Green Insulation Revolution: A Bibliometric Analysis of Cannabis-Based Composite Materials in Building Construction

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Abstract. Powdered activated carbon was used in different studies for evaluation in micropollutants removal. In this study, powdered activated carbon was tested to evaluate its removal efficiency for about 46 micropollutants. A total of 33 compounds were found in raw wastewater. The PAC was found to be efficient towards total suspended solids elimination. Powdered activated carbon reached high removal percentage for heavy metals (90%), while the majority of the other compounds it varied between 60 and 80%. The impact of advanced treatments combination with conventional treatments could lead to high removals.

1 Introduction

Cannabis sativa, primarily known for its applications in the pharmaceutical and textile industries, has recently gained significant attention for its potential in sustainable building materials. This interest is driven by the global push for environmentally responsible construction practices that not only mitigate the impacts of traditional building processes but also emphasize sustainability over the long term [1-4].

The fibrous part of the cannabis plant, commonly referred to as hemp, is at the forefront of this innovative shift. Hemp fibers are used to produce composites that are both lightweight and robust, making them ideal for a variety of construction applications, including insulation. These composites are typically made by combining hemp fibers with other natural fibers and eco-friendly resins, creating a bio-composite that is strong, sustainable, and versatile [5-9].

The properties of these materials are particularly notable. They exhibit high tensile strength, which enables them to support significant loads, making them suitable for structural applications. They are durable, capable of resisting wear and tear, which reduces the need for frequent replacements and repairs. Hemp fibers are naturally resistant to mold and pests, crucial for maintaining the integrity of indoor environments and reducing the

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need for harmful chemical treatments. Furthermore, their structure provides excellent thermal insulation, essential for energy efficiency in buildings [9-14].

In terms of environmental impact, using hemp in building materials can significantly reduce the carbon footprint of construction activities. Hemp plants absorb a considerable amount of CO_2 during their growth, which offsets the carbon emitted during the processing and manufacturing phases. Additionally, since these composites are predominantly made from natural materials, they are largely biodegradable and recyclable, further diminishing their environmental impact [5, 15-27].

By incorporating cannabis-based composites, the building industry is making significant strides towards sustainability. The eco-friendly nature of these materials, coupled with their impressive physical properties, positions them as a viable alternative to traditional construction materials. This shift not only aligns with global sustainability efforts but also paves the way for future innovations in green building technologies [2, 28-32].

Insulation efficiency is pivotal in reducing energy consumption and enhancing the environmental sustainability of buildings. Effective insulation is essential for maintaining comfortable indoor temperatures and minimizing the energy required for heating and cooling, which significantly contributes to a building's energy footprint. As global energy costs rise and environmental concerns become more pressing, optimizing insulation efficiency becomes critical for sustainable building practices [26, 33-43].

Superior Properties of Cannabis-Based Composites Cannabis-based composite materials are proving to be a superior alternative to traditional insulation materials such as fiberglass or foam. These conventional materials, while effective in insulation, often carry significant environmental drawbacks, including harmful emissions during their production and disposal. Cannabis-based composites, on the other hand, offer superior thermal resistance thanks to the natural fibrous structure of hemp—the primary component of these composites. The cellular structure of hemp fibers is inherently insulative, containing pockets of air that reduce heat conductivity and effectively regulate indoor temperatures by keeping interiors warm in winter and cool in summer.

Biodegradability and Health Benefits In addition to their insulative properties, cannabis-based composites are biodegradable. They decompose naturally over time, reducing long-term environmental impact and avoiding the landfill waste typically associated with synthetic insulation materials. This biodegradability also extends to the production phase, where these materials require less energy and produce fewer pollutants compared to their synthetic counterparts. Moreover, cannabis-based insulations promote a healthier living environment. They are free from volatile organic compounds (VOCs), which are commonly emitted by synthetic insulation materials and can cause a range of health issues, from eye and respiratory tract irritation to more serious long-term effects. By eliminating VOCs, cannabis-based composites ensure indoor air quality remains high, contributing to better overall health for building occupants.

This bibliometric analysis aims to map the research landscape surrounding cannabis-based composite materials used in building insulation. By examining publication trends, citation networks, and thematic clusters, this study seeks to identify the evolutionary trajectory of the field, pinpoint key research hubs, and uncover the most influential studies shaping its progress. Ultimately, the analysis will highlight potential gaps in the current research and suggest directions for future inquiry, thereby aiding scholars and practitioners in navigating this burgeoning field.

2 Methodology

Bibliometric analysis is a quantitative approach to scientific literature that utilizes various metrics such as publication patterns, citation analysis, and content exploration to assess the

impact and evolution of a specific research field. This methodological approach helps identify significant trends, leading contributors, and key research outputs, providing a comprehensive overview of the topic at hand. In this study, bibliometric analysis is employed to delve into the research landscape surrounding the use of cannabis-based composite materials in building insulation [19, 44-47].

The primary data for this analysis were sourced from Scopus, a reputable database known for its extensive coverage of peer-reviewed literature across various disciplines. The search strategy was designed to capture all relevant publications using a set of carefully chosen keywords. These keywords included "composite materials," "insulation," "cannabis," and "construction." The search aimed to retrieve documents that discuss the integration of cannabis-based materials in construction, with a particular focus on insulation properties and applications.

The inclusion criteria were set to consider papers published from the year 2002 onwards, encompassing a broad spectrum of research that could provide insights into the development and utilization of these materials over two decades. This timeframe was selected to reflect both the early research phases and the more recent advancements in the field. All subject areas and languages available in the Scopus database were included, ensuring a comprehensive analysis that captures global research efforts without linguistic or disciplinary boundaries.

To conduct the bibliometric analysis, two main tools were employed: Bibliometrix and VOSviewer. Bibliometrix is an R-tool designed for comprehensive bibliometric analysis and provides functionalities for data processing, analysis, and visualization. It is particularly useful for deriving statistical insights about publication trends, authorship, and citation patterns. VOSviewer, on the other hand, is used for constructing and visualizing bibliometric networks. It specializes in creating maps based on network data and can visualize various kinds of relationships such as those between authors, institutions, countries, and keywords. This combination of tools allows for a robust analysis of the data, supporting the extraction of both quantitative and relational insights from the literature.

3 Results and discussions

Table 1 provides the main results on a comprehensive analysis of research on cannabis-based composite materials in building insulation from 2002 to 2024 can be drawn. The data encompasses a variety of aspects, from publication metrics to author collaboration.

The analysis covers a period from 2002 to 2024, highlighting a relatively new but growing field of study. Over these 22 years, 77 documents have been published across 46 sources, including journals and books. This suggests a niche but recognized area within academic and industrial research with a moderate publication rate. The annual growth rate of publications stands at 3.2%, indicating steady but slow growth in the field. However, the high average citation per document, at 42.34, underscores the significant impact and relevance of the published works within the community. This high citation rate may reflect the innovative nature of the research in cannabis-based materials for insulation.

The large number of Keywords Plus (942) and Author's Keywords (287) indicates a diverse and interdisciplinary nature of the research, covering various aspects related to cannabis-based composites, such as material properties, sustainability, and specific applications in building insulation.

There are 266 authors involved in the literature, with only 6 documents being single-authored, which points to high collaboration in this research area. The number of single-authored documents being low suggests a trend towards collaborative research efforts, which is further supported by the average of 4.25 co-authors per document. International

collaborations constitute about 19.48% of the co-authorships, reflecting moderate global interaction and knowledge exchange between researchers from different countries.

The majority of the documents are articles (54), followed by conference papers (15), reviews (7), and a short survey (1). This distribution indicates a strong preference for detailed research articles in peer-reviewed journals, providing thorough examinations of the subject matter. Conference papers also play a significant role, suggesting ongoing discussions and developments being shared within academic and professional communities.

This bibliometric analysis reveals a dynamic yet specific field of study focused on the use of cannabis-based composite materials in building insulation. The data suggests an active, evolving research community that engages deeply with the topic through various forms of scholarly communication. The high citation rate particularly highlights the relevance and ongoing interest in this research, emphasizing its potential impact on sustainable building practices.

Table 1. Main informations.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2002:2024
Sources (Journals, Books, etc)	46
Documents	77
Annual Growth Rate %	3,2
Document Average Age	8,61
Average citations per doc	42,34
References	0
DOCUMENT CONTENTS	
Keywords Plus (ID)	942
Author's Keywords (DE)	287
AUTHORS	
Authors	266
Authors of single-authored docs	6
AUTHORS COLLABORATION	
Single-authored docs	7
Co-Authors per Doc	4,25
International co-authorships %	19,48
DOCUMENT TYPES	
article	54
conference paper	15
review	7
short survey	1

3.1. Publication trends over time

Fig. 1 illustrates the annual scientific production related to cannabis-based composite materials in building insulation from 2002 to 2024, showing fluctuating but overall increasing interest and research activity over the period. After a slow start from 2002 to

2007, a noticeable uptick occurs in 2008, followed by significant peaks in 2014 and 2016, suggesting periods of heightened research focus or possibly the influence of policy changes, technological advancements, or funding availability in these years. Post-2016, there is a sharp decline, reaching a low in recent years, which may indicate saturation in research topics, shifts in research priorities, or external economic or political factors impacting the field. This trend analysis is crucial for understanding the dynamics within the field, helping to identify factors that drive research peaks and troughs.

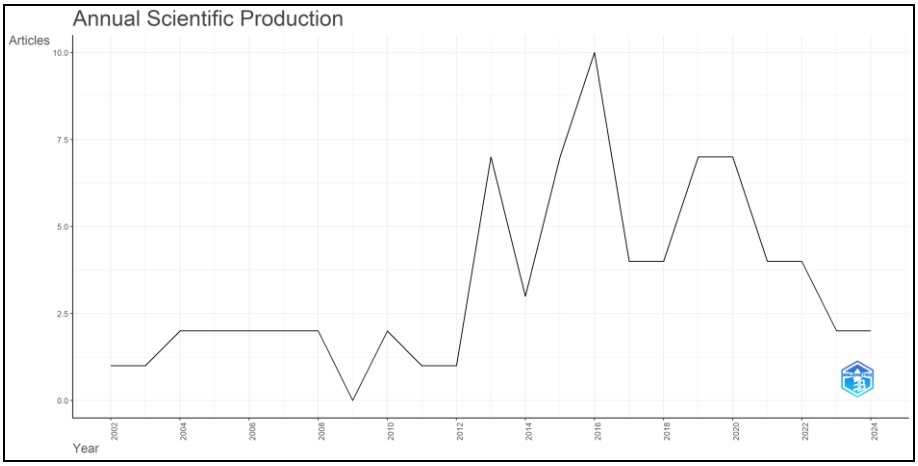

Fig. 1. Annual Scientific production.

3.2. Most relevant Countries / Affiliations / Authors

The corresponding author's countries (Fig. 2) reveals France, Germany, and Latvia as the leaders in publications, with France having the most substantial involvement in international collaborations (indicated by the pink section for multiple country publications). This suggests that French institutions might be central nodes in the international network of cannabis composite research, facilitating cross-border collaborations. Latvia's strong showing, both as a single-country and multiple-country publisher, reinforces its position as a key player in this research field, likely tied to the prominent output from Riga Technical University. The mix of countries across Europe and other continents including Canada and China indicates a global interest and diverse international efforts in researching cannabis-based composite materials for insulation.

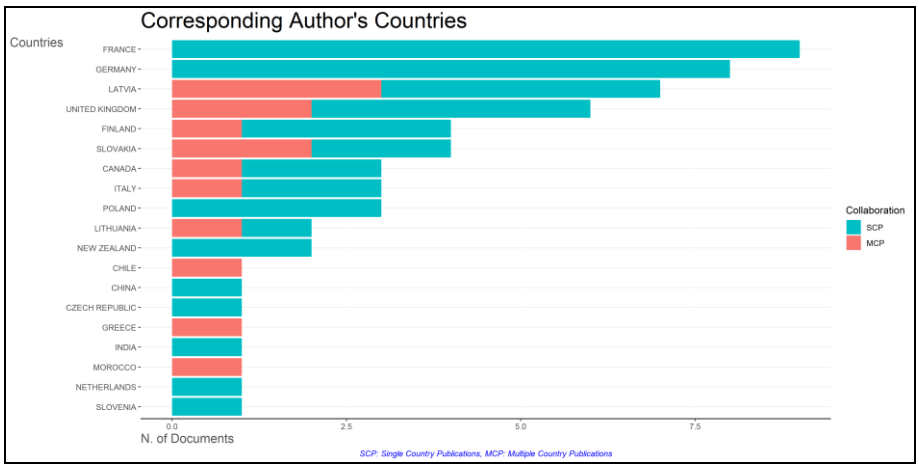

Fig. 2. Most relevant Countries.

Fig. 3 showcasing the most relevant affiliations indicates that Riga Technical University and the University of Helsinki lead in contributions, each with 18 articles. This suggests a strong regional research focus within Northern Europe, specifically Latvia and Finland, which may be due to local academic strengths or specific regional interest in sustainable building materials. Other notable contributors include the Latvia University of Agriculture and the Technical University of Kosice, highlighting a significant Eastern European academic involvement in this research area.

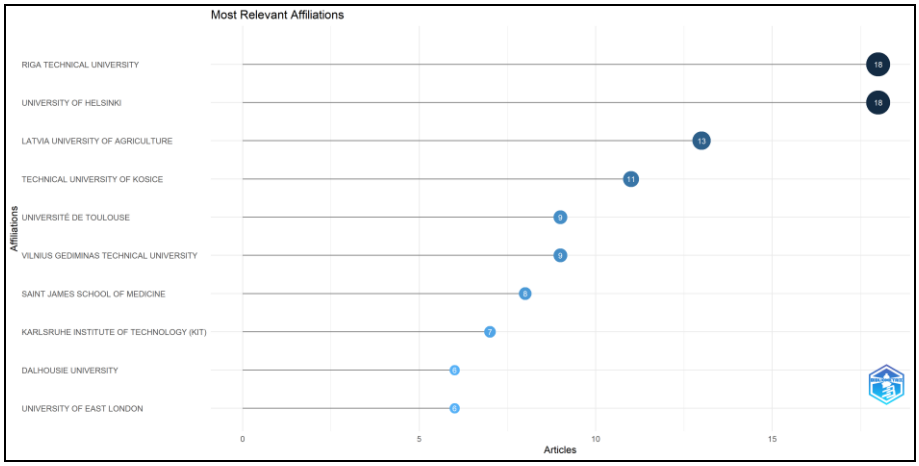

Fig. 3. Most relevant affiliations.

From Fig. 4, Berzins R, Berzins U, and Kakitis A stand out, each contributing to five publications. This clustering of top contributors within the same affiliation (as inferred from common last names and similar research outputs) underscores a concentration of expertise, potentially indicating collaborative teams or shared research facilities that specialize in this niche. The presence of multiple authors with multiple publications but relatively low total numbers indicates a field that is still developing, with a few key researchers driving much of the scholarship.

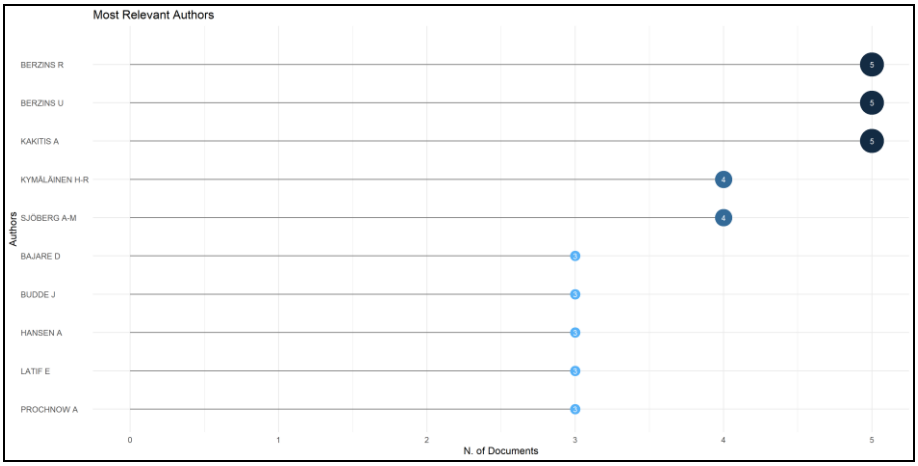

Fig. 4. Most relevant authors.

The analysis of relevant affiliations, authors, and countries paints a picture of a specialized, yet internationally collaborative research field. Northern and Eastern Europe appear to be significant hubs for research on cannabis-based composites in building insulation, with a notable spread into broader international collaborations. This distribution underscores the global relevance of sustainable building materials research and highlights specific regions and individuals as key contributors to the field. This global spread and focused expertise are crucial for driving forward innovations in sustainable construction materials.

3.3. Most Relevant Sources

The analysis of the most relevant sources (Fig. 5) shows that "Building and Environment" leads with ten documents, indicating its significance as a primary outlet for research on building materials, particularly those focusing on sustainability aspects such as cannabis-based composites. This journal's prominence could reflect a broader interest within the construction and environmental engineering communities in innovative and sustainable building solutions. Other notable sources include "Engineering for Rural Development" and "Sustainability (Switzerland)", each contributing significantly to the dissemination of research in this niche. This variety among journals from specific focuses on industrial applications to broader sustainability topics suggests an interdisciplinary interest and the application breadth of cannabis-based materials.

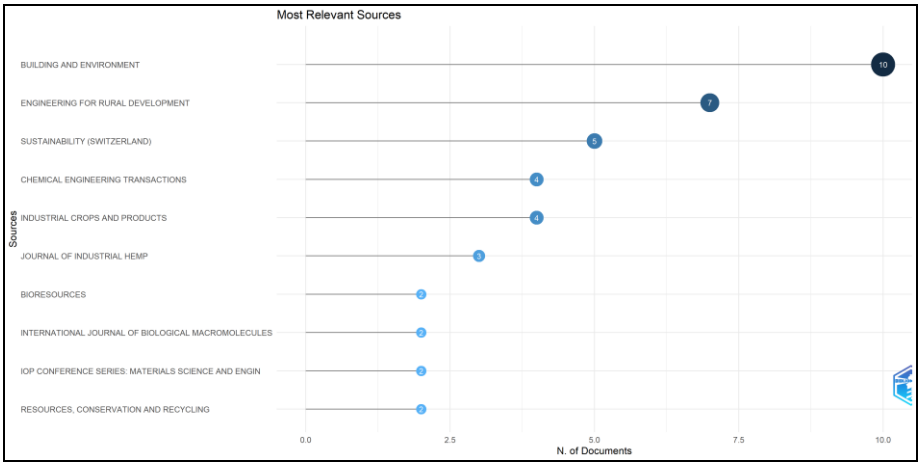

Fig. 5. Most relevant sources.

3.4. Most Global Cited Documents

Fig. 6 of the most globally cited documents highlights significant works that have shaped the discourse in the field. Arain M's 2013 article from "Neuropsychiatr Dis Treat" leads with an impressive 695 citations, suggesting it might be a pivotal piece, possibly discussing broader implications of cannabis, beyond just material science, impacting its high citation rate. Another highly cited article by Berardi U from "Build Environ" with 483 citations likely deals with key aspects of building materials, their environmental impacts, or innovative applications in construction, marking it as a foundational text in the practical applications of cannabis-based composites. The presence of these highly cited works in diverse journals underlines the multidisciplinary nature of research involving cannabis-based composites, spanning from environmental science to practical engineering applications.

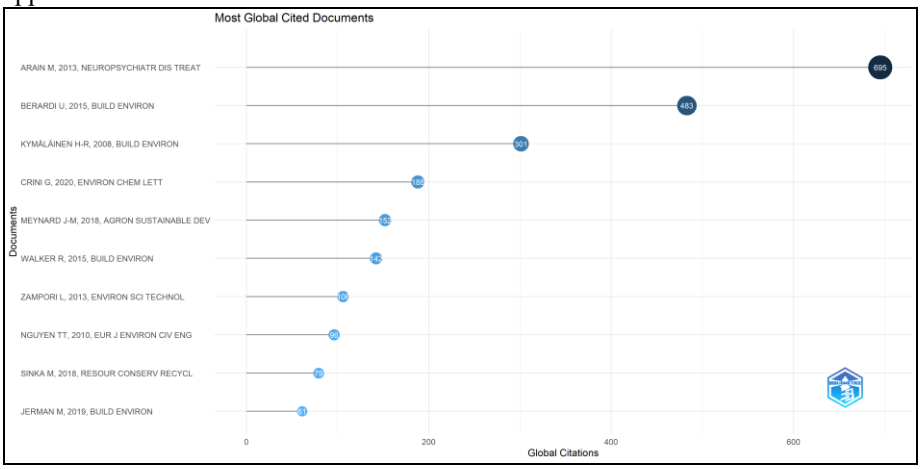

Fig. 6. Most global cited documents.

3.5.Keyword Analysis

The keyword analysis reveals a clear focus within the research community on several key aspects of cannabis-based materials. The term "cannabis sativa" leads with 61 occurrences,

highlighting it as the primary subject of study, followed closely by "hemp" with 51 occurrences. This indicates a strong emphasis on the plant's specific strain used for material production. The terms "thermal insulation" (33 occurrences) and "thermal conductivity" (31 occurrences) are also prominent, suggesting that much of the research is concerned with the practical applications of cannabis-based materials in insulation and their effectiveness in thermal management. The presence of keywords like "environmental impact" (19 occurrences) and "compressive strength" (15 occurrences) underscores the multidisciplinary nature of this research, incorporating environmental sustainability and material science.

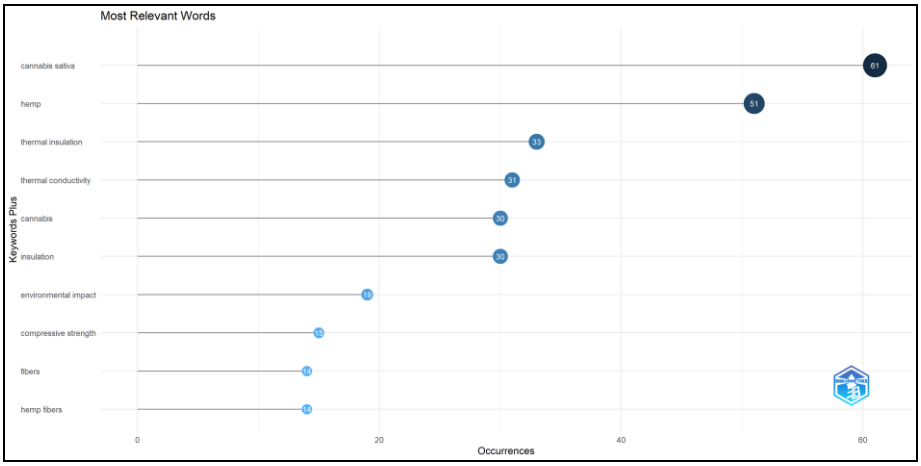

Fig. 7. Most relevant words.

The word cloud visually emphasizes the dominance of "cannabis," "hemp," and "insulation," with "thermal conductivity" also appearing significant, which aligns with the quantitative data. This visual aggregation illustrates how central these concepts are to the discourse in the field. Meanwhile, the network visualization from VOSviewer provides an insightful depiction of how these keywords are interconnected. Key terms such as "cannabis sativa" and "hemp" are strongly linked with "thermal insulation" and "thermal conductivity," showing that discussions around the plant material are often related to its application in thermal and insulation properties. The visualization also reveals clusters that connect "environmental impact" with life cycle assessments, indicating an interest in the broader ecological implications of using these materials.

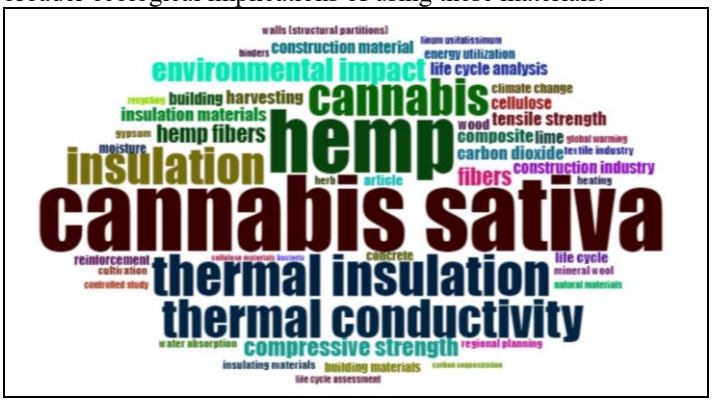

Fig. 8. Word cloud.

The interconnections between keywords suggest that while the core focus is on the material properties of hemp and its derivatives, there is a significant exploration of the implications for building construction and environmental sustainability. This research is not only about improving insulation materials but also about advancing sustainable construction practices. The emphasis on "thermal insulation" and "thermal conductivity" alongside "hemp fibers" and "environmental impact" reflects a holistic approach to developing building materials that are not only efficient but also environmentally beneficial.

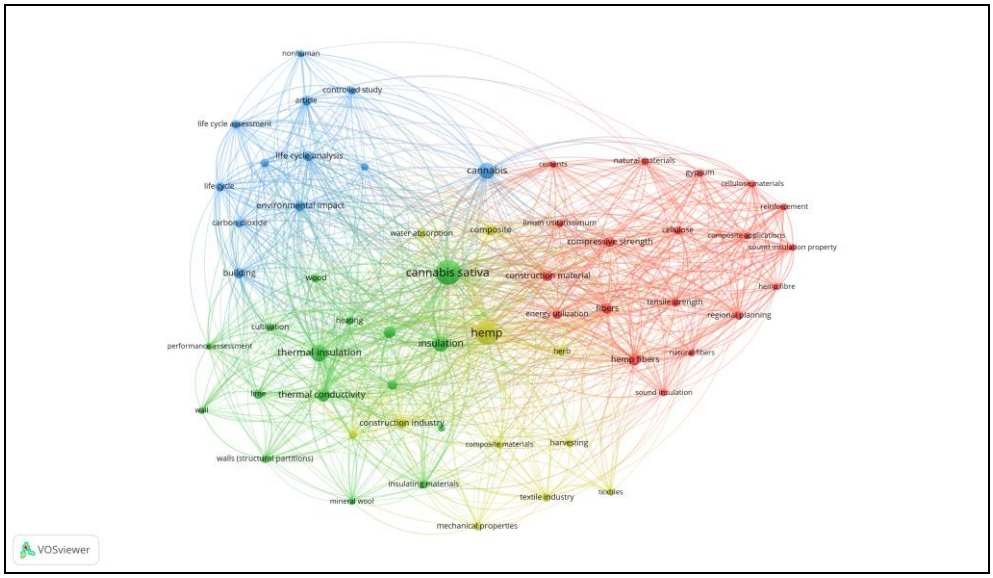

Fig. 9. Keywords co-occurrences.

4 Conclusion

The bibliometric analysis on the use of cannabis-based composite materials in building insulation has illuminated several critical insights. Firstly, there is a growing interest in this research area, evidenced by publication trends with peaks that likely correspond to technological advancements or increased funding. Predominantly, institutions in Northern and Eastern Europe, particularly Latvia and Finland, are spearheading this research, suggesting a regional hub of expertise and innovation in sustainable materials. Papers within this field are highly cited, reflecting their foundational impact and the active collaboration among researchers, especially notable in international partnerships involving France. The analysis also reveals that "cannabis sativa," "hemp," "thermal insulation," and "environmental impact" are frequently discussed topics, emphasizing the material's applicability and ecological benefits.

Considering the findings, future research should aim to diversify study contexts beyond the current European focus, potentially offering broader applicability and comparative insights from different climatic and regulatory environments. There is a significant opportunity to deepen investigations into the life cycle impacts of cannabis-based composites, which would help clarify their environmental advantages and potential drawbacks. Furthermore, adopting interdisciplinary approaches could propel forward the

integration of material science, environmental sustainability, and architectural design, fostering innovative solutions that address both performance and sustainability. Additionally, conducting long-term performance studies on cannabis-based insulation materials would be invaluable, providing data on their durability and cost-effectiveness relative to traditional insulation options.

The exploration of cannabis-based composite materials is set to substantially influence the field of sustainable building materials. Their excellent thermal insulation properties coupled with reduced environmental impacts align well with global sustainability objectives, such as lowering energy consumption and minimizing carbon footprints in construction. As research continues to advance, these materials may not only meet but potentially exceed current energy efficiency standards, offering significant contributions to the construction industry's shift towards sustainability. The continued development and implementation of cannabis-based materials could revolutionize building practices, making them more sustainable and environmentally friendly.

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