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Original Article

The Potential of Recycled Plastic Bricks: A Bibliometric Study on Carbon Footprint Reduction and Structural Properties

Albert Jorddy Valenzuela Inga[1], Yefry Huincho Quispe[1,2], Heydi Karina Hinostroza Maravi[1], Deyvid Froilán Matamoros Paitán[1], Carlos Javier Huaman Albino[1,*], Gonzalo Genaro Crespo Troya[3]

[1]*Universidad Continental, Huancayo, Perú.*
[2]*Department of Research and Training, ECOS Foundation, Peru.*
[3]*Universidad Católica de Cuenca, Cuenca, Ecuador.*

[1]*Corresponding Author : 70802620@continental.edu.pe*

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Abstract *- The construction sector faces environmental challenges, including high energy consumption and pollution from building material production. This study presents a bibliographic review evaluating the use of recycled plastic bricks, employing the Scopus database and VOSviewer software to analyze data and extract insights. Key aspects considered include carbon footprint reduction, thermal insulation, and compressive strength: bibliometric analyses identified frequently occurring keywords, leading research countries, and global publication trends. The results indicate the primary adoption of these bricks in countries with growing infrastructure needs and sustainable development potential. However, Peru exhibits a research gap in this area. Recycled plastic bricks offer environmental advantages, from material sourcing through recycling to application and disposal, contributing to sustainable construction. This study emphasizes responsible plastic waste recycling for eco-friendly building materials, reducing the carbon footprint, enhancing thermal performance in cold climates, and ensuring high compressive strength.*

Keywords *- Recycled bricks, Carbon footprint reduction, Compressive Strength, Scientometric.*

1. Introduction

Plastic pollution has been and continues to be a significant threat to ecosystems. Of the 9.2 billion tons of plastic produced between 1950 and 2020, approximately 7 billion tons have become plastic waste [1], accumulating in landfills or being discarded into rivers, lakes, and seas.

This has contributed to the decline of aquatic species, with an estimated 99% of seabirds having ingested plastic. Moreover, marine debris poses a threat to over 600 species, 15% of which have been affected by plastic ingestion and entanglement [2].

Many animals either ingest or become entangled in plastic waste, often leading to suffocation and death [3].

In the Peruvian context, as illustrated in (Figure 1), plastic waste is frequently discarded into irrigation canals in the city of Huancayo, obstructing water flow and contributing to water pollution. Plastic has a significant environmental impact, negatively affecting ecosystems, air quality, and climate [4]. When irresponsibly discarded in aquatic ecosystems, it breaks down into microplastics that contaminate the food chain of wildlife [5, 6].

Likewise, plastics disposed of in agricultural areas pollute the soil, while their incineration releases toxins harmful to the atmosphere [7]. Furthermore, chemicals present in plastics can interfere with the human hormonal system, reaching food and drinking water through microplastics [8].

To mitigate the impact of plastic pollution, it is crucial to reduce single-use plastics, improve recycling processes, and promote environmental education [9].

Some nations have implemented responsible production and consumption practices, which could significantly reduce the costs associated with plastic manufacturing [10].

In South American countries, legislation has been proposed to promote plastic reduction, reuse, and rationalization, prioritizing biodegradable materials [11].

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Fig. 1 Plastic waste

The construction sector faces two primary challenges: the rapid escalation in concrete demand driven by population growth and construction and demolition waste management. Furthermore, brick production, the second most utilized building material, generates significant emissions during manufacturing, including soot and various pollutants due to its dependence on fossil fuels for firing. Discontinuing this production proves challenging, as it represents a key economic sector in many countries, particularly South Asian nations such as Bangladesh [12].

A scientometric review by [13] evaluated the environmental impact of construction and demolition waste and its mitigation through recycled brick as aggregate in concrete. The authors identified the sources and volume of published literature, investigated keyword co-occurrence patterns, analyzed author collaboration networks, determined frequently cited authors and articles, and examined regions actively engaged in utilizing brick waste for sustainable concrete construction.

In contrast to previous reviews, the present scientometric analysis focuses on eco-friendly bricks that incorporate innovative materials designed to mitigate pollution, reduce carbon footprint, and provide enhanced thermal insulation and compressive strength, thereby offering a viable solution for cities with high environmental impact. These bricks, manufactured through thermal induction processes utilizing recycled plastic, contribute not only to air quality improvement but also to overall sustainability in the construction sector.

2. Materials and Methods

A bibliographic review analysis provides a solid foundation for scientific publication, effectively supporting the central theme of the article. The Scopus scientific database was utilized for this study, facilitating access to relevant and up-to-date information. The bibliographic analysis was conducted using VOSviewer, which enabled a global-level study.

First, the information obtained from Scopus allowed for the generation of tables and graphs supporting decision-making on the topic and creating a stratified bibliographic framework. Second, VOSviewer version 1.6.7, a software tool designed to construct and visualize bibliometric networks, was employed.

This tool enables access to journals, researchers, and publications, facilitating the construction of networks based on citations, bibliographic coupling, co-citations, and authorship relationships [14]. Using VOSviewer, it is possible to create networks of scientific publications, journals, researchers, research institutions, countries, and keywords [15].

Scopus is recommended due to its superior accessibility compared to other bibliographic databases [16, 17]. It is important to note that the color of an item in VOSviewer is determined by user-defined settings; if items lack assigned scores or colors, overlay visualization will not be available [18]. The results obtained led to the identification of the following subtopics.

- Comprehensive data collection (1998–2024): The first phase focused on the keywords "Brick" and "Plastic wastes", analyzing academic articles and journals specializing in civil engineering and materials science. This search identified a wide range of relevant documents from multiple countries.
- Research on bricks and carbon footprint reduction (2012–2024): The second phase expanded the analysis to studies on bricks contributing to reducing the carbon footprint. Related to the keywords “carbon footprint “and “reduction”. This approach, based on articles and journals in civil engineering and materials science, provided an international perspective on this topic.
- Compressive strength analysis (2005–2024): The third phase examined the keywords "Brick", "Compressive Strength", and "Plastic wastes". This analysis identified studies exploring the compressive strength of bricks manufactured using plastic waste, contributing to the existing literature across various countries.

3. Results and Discussion

3.1. Bibliometric Analysis of Bricks Made from Plastic Waste

Since 1998, significant research has been conducted on the manufacturing of bricks using recycled plastic. As illustrated in (Figure 2), the number of studies was scarce in the early years; however, a notable increase is observed, reaching a peak of 33 related documents in 2024, the highest in the analyzed time series. In total, 206 relevant documents have been identified to date.

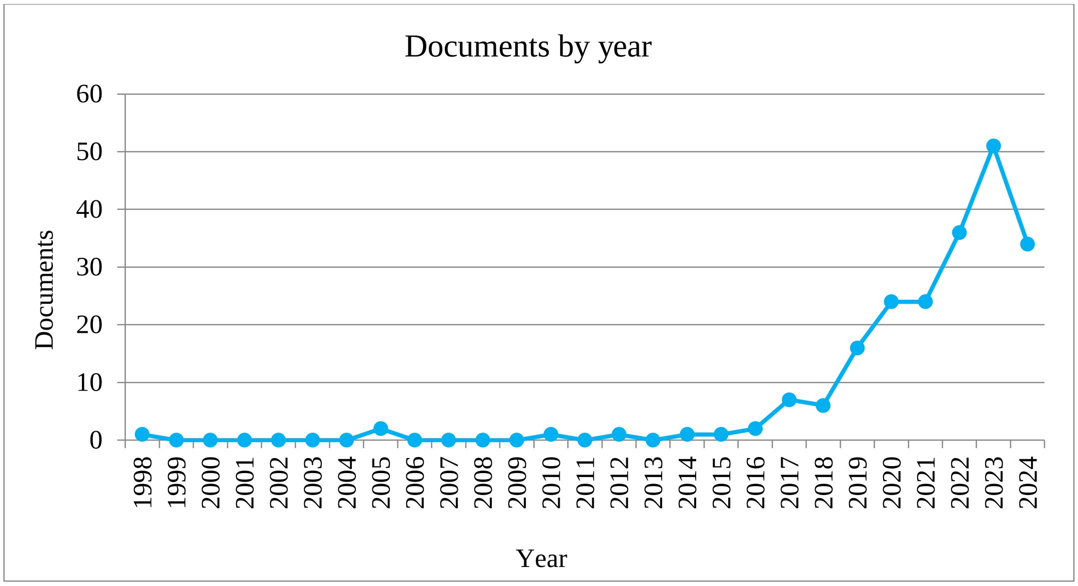

Fig. 1 Publication Trends: "brick" and "plastic waste" in scientific literature (Source: Scopus)

The geographical analysis reveals that research on this topic has been conducted in 10 countries, as shown in (Figure 3). Notably, India and Malaysia have contributed over 14 studies each. In a secondary tier, Indonesia, Australia, and South Africa have published more than 10 documents highlighting the relevance of continents such as Europe, America, and Asia in this field.

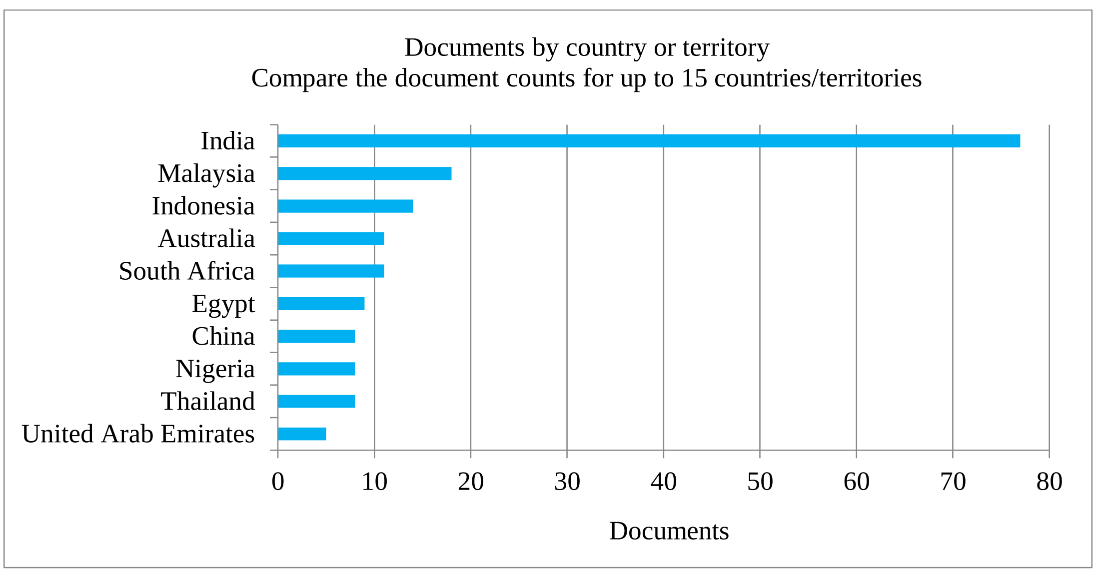

Fig. 2 Geographic distribution of research on "brick" and "plastic waste" (Source: Scopus)

The data analysis conducted using VOSviewer software enabled the identification of the most relevant keywords, such as "Brick" and "Plastic waste". This keyword identification provides a solid foundation for analyzing each of the reviewed documents. Additionally, a colorimetric representation illustrates the research growth from 2019 to 2023, as depicted in (Figure 4).

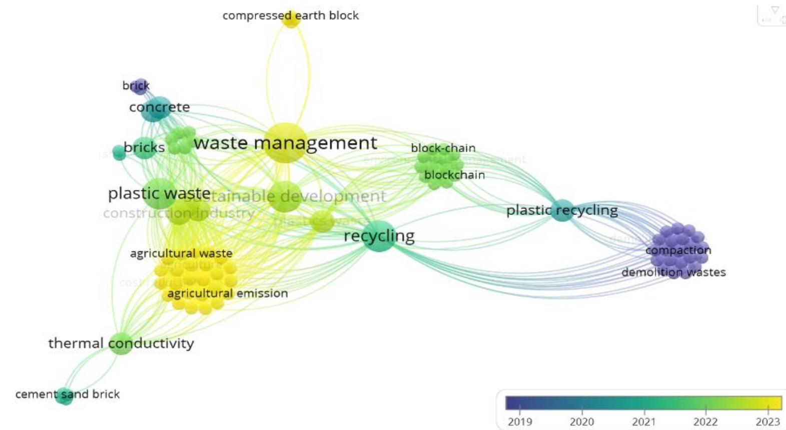

Fig. 3 Network analysis of "brick" and "plastic waste" keywords (Source: VOSviewer)

3.2. Bibliometric Analysis of Bricks that Reduce Carbon Footprint

Since 2012, significant research has been conducted on producing bricks using recycled plastic. As illustrated in (Figure 5, the number of studies was initially low; however, 67 related documents were recorded in 2022 and 2023, and 45 documents have been identified in 2024. The geographical analysis reveals that research in this field has been conducted in ten countries, as shown in (Figure 6). India stands out with more than two published studies, while Australia, Austria, China, France, Latvia, Malaysia, Mexico, Romania, and Singapore have each contributed one document.

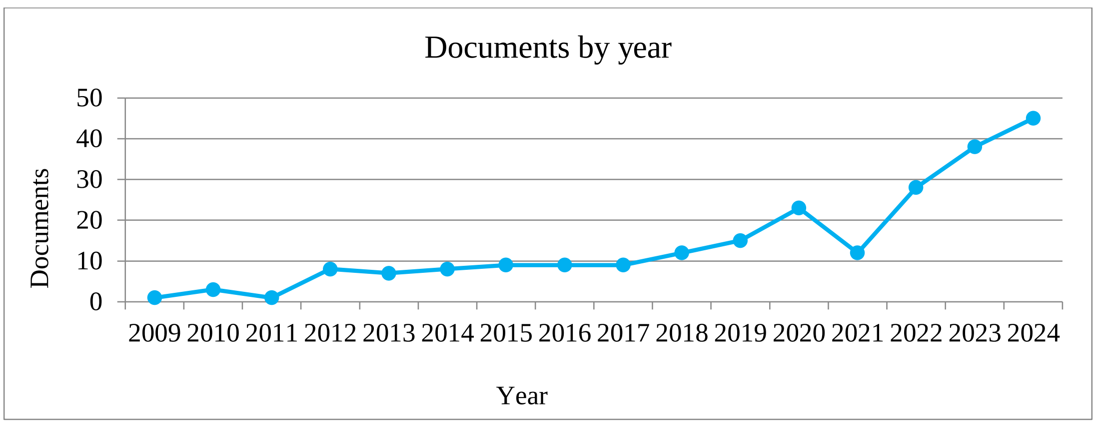

Fig. 4 Publication trends: "brick" and "carbon footprint" (Source: Scopus)

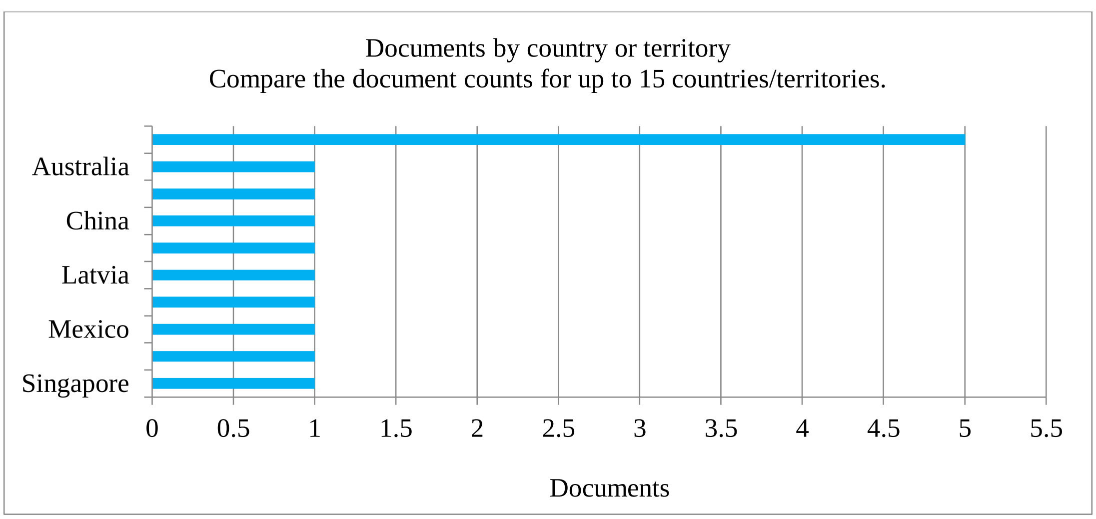

Fig. 5 Geographic Distribution of Research on “Brick” and “Carbon Footprint” (Source: Scopus)

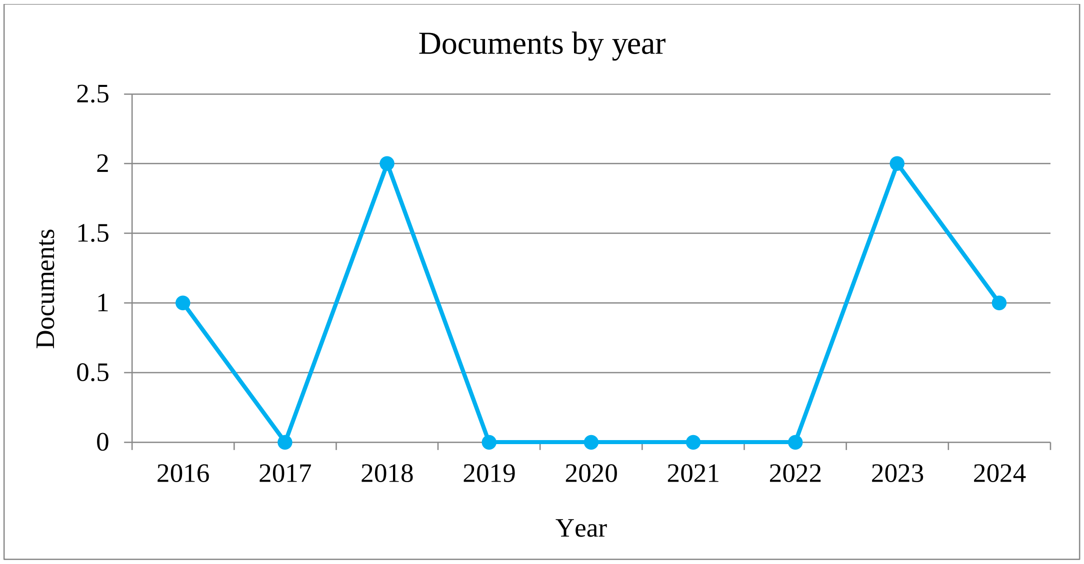

Fig. 6 Number of publications per year featuring "brick" and "carbon footprint" (Source: Scopus)

This distribution suggests an increasing global interest in using recycled plastics in construction. (Figure 7) depicts the publications trends per year featuring keywords “Brick” and “Carbon Footprint”. The data analysis using VOSviewer software and utilizing data from Scopus identified the most relevant keywords, "Brick" and "carbon footprint", which provide a strong foundation for reviewing each of the analyzed documents. Additionally, a colorimetric representation illustrates the growth of research from 2010 to 2025, as depicted in (Figure 8).

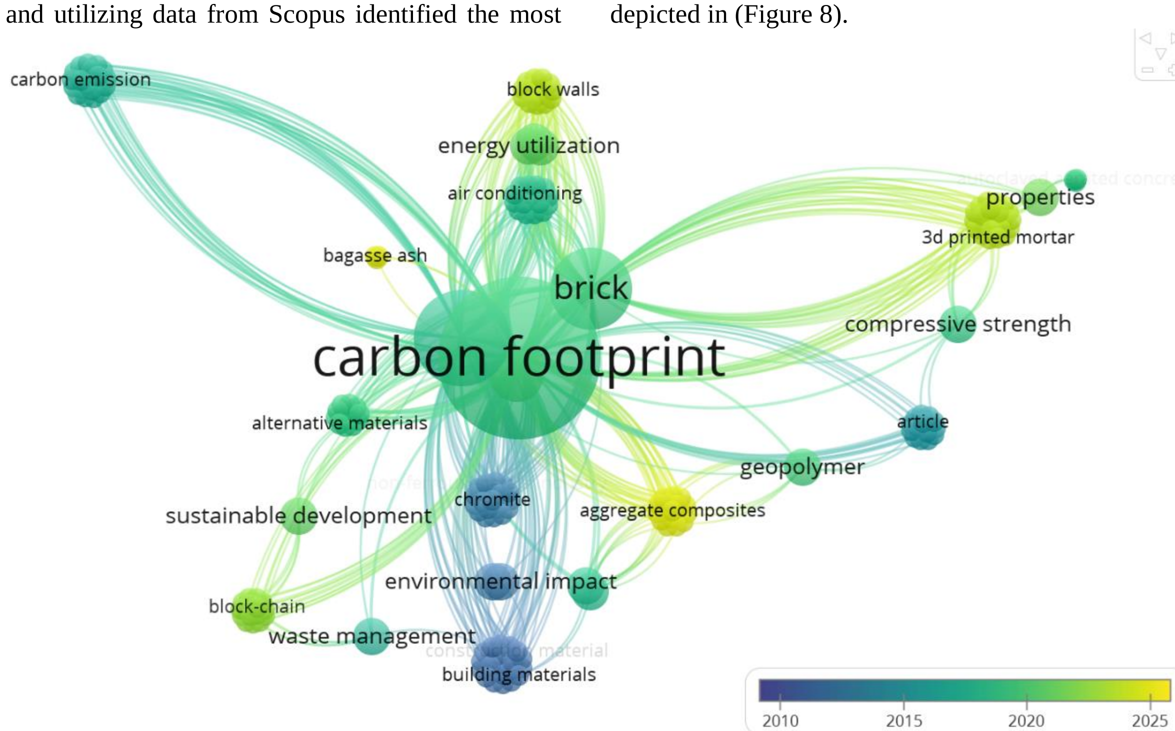

Fig. 8 Network analysis of "brick" and "carbon footprint" keywords (Source: VOSviewer)

3.3. Bibliometric Analysis of Bricks Made from Plastic Waste and Compressive Strength Evaluation

Since 2005, significant research has been conducted on producing bricks using recycled plastic. As illustrated in (Figure 9), the number of studies was initially low; however, 28 related documents were recorded in both 2021 and 2023, and 19 documents have been identified so far in 2024. This increase in scientific literature suggests a growing interest in the sustainability of construction materials.

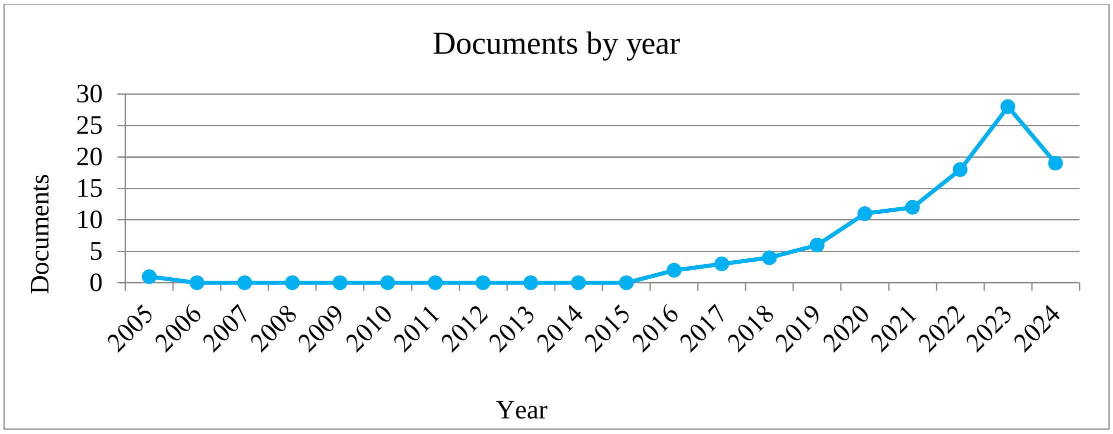

Fig. 9 Publication trends: "brick", “plastic waste”, and “compressive strength

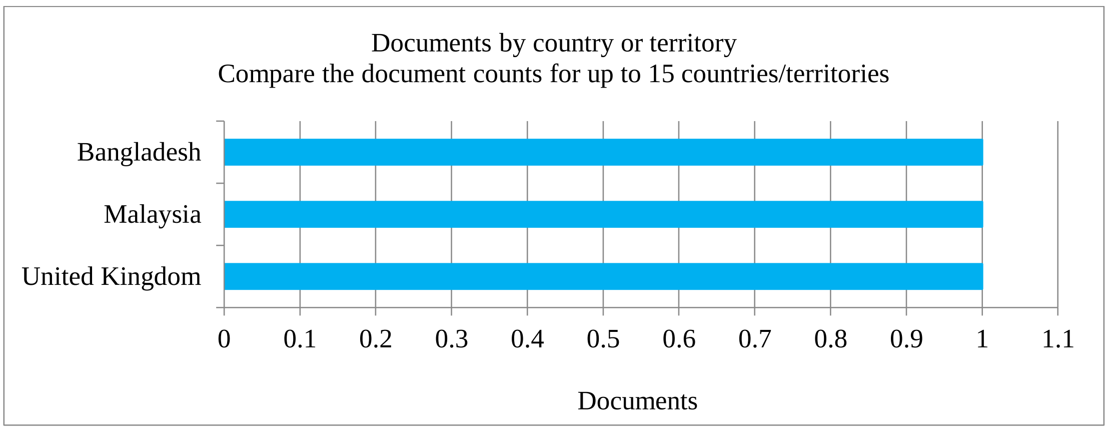

Fig. 10 Geographic distribution of research on “brick”, “plastic waste”, and “compressive strength” (Source: Scopus)

The geographical analysis reveals the participation of three countries in this research area, as shown in (Figure 10). In this context, Bangladesh, Malaysia, and the United Kingdom contributed one document, indicating a limited but noteworthy international collaboration in studying eco-friendly bricks. Additionally, a colorimetric representation illustrates the growth from 2020 to 2024, as depicted in (Figure 11).

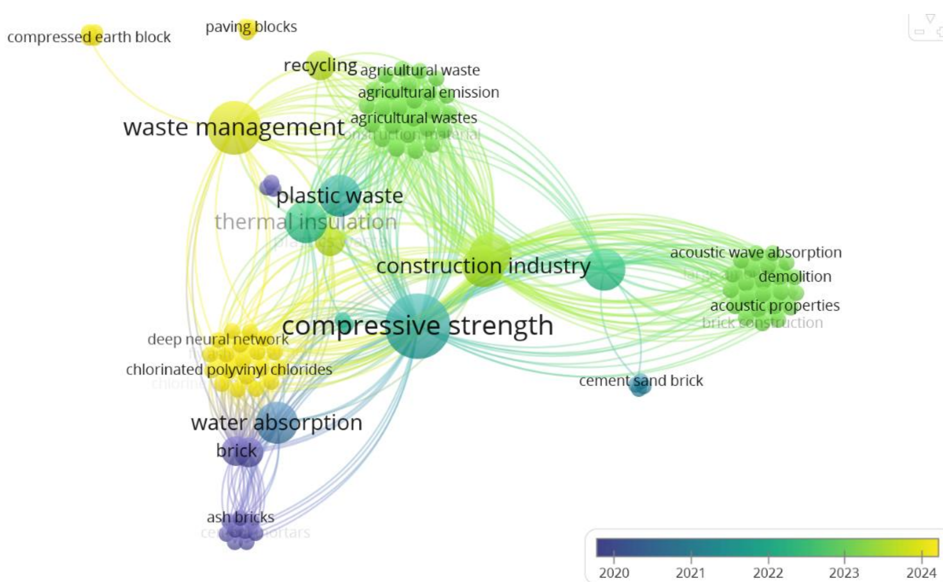

Fig. 11 Network analysis of “brick”, "plastic wastes” and "compressive strength" keywords (Source: VOSviewer)

3.4. Bibliometric Analysis of Recycled Plastic Bricks for Thermal Insulation ("Plastic Waste," "Thermal," "Insulating," and "Brick")

Since 2012, research on the fabrication of bricks using recycled plastic has continued. As illustrated in (Figure 12), although the number of studies was initially low, two related documents were recorded in 2022 and 2023, and three documents have been identified so far in 2024. This pattern suggests a growing trend in exploring sustainable construction alternatives, which could positively impact carbon footprint reduction and promote eco-friendly building practices.

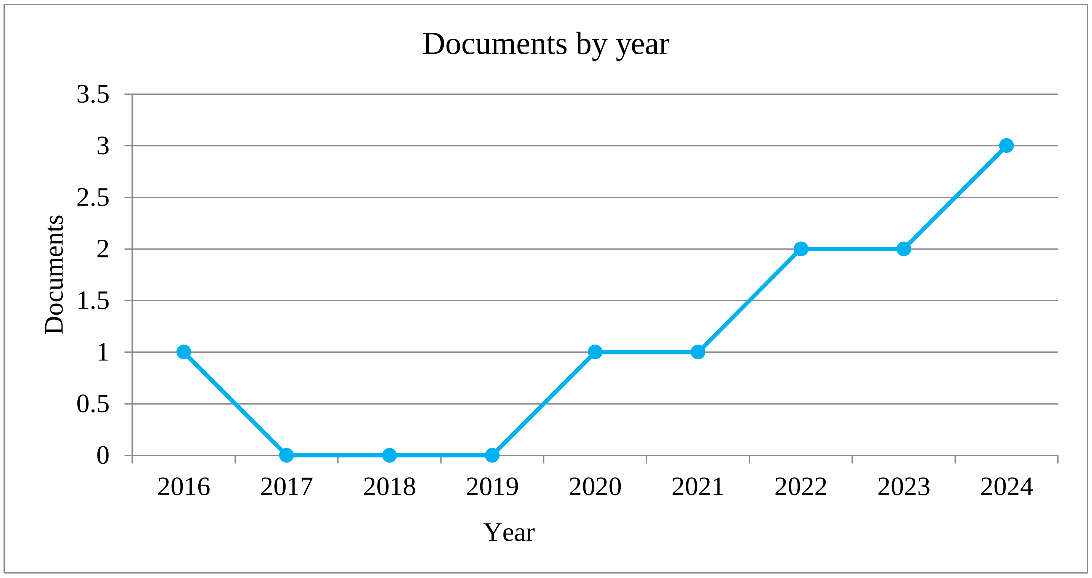

Fig. 12 Number of publications per year featuring "plastic wastes", "thermal", "insulating", and "brick" (Source: Scopus)

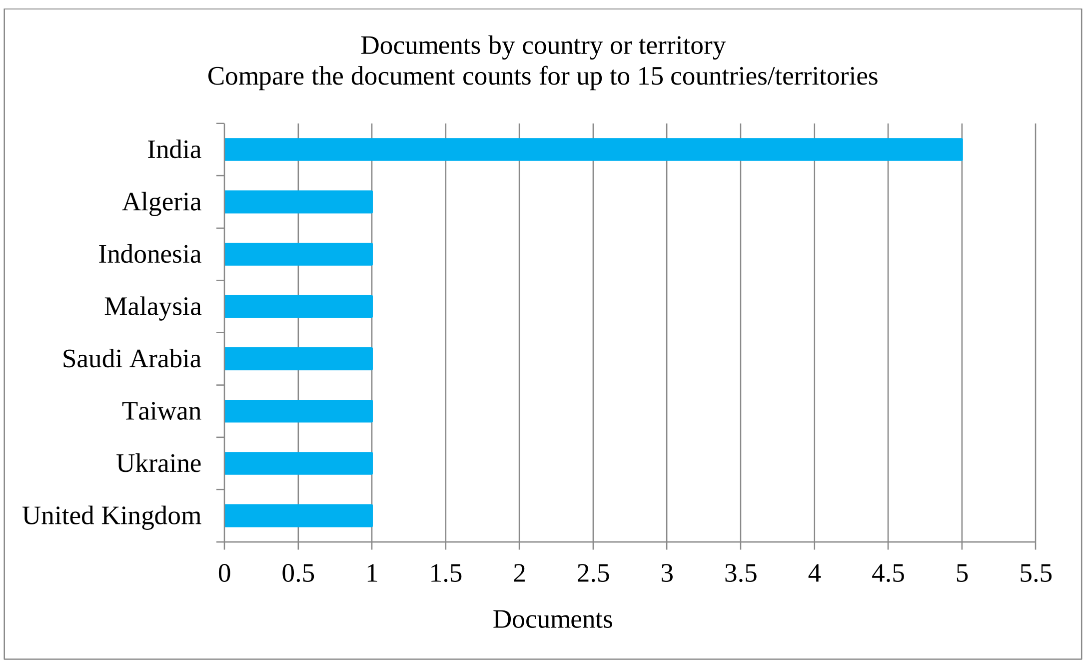

Fig. 13 Geographic distribution of research on "plastic wastes", "thermal", "insulating", and "brick" (Source: Scopus)

Research on recycled plastic bricks has been conducted in eight countries, as detailed in (Figure 13). In this context, India stands out with more than two published studies, while Indonesia, Algeria, Malaysia, Saudi Arabia, Taiwan, Ukraine, and the United Kingdom have each contributed one document. Additionally, a colorimetric representation illustrates the research growth from 2020 to 2023, as depicted in (Figure 14).

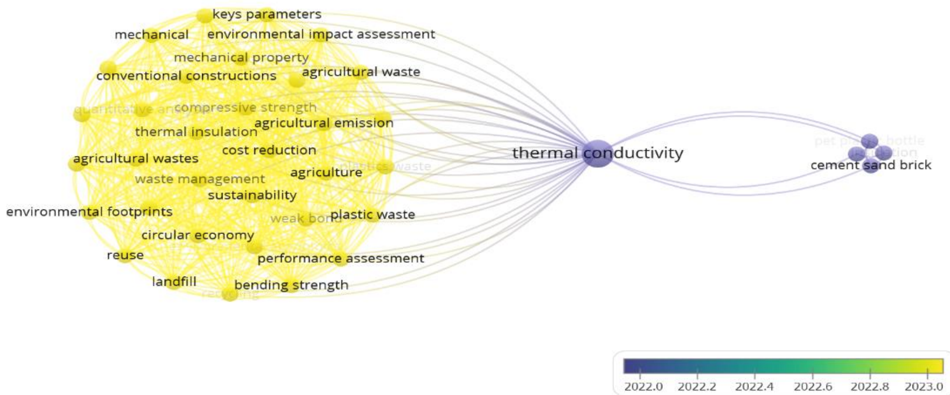

Fig. 14 Network analysis of "plastic wastes", "thermal", "insulating", and "brick" keywords (Source: VOSviewer)

3.5. Bricks Made of Plastic Waste

The recycling of plastics dates back to the 1960s and 1970s, although it did not gain widespread adoption until the 2000s, driven by technological advancements, stricter regulations, and increasing social awareness. Today, the ability to recycle a wider range of plastics has improved significantly. However, the concept of sustainability extends beyond mere recycling. This article aims to explain the industrial plastic recycling process [19].

Recycling has evolved from being merely an environmentally responsible practice to becoming a key component of sustainability strategies adopted by companies and governments [20]. Technological advancements continue to facilitate the production of recyclable and biodegradable plastics, contributing to the reduction of environmental impact.

Manufacturing bricks from recycled plastics presents a simpler and more cost-effective process, making it a viable solution for Small and Medium-Sized Enterprises (SMEs) [21]. Additionally, the use of these bricks not only reduces the amount of plastic waste entering the environment and helps lower greenhouse gas emissions.

Bricks made from recycled plastic are stronger and lighter than traditional bricks, facilitating their transportation and handling. A notable example is materials engineer Nzambi Matee, who developed an innovative method to recycle plastic waste into bricks, significantly contributing to global environmental impact mitigation [22].

(Figure 15) illustrates the key advantages of recycled plastic bricks, which include

- Thermal insulation
- Acoustic insulation
- Imperviousness to liquids
- High compressive strength
- High tensile strength
- Impact energy absorption
- Recyclability and reusability

Fig. 15Advantages of recycled plastic bricks

3.6. Recycled Brick Manufacturing Process

Manufacturing bricks made from recycled plastics involves careful selection and combination of materials. The key components include cement, silica, and foundry sand [23]. Additionally, the incorporation of Ground Granulated Blast Furnace Slag (GGBFS) and rice husk ash has been proposed to enhance the final product's strength [24]. Clays also play a crucial role in the formulation of these bricks [25].

The recycled plastics used in this process include Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), and Low-Density Polyethylene (LDPE), among others. Cement is commonly used as a binding agent in the production of eco-friendly bricks [23-26].

Before incorporating recycled plastic into the mixture, it must meet specific quality conditions to ensure optimal performance. The preparation process includes collection, sorting, and cleaning, with pressure washing being a critical step for impurity removal [23, 25].

The plastic is then air-dried to remove residual moisture [25, 27]. Once a homogeneous mixture is achieved, it is poured into steel moulds and subjected to a compaction process, which can be performed using a hydraulic press at 5 tons of pressure [23] or steel rods in some cases

The next step is drying, where some studies suggest a 5-hour drying period, as plastics melt at 249°C, acting as a binding agent [26]. When cement is used as a binder, a 24-hour demolding time is typically required [25, 26]. The bricks then undergo a curing process in a controlled environment, allowing them to achieve maximum strength and durability [24]. Finally, the product is subjected to a rigorous quality control process, ensuring compliance with specific national regulations and standards.

Research has determined that the optimal PET dosage in the mixture is 20% of the total weight, achieving a compressive strength of 52 MPa, which surpasses conventional clay bricks and fly ash bricks [25]. Other studies suggest that higher amounts of recycled plastic waste can be used, reaching up to 24% [23] and even 35% [26]. A recent study proposes a maximum dosage of 50% plastic waste to achieve optimal mechanical properties in masonry structures [24]

3.7. Environmental Impact of Bricks

Over more than 11,000 years of history, handmade bricks have become one of the most widely used construction materials. However, their manufacturing process is also known to be one of the most polluting, particularly in kilns that release harmful gases into the atmosphere. This activity not only contributes to environmental degradation but also weakens the ozone layer, increasing UV radiation exposure [28].

Replacing highly polluting materials, such as cement, with recycled plastics offers an effective strategy to reduce environmental impact and mitigate plastic pollution through waste reutilization [29]. According to an environmental impact analysis based on the Swiss Ecoinvent database, the most harmful construction materials include aluminum, which generates 8.57 kg of CO_2 per kilogram produced, followed by expanded polystyrene (7.34 kg CO_2/kg), rigid polyurethane foam (6.79 kg CO_2/kg), PVC (4.27 kg CO_2/kg), and copper (2.00 kg CO_2/kg). In contrast, the most sustainable materials are wood composites, cork, and lightweight clay bricks [30].

(Figure 16) illustrates a house built using recycled plastic, highlighting its key features: adaptability and design, speed of construction, thermal and acoustic insulation, and environmental sustainability. This innovative approach not only promotes sustainability but also redefines possibilities in modern construction.

Fig. 7 Prototype house constructed from recycled plastic bricks

3.8. Reducing Carbon Footprint

Reducing carbon footprint is a critical objective that necessitates the adoption of sustainable practices across various sectors. This includes the selection of renewable energy sources, enhancing energy efficiency in residential and industrial settings, and promoting public transportation or electric vehicles, which contribute to a significant reduction in pollutant emissions [31]. Furthermore, adjustments in dietary habits, such as prioritizing locally sourced products and reducing the consumption of animal-based foods, have been identified as effective measures to mitigate the environmental impact associated with food production. Implementing waste reduction, reuse, and recycling strategies, combined with efficient water management, substantially decreases waste generation [32].

In addition, reforestation initiatives and the conservation of green spaces play a fundamental role in CO_2 capture and biodiversity preservation, thereby contributing to climate change mitigation [33]. When integrated into a comprehensive sustainability framework, these measures not only support environmental resilience but also enhance long-term ecological stability.

4. Discussion

Research in the field of sustainable construction serves as a fundamental starting point for fostering investment in the development of brick prototypes that align with local conditions, thereby contributing to the advancement of sustainable construction materials in Peru. Through a comprehensive bibliographic analysis supported by

VOSviewer, several significant correlations have been identified. First, a relationship between "Brick" and "Plastic wastes" has been observed in 24 studies since 1998. Second, the connection between "Brick", "Reduces", and "Carbon footprint" has been documented in 5 studies since 2012. Additionally, the interrelation between "Brick", "Compressive Strength", and "Plastic wastes" has led to 28 studies since 2005. Finally, the association between "Plastic wastes", "Thermal", "Insulating", and "Brick" has been the focus of 2 studies from 2012 to the present.

The integration of plastic waste in brick manufacturing has the potential to alter the material's microstructure, a crucial factor in ensuring durability and mechanical performance [29]. This approach not only provides a cost-effective alternative to traditional materials but also reduces production costs and enhances economic feasibility [34]. To achieve high-strength bricks, it is essential to determine the optimal proportion of PET, HDPE, and LDPE through compressive strength tests [27].

The economic viability of plastic recycling is enhanced when sufficient material is available, alongside its potential to improve the properties of construction aggregates [35]. Given the rising fuel prices and the urgent need to reduce emissions, plastic recycling, particularly through pyrolysis, emerges as an effective solution for waste management and sustainability.

The production process of plastic-based bricks requires less energy than conventional methods, thereby lowering the carbon footprint and reducing landfill costs, which benefits future infrastructure projects [29]. Also, the use of recovered plastic mixtures in combination with demolition aggregates, such as recycled concrete and crushed brick, for railway ballast applications has been studied [36]. Moreover, the potential of these composite mixtures for carbon capture has been evaluated, demonstrating their role in reducing the carbon footprint in construction [37]. These findings highlight the need to advance research and application of sustainable bricks in Peru, fostering a more responsible and efficient approach to construction practices.

Recent studies have demonstrated that bricks incorporating recycled plastic exhibit significant advantages over conventional bricks, particularly in compressive strength and insulating properties. These characteristics make them a viable alternative for various construction applications [29].

Specifically, plastic-based bricks have been shown to double the strength of clay bricks, and their combination with demolition aggregates enhances abrasion resistance and optimizes energy absorption [27]. Experimental results confirm the robustness of these materials, as they meet high standards of compressive and tensile strength, with a minimum wet strength of 3 MPa in all tested samples [37].

Research on recycled plastic bricks has revealed notable improvements in mechanical strength, durability, and thermal insulation, positioning them as a more sustainable and energy-efficient alternative in construction [29].

Furthermore, a study incorporated experimental methodologies and machine learning techniques to evaluate these properties, indicating that plastic-based bricks provide better insulation than clay bricks and exhibit strong adhesion to mortar [29]. Although mixed plastic waste is not directly reusable, its low cost, accessibility, and long lifespan offer significant advantages in construction applications [38].

Novel emerging technologies aimed at converting plastic waste into valuable materials emphasize its potential for thermal insulation [39]. The thermal conductivity values obtained ranged from 0.2 to 0.3 W/m·K, suggesting that these composite materials possess high potential as insulating materials [37]. This is attributed to plastics' inherently low thermal conductivity, making them effective for thermal insulation in buildings [39].

5. Conclusion

This study has provided significant insights into the environmental challenges the construction sector poses over the past five years. The findings indicate a notable increase in research focused on sustainable solutions based on recycled plastics, which has contributed to a reduction in environmental pollution. This analysis not only underscores the importance of plastic reuse but also highlights its potential as a decontaminating agent, aiding in restoring marine ecosystems. These conclusions are based on an extensive bibliographic review conducted through the Scopus database.

The development of environmental innovations is crucial in the construction sector, given that this industry accounts for 55.2% of total waste generation, of which 10.2% corresponds to plastics, 6.5% to paper and cardboard, 2.9% to glass, 2.5% to metals, and 22.7% to other materials [40]. This scenario presents a critical challenge: the urgent need to address both marine and terrestrial pollution through effective waste management strategies.

There is a clear need for further studies to assess the feasibility and effectiveness of implementing bricks made from recycled plastics in the construction industry. Therefore, research in this area is recommended to continue, encouraging developing countries to actively engage in this field.

Specifically, these initiatives could greatly benefit nations such as Peru, which experience high plastic waste generation due to their climatic diversity. Reducing environmental pollution would contribute to the preservation of the planet and support the recovery of marine ecosystems, fostering biodiversity essential for ecological balance.

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