste management, detailing their impact factors (IFs), h-indexes, subject areas, countries, publishers, and the number of publications. The IF is used to gauge the journal's value[67], while the h-index reflects the number of publications (h) that have received at least h citations each[68]. The information on journals, conferences, and book series in Table 2 was sourced from "Scopus" and "SJR"[61], [62].

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ISSN:1000-3673

Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

As indicated in Table 2, 238 publications, accounting for 44.6% of the total, were published in these ten sources. The list includes eight journals, one book series, and one conference proceeding. The United Kingdom leads with four sources, while Switzerland and the Netherlands each have two sources contributing significantly to this classification. Notably, nine of these ten sources cover environmental science among their subject areas. Elsevier and Springer emerged as the most prolific publishers in this field. Specifically, "Resources Conservation and Recycling" ranked first in terms of the number of publications (43), impact factor (13.2), and h-index (196) among the journals. Additionally, the "Iop Conference Series Earth and Environmental Science" was the most influential source in the conferences and proceedings category, with 17 papers.

Table 2 The top ten most productive sources and specifications

#	Source Title	Number of Publications	IF	h-index	Subject Area	Country	Publisher
1	Resources Conservation and Recycling	43	13.2	196	Environmental Science, Economics, Econometrics, Waste Management	Netherlands	Elsevier
2	Sustainability Switzerland	38	3.9	NA	Environmental Sciences, Environmental Studies, Green & Sustainable Science & Technology	Switzerland	MDPI AG
3	Journal Of Cleaner Production	36	11.1	309	Environmental Science, Energy, Engineering, Management and Accounting	United Kingdom	Elsevier
4	Waste Management	28	8.1	220	Environmental Science	United Kingdom	Elsevier
5	Waste Management and Research	22	3.9	97	Environmental Science	United Kingdom	SAGE Publications Ltd
6	Iop Conference Series Earth and Environmental Science	17	NA	NA	Earth and Environmental Science	United Kingdom	IOP Publishing
7	Environmental Science and Pollution Research	16	5.8	179	Environmental Science, Medicine	Germany	Springer

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ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

#	Source Title	Number of Publications	IF	h-index	Subject Area	Country	Publisher
8	Lecture Notes in Civil Engineering	14	NA	NA	Civil Engineering, Environmental Science	Switzerla nd	Springer
9	Materials Today Proceedings	13	NA	NA	Materials Science, Engineering	Netherlan ds	Elsevier
10	Journal Of Environmental Management	11	8.7	243	Environmental Science, Medicine	United States	Academic Press

Affiliations

Table 3 lists the top ten most productive affiliations in the field of sustainable construction and demolition (C&D) waste management. These ten affiliations are responsible for over 18% (114) of the publications in this field. "The Hong Kong Polytechnic University" leads with 20 publications, followed by Shenzhen University (China) with 17, Western Sydney University (Australia) with 16, and Universidade do Porto (Portugal) with 9 publications. Notably, three institutions from China are among the top ten affiliations, with two from Australia and Portugal each.

Table 3 Top ten productive institutes

Affiliation	Number of publications
The Hong Kong Polytechnic University	20
Shenzhen University	17
Western Sydney University	16
Universidade do Porto	9
RMIT University	9
Chongqing University	9
Guangzhou University	9
Universidad de Sevilla	9
Instituto Superior Técnico	8
Parthenope University of Naples	8

Authors

Table 4 presents the top ten most active authors in the field of sustainable construction and demolition (C&D) waste management. It includes their respective countries, affiliations, h-indexes, subject areas, number of citations, and number of publications. The authors with the most publications are Poon, C.S. (8), Tam, V.W.Y. (8), and Kamrath, P. (7). Poon, C.S. also

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

leads in citations with 45,058, followed by Tam, V.W.Y. with 20,409. Regarding h-index, Poon, C.S. ranks first with 112, followed by Tam, V.W.Y. with 77, and Duan, H. with 46.

According to Table 4, two authors are from Australia, and two are from Italy. The most common subject area among these authors is environmental science.

Table 4 Top ten productive authors

#	Author	number of publications
1	Poon, C.S.	8
2	Tam, V.W.Y.	8
3	Kamrath, P.	7
4	Vieira, C.S.	6
5	Blengini, G.A.	5
6	Duan, H.	5
7	Garbarino, E.	5
8	Ghisellini, P.	5
9	Kabirifar, K.	5
10	Kawamoto, K.	5

All keywords

This bibliometric research analyzed a total of 4,539 keywords from 2001 to 2023. Of these, 3,281 keywords (72%) appeared only once, and 563 keywords (12%) occurred twice. In the network visualization, each node represents a specific author keyword, with larger nodes indicating higher occurrences of keywords[66].

Using software settings with a minimum keyword occurrence set to six, the related keywords were grouped into clusters, each characterized by a distinct color. Figure 4 illustrates these keywords classified into four clusters. Each cluster contains at least 40 keywords, with the largest being Cluster 1, comprising 108 keywords, and the smallest, Cluster 4, consisting of 45 keywords.

Cluster 1 (red) primarily includes general and primary research topic keywords, such as “construction and demolition waste,” “sustainable development,” “building material,” and “waste management.” Cluster 2 (green) focuses on recycling studies, featuring keywords like “recycling,” “recycled materials,” and “recycled aggregates.” Cluster 3 (blue) encompasses environmental sustainability keywords, including “environmental sustainability,” “carbon dioxide,” “greenhouse gases,” “life cycle assessment,” and “carbon footprint.” Cluster 4 (yellow) is dominated by economic and efficiency-related terms like “circular economy,” “economic growth,” “resource efficiencies,” and “industrial economics.”

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

Figure 5 shows the network visualization maps of frequently used keywords over two time periods (2001–2012 and 2012–2023). Keywords with at least two occurrences are displayed in the first period, and those with at least six occurrences in the second period. To enhance clarity, the keywords “construction and demolition waste” and “waste management” were manually removed from the maps. In the second period, “sustainable development” ranks first with 270 repetitions, whereas “recycling” ranks first in the first period with 44 repetitions. "Recycling" ranks second in the second period with 260 repetitions, and “demolition” ranks second in the first period with 40 repetitions.

Comparing the trends across the two periods, there is a notable increase in the usage of keywords like “sustainable development,” “sustainability,” and “recycling,” which rose from 32, 12, and 44 occurrences (2001–2012) to 270, 138, and 260 occurrences (2012–2023), respectively.

Emerging keywords such as “circular economy,” “global warming,” “material flow analysis,” and “ecodesign” were absent in the first period but appeared 91, 18, 7, and 6 times in the second period, respectively. Keywords related to sustainability have also seen significant growth. For instance, “sustainable development,” “life cycle,” “sustainable construction,” and “economic aspect” increased from 32, 5, 7, and 3 occurrences in the first period to 270, 82, 51, and 24 occurrences in the second period.

Analyzing the CSV output from VOSviewer software reveals significant growth in specific keywords, highlighting the surge in related research in recent years. Notably, “global warming” and “circular economy” have shown substantial increases and are expected to become prominent in future VOSviewer maps.

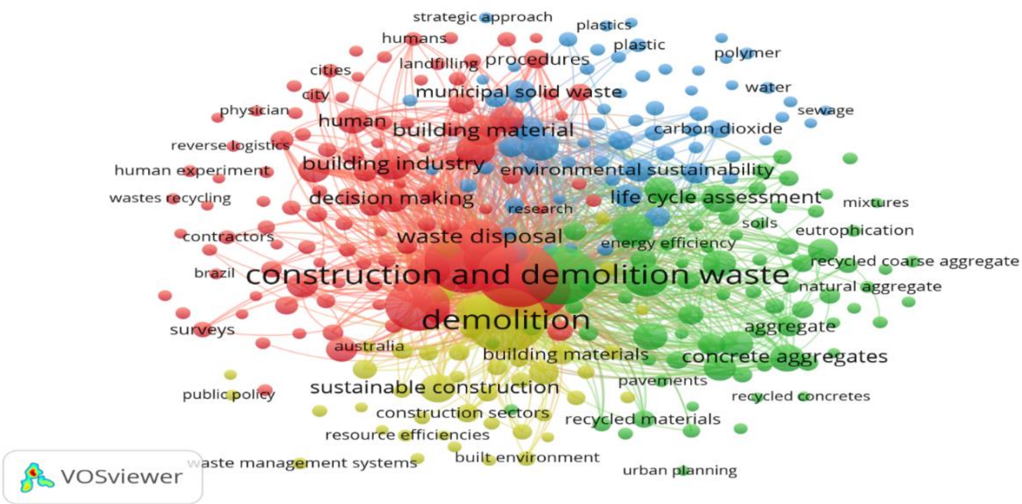

Fig. 4 The author keywords overlay visualization network map

Power System Technology
ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

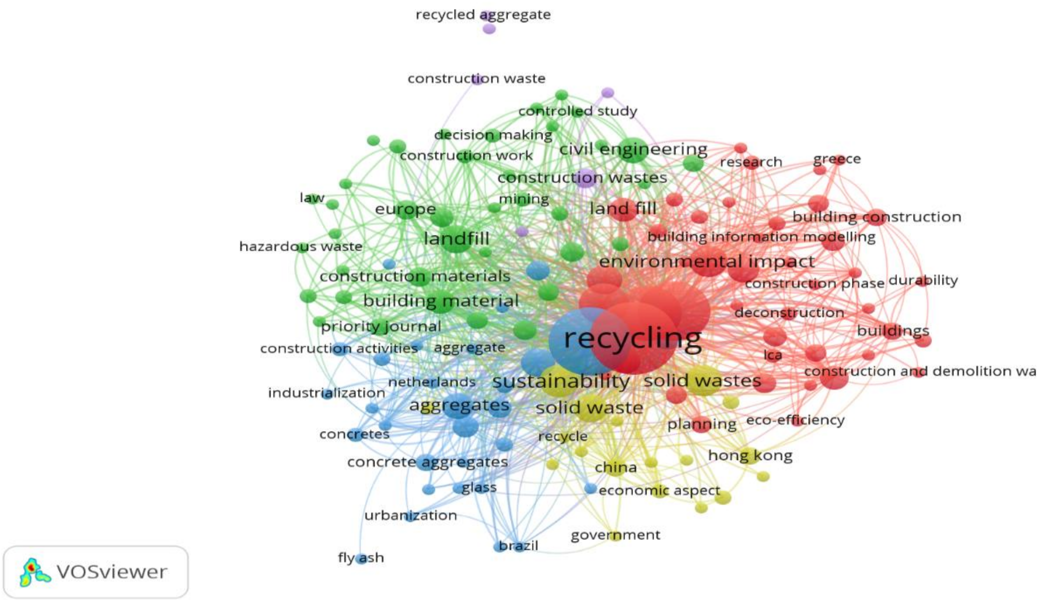

Fig. 5 Keyword network visualization map in two periods. a 2001–2012. b 2012–2023

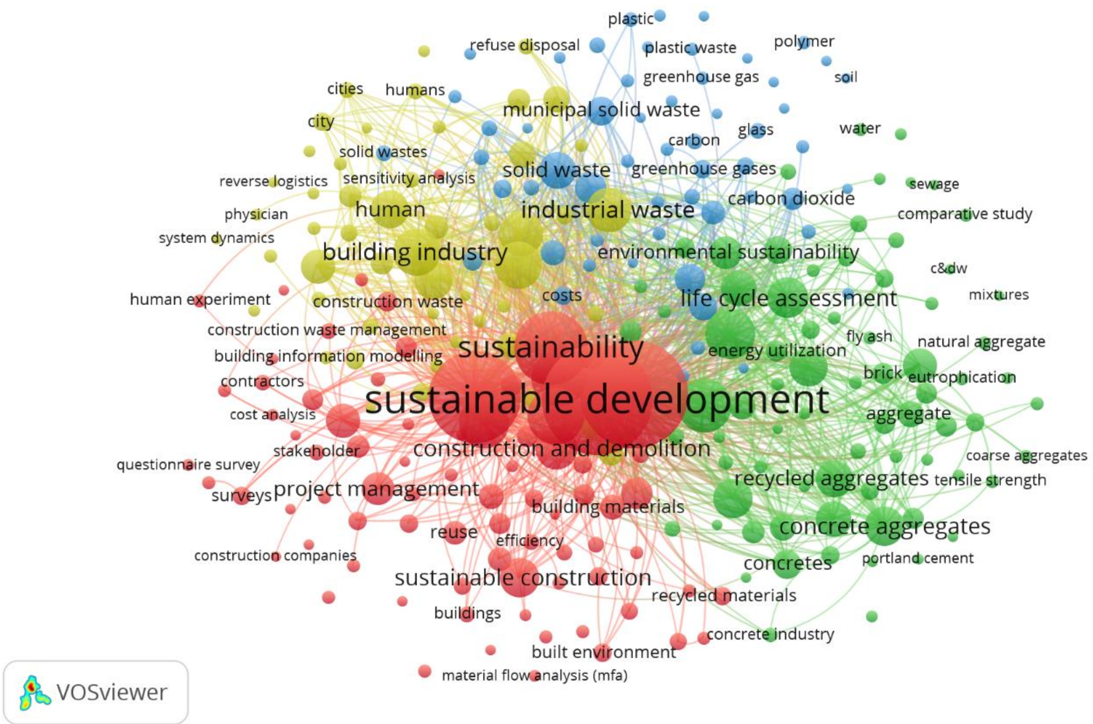

Fig. 5 (continued)

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ISSN:1000-3673
Received: 06-04-2024 Revised: 15-05-2024 Accepted: 28-06-2024

Discussion

This comprehensive bibliometric analysis of sustainable Construction and Demolition Waste (CDW) management underscores the critical importance of addressing the environmental impacts associated with CDW. The study identifies significant contributions from countries like China, India, and the United Kingdom, reflecting their leadership in research and implementation of sustainable practices. The analysis reveals an increasing trend in scholarly output and a growing focus on key themes such as greenhouse gas emissions, carbon footprint, and human factors in waste management. The integration of advanced technologies such as Building Information Modelling (BIM) and 3D printing is highlighted as a crucial strategy for enhancing sustainability. Despite the progress, the study emphasizes the ongoing need for innovation, policy development, and international cooperation to effectively manage CDW and mitigate its environmental impacts. Sustainable CDW management not only contributes to environmental preservation but also supports economic growth and social well-being, aligning with global sustainable development goals.

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