Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Civil

Tesis

Review of the hemp-based brick that purifies air pollution, reduces humidity and is a thermal insulator: An innovative solution to reduce environmental pollution in the construction industry

Katherine Revatta Alvites
Delta Margoth Chuco Solorzano
Jimmy Emilio Canchari Ramon
Rafael De la Cruz Casaño

Para optar el Título Profesional de
Ingeniero Civil

Huancayo, 2023

PUBLICACIÓN - CHUCO - REVATTA - CANCHARI

INFORME DE ORIGINALIDAD

47%	46%	13%	13%
INDICE DE SIMILITUD	FUENTES DE INTERNET	PUBLICACIONES	TRABAJOS DEL ESTUDIANTE

FUENTES PRIMARIAS

1	www.researchgate.net Fuente de Internet	23%
2	growingscience.com Fuente de Internet	21%
3	Submitted to University of Sydney Trabajo del estudiante	1%
4	hdl.handle.net Fuente de Internet	<1%
5	Submitted to University of Arizona Global Campus (UAGC) Trabajo del estudiante	<1%
6	Submitted to Centre of Excellence for Library Services at Jordanian Private Universities Trabajo del estudiante	<1%
7	tailieu.vn Fuente de Internet	<1%
8	mafiadoc.com Fuente de Internet	<1%

Excluir citas	Apagado	Excluir coincidencias	Apagado
Excluir bibliografía	Apagado		

PUBLICACIÓN - CHUCO - REVATTA - CANCHARI

INFORME DE GRADEMARK

NOTA FINAL

/0

COMENTARIOS GENERALES

Instructor

PÁGINA 1

PÁGINA 2

PÁGINA 3

PÁGINA 4

PÁGINA 5

PÁGINA 6

PÁGINA 7

PÁGINA 8

PÁGINA 9

PÁGINA 10

Contents lists available at GrowingScience

Journal of Project Management

homepage: www.GrowingScience.com

Review of the hemp-based brick that purifies air pollution, reduces humidity and is a thermal insulator: An innovative solution to reduce environmental pollution in the construction industry

Katherine Revatta Alvites[a], Delta Margoth Chuco Solorzano[a], Jimmy Emilio Canchari Ramon[a*] and Rafael De la Cruz Casaño[a]

[a]*Universidad Continental, Peru*

C H R O N I C L E

Article history:
Received: December 1, 2022
Received in revised format: December 29, 2022
Accepted: January 17, 2023
Available online: January 20, 2023

Keywords:
Hemp-based brick
Humidity reduction
Pollution purifier
Thermal insulation
Carbon dioxide

A B S T R A C T

In the construction industry there are several problems that negatively impact the environment from the process of obtaining materials, the construction of buildings and their use. That is why the bibliographic review research analyzes the use and application of the hemp-based brick with the support of the Scopus database and the VOSviewer software as data analytics, the characteristics of the brick were taken into account as well As an air pollution purifier, humidity reduction and thermal insulation, graphs related to these characteristics were obtained, highlighting the words with the highest frequency in the research, countries that published and bibliometric maps worldwide. The results help us determine that there is an application of this brick in countries with the greatest needs and growth and also in potential countries, however we believe that in Peru there is no analysis or interest in this brick. This hemp-based brick has positive advantages for the environment and is potentially ecological from the beginning of obtaining the materials, used in the construction of houses and then as waste, in these three phases it contributes to the environment. The purpose of the research is to be the beginning for future investments and research related to the hemp-based brick applied in the construction industry and the other objective is to motivate professionals to use and apply this brick that will have benefits for the environment.

1. Introduction

Global air pollution both indoors and outdoors generates four million deaths each year (Khadak et al, 2018) harming the health of the population, the construction sector worldwide involves the use of large amounts of resources and energy, likewise this sector emits a third of greenhouse gas emissions (Soulios et al., 2021) generating a great environmental impact that increases the existing gases and harmful to the air, this due to the consumption of energy and materials that are required for the construction of buildings, homes, houses and large-scale works (Di et al., 2021).

Construction in other countries such as India is experiencing great growth due to the increase in buildings, which increased the use of materials and illegal mining to obtain these materials such as brick, cement and sand (Rautray et al, 2019), which generates a problem since in this country there are deaths due to greenhouse gas emissions (Seay et al., 2021), likewise in the United States 1000 Americans die annually caused by extreme heat (Kandya & Mohan, 2018).

* Corresponding author.
E-mail address: 71571641@continental.edu.pe (J.E. Canchari Ramon)

doi: 10.5267/j.jpm.2023.1.001

Brick production kilns emit pollutants such as carbon monoxide (CO), sulfur dioxide (SO2) and nitrous oxides (NOx) (Hussain et al., 2022), with 9% of these emissions being emitted in India (Rautray et al.; 2019). Likewise, in Asia, kilns emit sulfur dioxide (SO2) and among others, these pollutants are emitted into the air, harming people's health and affecting the temperature of the Arctic (Brannon, 2021), therefore the growth of brick production of clay grows by 6.6% by 2030 increasing the negative impact for the air and health of the population (Brannon, 2021).

Environmentally friendly materials are the effective solution worldwide (Di et al., 2021), since they respect the environment and generate a micro climate in buildings to reduce energy consumption (Soulios et al., 2021), This is why technologies and innovation are looking for new solutions (Donatelli et al., 2017) such as brick that works as a heat insulator and purifies air pollution, thermal insulation through walls that inhibit heat continues to be a solution for many diseases caused by heat (Zach et al., 2012), at the same time this brick is considered the best option for thermal insulation (Zach et al., 2012). This brick is made possible with the application of hemp that is used in the construction industry (Donatelli et al., 2017) with the application of other essentials such as lime (Abdellatef, 2020) but its use in the construction field is still low (Abdellatef, 2020), but in order to obtain an efficient and effective brick for environmental problems.

For the aforementioned, a bibliographic analysis was carried out together with the VOSviewer software for a global analysis. The results obtained provide us with the following sub-items.

2. Materials and methods

A bibliographic review analysis provides greater stability to a scientific publication to support a scientific basis, the subject of this article is identified in an ecological brick that purifies pollution, reduces humidity and thermal insulation made from hemp, being a solution for cities with high environmental impact. For the elaboration, the scientific tool offered by Scopus was used.

First, the analysis provided by Scopus was used, which provided us with tables to make decisions regarding the subject and provide stratified bibliographic support based on the ecological brick that purifies air pollution, reduces humidity and thermal insulation made based on hemp.

Second, an analysis of the bibliometric map of scientific contribution was used with the VOSviewer software, which allows us to show maps in different ways with a minimum number of 100 elements to analyze (van Eck & Waltman, 2010), it also has the purpose of labeling words. of greater frequency used in the articles and with the purpose of being visible the nodes that are shown in the graphs (Ding Ying et al., 2014). For this, the Scopus data was obtained in formats (.csv) that were obtained from the beginning of the investigation until December 2022. The criteria analyzed were as follows:

- First, the data was obtained from 2004 to the year 2022, with the following research words “brick” made from “hemp” identified in articles, papers related to the subject and civil engineering and materials science magazines, which documents were detected in various countries.
- Second, the data was obtained from 1990 to the year 2022, with the following research words "brick" that “reduces” “humidity” identified in articles, papers related to the subject and civil engineering and materials science magazines, which documents were detected in various countries.
- Third, the data was obtained from 2007 to the year 2022, with the following research words “purifies” the “pollution” of the “air” identified in articles, papers related to the subject and civil engineering and materials science magazines, the which documents were detected in various countries.
- Fourth, the data was obtained from 2010 to 2022, with the following research words "hemp" the "thermal" of the "insulating" and "Brick" identified in articles, papers related to the subject and civil engineering and environmental sciences magazines. materials, which documents were detected in various countries.

Figures 1, 3, 5, 7 and graphs 2, 4, 6, 8 were obtained with the data obtained from the previous points. These analyzes are the result of analyzing with the VOSviewer software and obtaining the relationship between each word and the great interaction between them.

3. Results

3.1 Biometric analysis of the brick made from hemp

Since 2004, investigations related to the subject of hemp-based brick manufacturing can be found in Fig. 1, we can see that the investigations are minimal at the beginning and with 13 related documents in the year 2022, this being the highest in all of them. the years, in addition, 67 related documents were found up to the present.

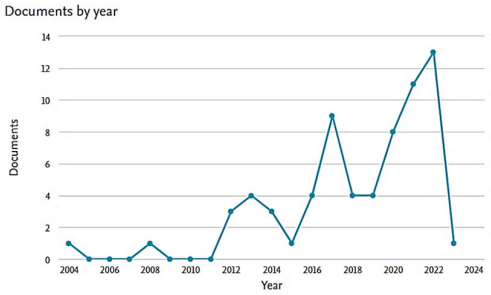


Fig. 1. Analysis and evolution of the words “brick” and “hemp” Source: Scopus scientific review

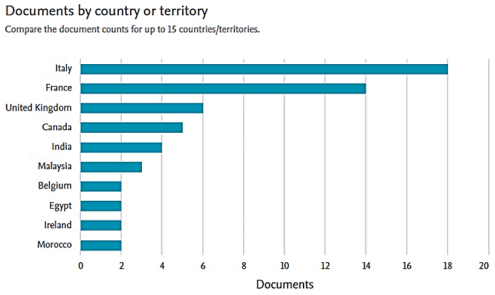
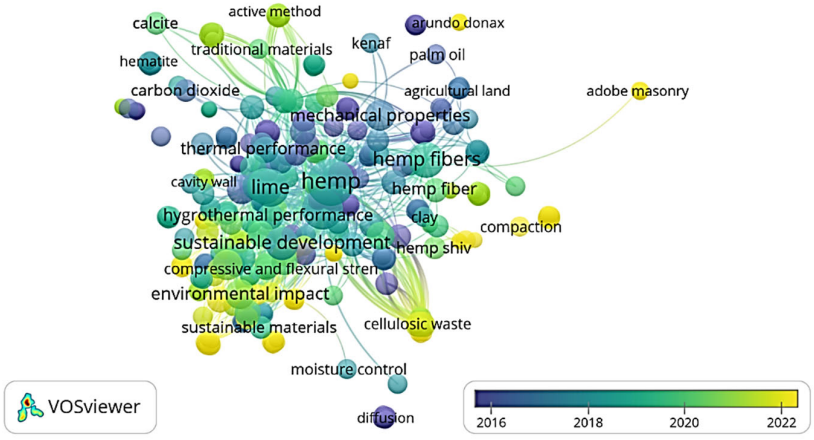


Fig. 2. Countries that published related to the words “brick” and “hemp” Source: Scopus scientific review

The interaction in the countries was found in 10 countries where it is shown in Fig. 2, where it is observed that there are countries such as Italy and France with more than 14 investigations carried out and secondly, we have Canada, the United Kingdom and India with more than 4 documents carried out. which are found in continents such as Europe, America and Asia as the main impactors of the research topic. The data mining analysis obtained through the VOSviewer software with the data obtained from Scopus, where the most related words were found, which are: Hemp, environmental impact and sustainable development, which gives us greater coherence to investigate each of the documents. , in addition, there is the colorimetry with respect to the century of growth from the year 2016 to the year 2022 as observed in Graph 1.



Graphic 1. Map of the analysis of words "brick" and "Hemp" with the highest interaction. Source: Obtained from VOSviewer.

3.2 Biometric analysis of brick that reduces humidity

Since 1990, you can find research related to the topic of brick that reduces humidity, in Fig. 3 we can see that the research is minimal at the beginning and for the year 2014 and 2017, 3 related documents were obtained for each year and for the 2022, 2 documents were obtained, in addition, 20 related documents were found to date.

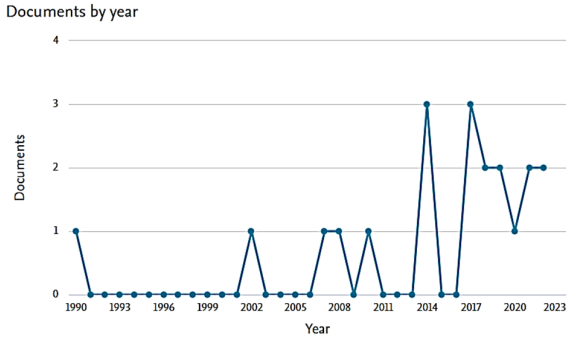


Fig. 3. Analysis and evolution of the words “brick” and “humidity” Source: Scopus scientific review.

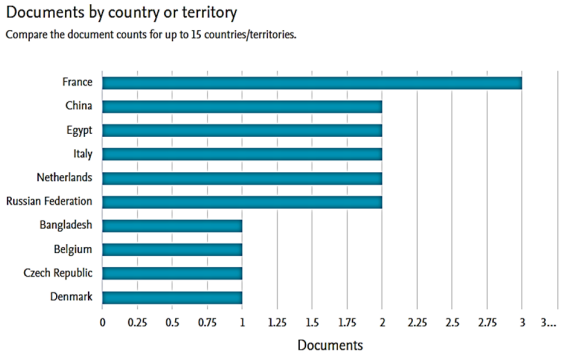
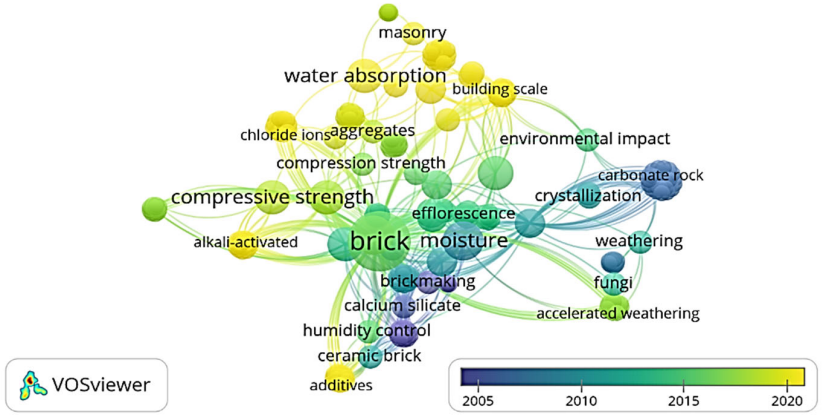


Fig. 4. Countries that published related to the words “brick”, “reduces” and “humidity” Source: Scopus scientific review.

The interaction in the countries was found in 10 countries where it is shown in Fig. 4, where it is observed that there are countries such as France, China, Egypt and others with more than 2 investigations carried out which are found in continents such as Europe, America, Asia and Africa as the main impactors of the research topic. The analysis of the data mining obtained through the VOSviewer software with the data obtained from Scopus, where the most related words were found, which are: Moisture, humidity control, brick which gives us greater coherence to investigate each of the documents, In addition, the colorimetry is available with respect to the century of growth from the year 2005 to the year 2020, as can be seen in Graph 2.



Graphic 2. Map of the analysis of words "brick", "reduces" and "moisture" with the highest interaction. Source: Obtained from VOSviewer.

3.3 Biometric analysis of the brick that purifies air pollution

Since 2007, investigations related to the topic of brick that reduces air pollution can be found in Fig. 5, we can see that the investigations are minimal at the beginning and with 3 related documents in 2017 and 2020, these being the highest in every year, in addition, 11 related documents were found up to the present.

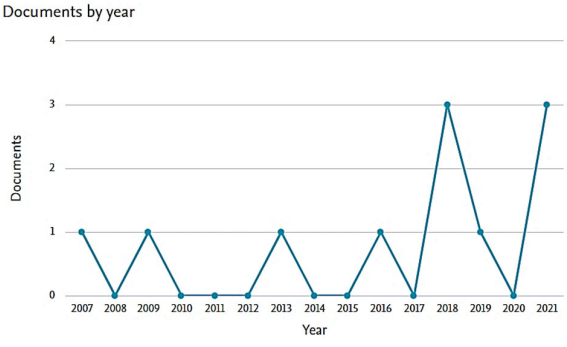


Fig. 5. Analysis and evolution of the words "brick", "reduces", "air" and "pollution". Source: Scopus scientific review.

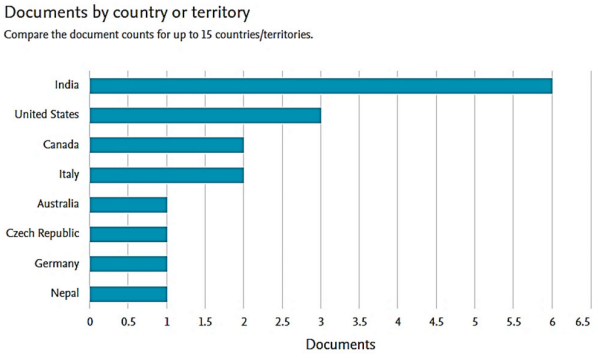
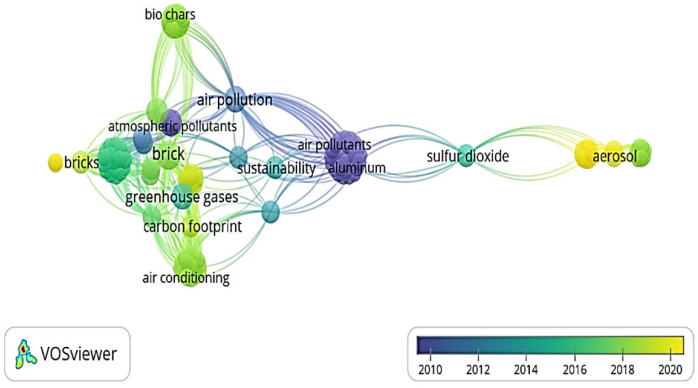


Fig. 6. Countries that published related to the words "brick", "reduces", "air" and "pollution". Source: Scopus scientific review.

The interaction in the countries was found in 8 countries where it is shown in Fig. 6, where it is observed that there are countries such as India with 6 related investigations, secondly, we have countries such as the United States, Canada, Italy with more than 2 investigations carried out which are They are found in continents such as America and Asia as the main impactors of the research topic.

The data mining analysis obtained through the VOSviewer software with the data obtained from Scopus, where the most related words were found, which are: Air pollution, brick, greenhouse gases, which gives us greater coherence to investigate each of the documents. In addition, there is the colorimetry with respect to the century of growth from the year 2010 to the year 2020 as shown in Graph 3.



Graphic 3. Map of the analysis of words “brick”, “reduces”, “air” and “Pollution” with the highest interaction. Source: Obtained from VOSviewer.

4. Biometric analysis of the brick that serves as thermal insulation of hemp

Since 2012, research related to the topic of hemp thermal insulating brick can be found in Fig. 7, we can see that the research is minimal at the beginning and with one document remaining until the year 2021, in addition, 5 related documents were found to date.

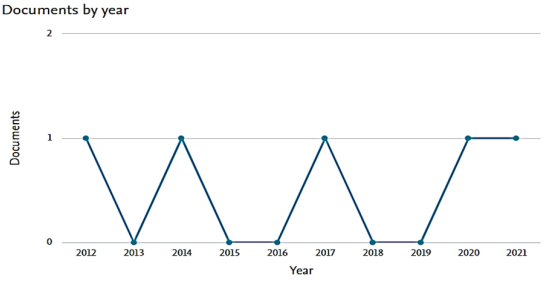


Fig. 7. Analysis and evolution of the words “hemp”, “thermal”, “insulating” and “brick” Source: Scopus scientific review.

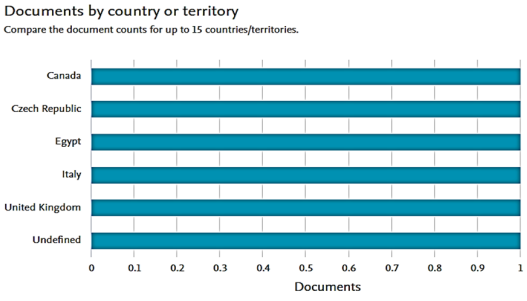
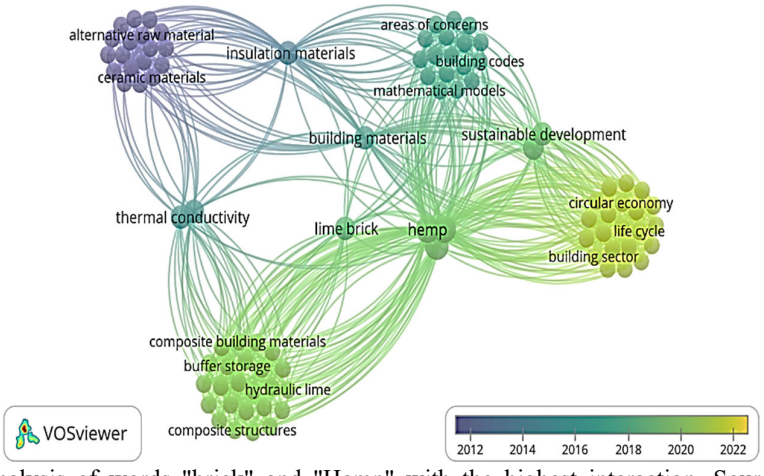


Fig. 8. Countries that published related to the words “hemp”, “thermal”, “insulating” and “brick”. Source: Scopus scientific review.

The interaction in the countries was found in 6 countries where it is shown in Fig. 8, where it is observed that there are countries such as Canada, Egypt and among others with an investigation. The analysis of the data mining obtained through the VOSviewer software with the data obtained from Scopus, where the most related words were found, which are: Hemp, building materials, insulation materials, thermal cnductivity, which gives us greater coherence to investigate each one of the documents, also has the colorimetry with respect to the century of growth from the year 2012 to the year 2022 as observed in Graph 4.



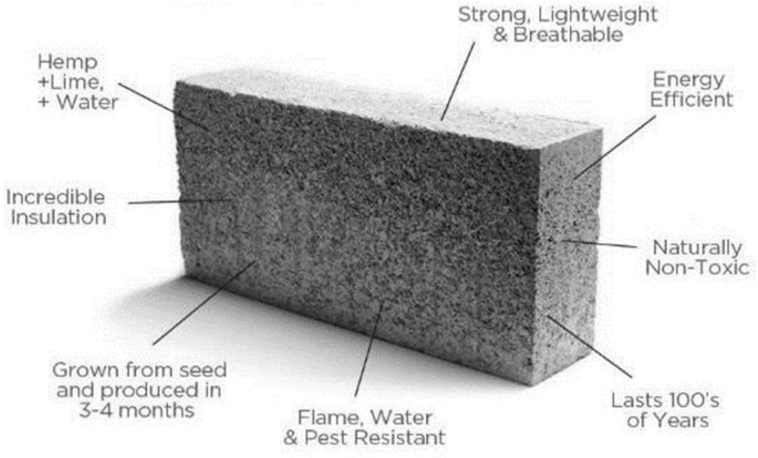
Graphic 4. Map of the analysis of words "brick" and "Hemp" with the highest interaction. Source: Obtained from VOSviewer.

4.1 Hemp based brick

Hemp is a very strong plant that even in times of the 20th century or in the midst of a drought did not stop growing and producing (Di et al., 2021), with rapid growth and has positive advantages with environmental impact from its planting process. yaqué manages to suck 15 tons of CO2 in this process in a space of one hectare of crops (Adam et al.; 2021) and thus the plant retains carbon within its filaments (Di et al., 2021), likewise hemp it can grow even without water (Saravanakumar et al., 2021), in addition, hemp has the facility to adapt to different climates for its sowing process (Di et al., 2021) and finally it does not require sun to grow, however it absorbs all the nutrients from the soil and grows from 2 to 4 m tall in an average growth period of 100 days (Saravanakumar et al., 2021), becoming the best option to be part of construction materials. In an applied survey, they showed that the population is more interested in the comfort and ease that the home provides and does not show interest in thermal or ecological insulation walls (Griffiths & Goodhew, 2015), which implies that there is no interest in these benefits of the walls, however the hemp-based brick is the best solution in environmentally sustainable construction materials. The hemp-based brick does not suffer alterations over time, the color, shape, weight and putrefaction are maintained (Donatelli et al., 2017), being effective in providing the quality and durability of the brick in order to compete with other substitutes for construction.

4.2 Brick manufacturing process

The materials for the manufacturing process are hemp fibers, hydrated lime, sodium hydroxide (NaOH) (Adam et al., 2021), sodium silicate, binder, fine stone ground and water (Rautray et al., 2019), likewise adding calcium hydroxide as an additive to the hemp brick will improve resistance to mold, durability, propagate pests and high-water permeability (Komisarczyk et al., 2019), these materials must be present in 5% of each one, in order to reduce the porosity of the brick (Komisarczyk et al., 2019). The hemp fiber must receive a treatment based on sodium hydroxide to improve the resistance of the brick (Adam et al., 2021), the properties of this hemp allow the filling walls to be shaped by the function of lime (Abdellatef, 2020), this brick is a good option to be an effective wall filling and turning it into an ecological element of the construction. The production process consists of the union of the materials until a stable homogeneity is obtained, in which this mixture is united in molds and they are air-dried and the drying time is approximately one month (Rautray et al., 2019), The final process of this brick consists of a compaction of 100 Mpa, achieving rigidity and resistance to reduce humidity for greater absorption (Bruno et al., 2017). The figure shows the benefits of brick which are:



In addition, the use of basalt and barytes can be added, however, these must meet requirements that give the confidence of being effective for a construction material, thus providing the benefit to the brick to make it effective and resistant in water absorption, being the range of 1900 - 2400 kg/m3 (Komisarczyk et al., 2019), being efficient in reducing humidity, finally, the brick comes out with a lime coating that means calcination, making the brick more resistant. (Rautray et al., 2019).

4.3 Brick environmental impact

The increase in carbon dioxide (CO2) in the industrial era generates an increase in the temperature of the planet earth by 2°C to 6°C, being industries, buildings, automobiles and the felling of trees that harm air quality caused even premature deaths (Rautray et al., 2019), which is why planting hemp is beneficial to the environment since it reduces carbon dioxide in its growth process (Griffiths & Goodhew, 2015). The use of heating and cooling in industrialized cities increases frequently and consumption in each home is gradual, for this reason the use of hemp in construction materials is a solution to mitigate these problems by improving and respecting the environment (Moussa et al., 2018). The hemp brick has a carbonation process that is achieved together with the lime allowing it to absorb carbon dioxide from the air, in an investigation it

was shown that for each m2 of wall built with the hemp brick it can reduce up to 13 kg of carbon dioxide. carbon (Griffiths & Goodhew; 2015), likewise in another study it was shown that for each m2 it is reduced up to 44 kg (Di et al., 2021) with the addition of some additives. Hemp-based bricks are determined as a porous, heterogeneous and anisotropic material (Soulios et al., 2021), which has the purpose of storing heat and humidity favoring the release and not allowing humidity to enter the rooms, over time the brick improves the thermal efficiencies of brick considering that it also has expiration time (Benmahiddine et al., 2021).

4.4 Air pollution reduction

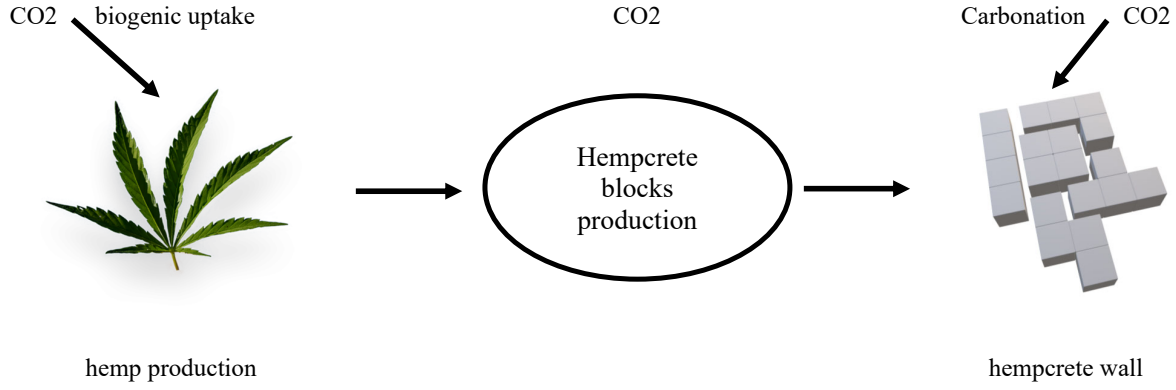
The absorption of carbon dioxide CO2 by the hemp-based brick with lime allows it to be more effective in absorption, demonstrating in the construction of a building (Di et al., 2021), since these bricks not only exist to be walls but also as carbon sinks, with the carbonation process that allows the release of carbon dioxide CO2 (Rautray et al., 2019). This is how the carbonation process is an effective solution to reduce air pollution, being a good construction material since it retains carbon dioxide (CO2) (Rautray et al., 2019) and this, at the same time, is an entry barrier. of CO2 to the houses, with this it is possible to obtain a stable acoustic level, providing greater comfort within the home (Saravanakumar et al., 2021).

$$Ca(OH)_{2(s)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(1)}$$

Graphic 5. Chemical formula of carbonation.

Note. The graph represents the CO2 carbonation process. Taken from Bio-Brick - Development of Sustainable and Cost Effective Building Material. (p. 3178), by Rautray et al, 2019. In the chemical formula, it can be seen that through carbonation, calcium hydroxide (Ca(OH)2) sucks carbon dioxide (CO2) and calcium bicarbonate (CaCO3) is obtained plus water, which the water evaporates (Rautray et al. al.; 2019).

The main function of using hemp for the brick is that it fulfills the function of purifying carbon from the air in order to absorb and store these gases (Saravanakumar et al., 2021).



Graph 6. Graphic carbonation process.

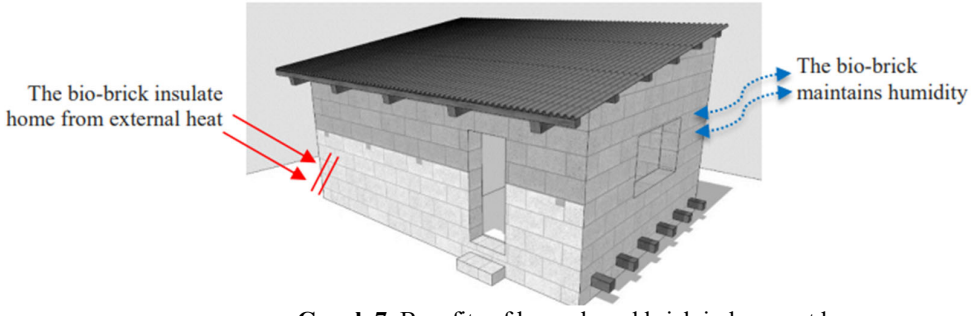
Note. The graph represents how both the plant and the brick comply with the CO2 purification process. Taken from Bio-Brick - Development of Sustainable and Cost Effective Building Material. (p. 3176), by Rautray et al, 2019.

The hemp-based bricks were applied to small houses, with the result that they can capture up to 322.2 g of carbon dioxide per m2 of construction, which is recommended for low-cost or small houses. (Rautray et al., 2019)

4.5 Heat insulation and humidity reduction

The construction sector generates 2 to 3 million construction waste worldwide each year, for which the hemp-based brick is the best option to mitigate this problem (Saravanakumar et al., 2021) since at the end of the time, the life of the brick will serve as a fertilizer for the crops, that is, the construction waste will be reused. In addition, according to the increase in the temperature of the planet, the use of this type of barriers is necessary due to the increase in heat, becoming more efficient in use and application (Saravanakumar et al., 2021). Hemp is used at home in different functions, however now it needs to be applied in the construction industry to convert it into biodegradable materials (Saravanakumar et al., 2021). In cities with hot climates and close to the sea, humidity is generated and this generates deterioration to the structures in its different forms since humidity affects both the liquid, solid and gaseous state, harming everything that is inside the home (Novak, 2018), this is how the hemp brick chemically treated with salicylic acid provides durability to the hemp fiber and allows it to be more effective in absorbing moisture (Donatelli et al., 2017). This combination was born thanks to a mason who experimented with this material with different sources such as lime, aggregates, cement and among others, which he used to correct deterioration in houses and achieve the resistance and efficiency he was looking for (Di et al., 2021). This

mixture is the hemp fiber with the lime which turns out to be efficient to form a thermal conductivity and to reduce the internal humidity of the houses (Griffiths & Goodhew, 2015) that acts as a humidity diffuser (Balksten, 2021), in addition, this allows it to be breathable so that the vapor will pass through the entire wall and thanks to the properties of the lime the salt ions will crystallize and come out around the brick (Gupta et al., 2014), that is, it will be absorbed and dried (Griffiths & Goodhew, 2015), likewise the lime in the brick allows CO2 to be absorbed from the air for an approximate time of the life cycle of the brick in an average of 249 kilos of CO2 in a period of 100 years. In a coating experiment in a church, hemp was applied with which it turned out that it does not contain salts on the outside. (Balksten, 2021).



Graph 7. Benefits of hemp-based brick in low-cost homes.

Note. The graph can show the benefits of this brick such as maintaining a stable internal humidity and a stable internal temperature. Taken from Bio-Brick - Development of Sustainable and Cost Effective Building Material. (p. 3178), by Rautray et al, 2019.

The advantages of this consequence are energy savings because a stable temperature is maintained and being a barrier against extreme heat (Saravanakumar et al., 2021) which allows savings in electric heaters, contributing to reduce air pollution (Griffiths & Goodhew; 2015).

5. Discussion

Research of this type allows us to generate starting points for good investments in research with bases and recommended sources, likewise it allows us to contribute to the community of interest in sustainable and intelligent materials in Peru. In this bibliographic review analysis with the support of the VOSviewer tool, it was possible to investigate the following connotations, firstly the relationship between the words “brick” and “Hemp” with a result of 67 investigations and present since 2016, secondly the relationship between the words “brick” and “humidity” with a result of 20 investigations and present since 2005, thirdly the relationship between the words “brick”, “reduces”, “air” and “pollution” that resulted in 11 investigations and was present since 2010 and finally the relationship between the words “hemp”, “thermal”, “insulating” and “brick” with a result of 5 investigations and that was present from 2012 to the present, all of them present in different countries and more where the use and application of the brick is necessary, however, no research from Peru.

Innovation in construction materials has a greater weight in interest in the impact on the environment from the beginning of its manufacture, its use and until its final process or that it meets its life limit (Moussa et al., 2018), likewise the brick must to comply with the three aspects of sustainability such as the social one that allows generating quality of life for people, secondly the environment that cares for and preserves environmental quality and the third one that is economical and accessible for its application (Griffiths, 2012) is for this reason that the results obtained from the analysis of the manufacture and materials for the production of bricks based on hemp are found in quantity and do not generate any greater cost, however in the drying process it does generate extra expenses since the use of spaces and time to be able to be air dried generates extra time and storage.

The production of cement generates 7% of carbon dioxide CO2 emitted worldwide and the manufacture of bricks that for each brick 0.41 kg of CO2 carbon dioxide is contaminated (El-Mahllawy, 2018), this is how hemp bricks It provides an effective and friendly solution for the environment, likewise the benefits are a lot as well as in the reduction of humidity and keeping the air fresh inside a house and being able to maintain a stable temperature inside the hemp walls (Griffiths & Goodhew; 2015), suck the environmental contamination from the beginning of the use until the end of the limit of its life that is 100 years and this thanks to the addition of lime that has the potential to insulate the heat that allows energy savings (Griffiths, 2012). Therefore, Kandya and Mohan (2018) state that the bricks must comply and have larger holes to be able to ventilate and generate greater cooling in places where temperatures exceed what is allowed. do, however for cold climates it is required that they be with smaller holes.

It is necessary to take into account the study of the proportion quantities of each material for the manufacture and continue with subsequent studies in order to have specific quantities that allow the durability, resistance, quality and functionality of the brick for the manufacture of walls and to be present. In homes, the design of the brick must also be studied since due to various sectors and needs, the size and shape of the brick must be taken into account, considering universal standards and bringing innovation to solve problems such as the time of the construction of a wall making brick easy to use.

6. Conclusion

The analysis of this research allows us to know the following results: the concern to solve the environmental problems generated by the construction sector are few, however, in the last 3 years, research based on sustainable solutions such as hemp-based brick has increased. and the analysis of the benefits such as the reduction of humidity, CO2 absorption, giving it the value of a decontaminant, that is, purifying the air quality and finally maintaining the temperature inside the home, all thanks to a Scopus bibliographic review. At this time, innovation in environmental solutions continues to be of greater importance and more so in the construction sector, since this industry generates 25% of the consumption of water, 40% of the consumption of natural resources and 40% of the energy worldwide. (Moussa et al., 2018), making it a challenge to solve global warming of planet earth. We conclude that we need investment to investigate in depth and apply it to hemp-based brick in order to determine in which aspects and circumstances we can apply it in the construction industry, likewise it is recommended to continue with the investigation and invite American countries that they get involved with the issue since there are countries where they have diverse climates such as Peru, where hemp planting would be very fruitful since it would provide economic income, solutions to mitigate environmental impact and raise awareness among the population to improve air quality.

References

Abdellatef, Y., Khan, M., Khan, A., Alam, M., & Kavgic, M. (2020). Mechanical, Thermal, and Moisture Buffering Properties of Novel Insulating Hemp-Lime Composite Building Materials. *Materials, 13*(21), 5000. https://doi.org/10.3390/ma13215000

Adam, L., sopescu, D., & Maxineasa, S. (2021). Improving the mechanical and thermal properties of hemp concrete by treating the hemp hurds with sodium hydroxide solution. *Materials Science and Engineering. 1242*, 012001. doi:10.1088/1757-899X/1242/1/012001.

Balksten, K., & Strandberg-de Bruijn, P. (2021). Understanding Deterioration due to Salt and Ice Crystallization in Scandinavian Massive Brick Masonry. *Heritage*, *4*, 349-370. https://doi.org/10.3390/heritage4010022.

Benmahiddine, F., Belarbi, R., Berger, J., Bennai, F., & Tahakourt, A. (2021). Accelerated Aging Effects on the Hygrothermal Behaviour of Hemp Concrete: Experimental and Numerical Investigations. *Energies*. *14*, 7005. https://doi.org/10.3390/en14217005

Brannon, S., Adetona, A., Natasha, S., Sarofim, M., & Kolian, M. (2021). Impact of South Asian brick kiln emission mitigation strategies on select pollutants and near-term Arctic temperature responses. *Published by IOP Publishing Ltd. 3*(6). DOI: 10.1088/2515-7620/ac0a66

Bruno, A., Gallipoli, D., Perlot, C., & Mendes, J. (2017). Mechanical behaviour of hypercompacted earth for building construction. *Materials and Structures, 50*(2), 160. doi:10.1617/s11527-017-1027-5

Di, C., Salvatore, E., Paolotti, L., Moretti, E., & Rocchi, L. (2021). Evaluation of the Environmental Sustainability of Hemp as a Building Material, through Life Cycle Assessment. *Environmental and Climate Technologies, 25*(1), 1215-1228. https://doi.org/10.2478/rtuect-2021-0092.

Ding, Y., Rousseau, R., & Wolfram, D. (2014). Measuring Scholarly Impact Visualizing Bibliometric Networks. (Chapter 13), 285–320. Doi:10.1007/978-3-319-10377-8_13.

Donatelli, A., Cuna, D., Tagliente, M., Protopapa, M., Mevoli, A., Aversa, P., Blasi, C., Capodieci, L., & Luprano, V. (2017). Effect of treatments on the aging behaviour of hemp fibres for building construction in the Mediterranean Area. *Journal of Building Engineering, 11*, 37–47. doi:10.1016/j.jobe.2017.03.013

El-Mahllawy, M. S., Kandeel, A. M., Abdel Latif, M. L., & El Nagar, A. M. (2018). The feasibility of using marble cutting waste in a sustainable building clay industry. *Recycling*, *3*(3), 39. https://doi.org/10.3390/recycling3030039

Griffiths, R., & Goodhew, S. (2012). Sustainability of solid brick walls with retrofitted external hemp-lime insulation. *Structural Survey, 30*(4), 312–332. DOI:10.1108/02630801211256661.

Griffiths, R., & Goodhew, S. (2015). Thermal properties of cob retrofitted with external hemp–lime. *Proceedings of the Institution of Civil Engineers - Construction Materials*, 1–13. doi:10.1680/jcoma.15.00029

Gupta, S., Huinink, H. P., Prat, M., Pel, L., & Kopinga, K. (2014). Paradoxical drying of a fired-clay brick due to salt crystallization. *Chemical Engineering Science*, *109*, 204-211. DOI:10.1016/j.ces.2014.01.023

Hussain, A., Khan, N. U., Ullah, M., Imran, M., Ibrahim, M., Hussain, J., ... & Attique, F. (2022). Brick Kilns Air Pollution and its Impact on the Peshawar City. *Pollution*, *8*(4), 1266-1273. DOI: 10.22059/POLL.2022.341450.1436

Kandya, A., & Mohan, M. (2018). Mitigating the Urban Heat Island effect through building envelope modifications. *Energy and Buildings, 164*, 266–277. doi: 10.1016/j.enbuild.2018.01.014

Khadak, M., Maheswar, R., Arnico, k., Piyush, B., Manish, N., Ashish, S., Andrea, M., Paolo, C., Deepak, P., & Mark, L. (2018). Observation and analysis of spatiotemporal characteristics of surface ozone and carbon monoxide at multiple

sites in the Kathmandu Valley, Nepal. *Atmospheric Chemistry Physics, 18*, 14113–14132. DOI: 10.5194/acp-18-14113-2018.

Komisarczyk, K., Dachowski, R., & Czapik, P. (2019). Silicate composites modified with the use of diabase and barite aggregate as an alternative for low-energy construction. *IOP Conference Series: Earth and Environmental Science, 214*, 012072. doi:10.1088/1755-1315/214/1/012072

Moussa, T., Maalouf, C., Ingrao, C., Scrucca, F., Costantine, G., & Asdrubali, F. (2018). Bio-based and recycled-waste materials in buildings: A study of energy performance of hemp-lime concrete and recycled-polyethylene terephthalate façades for office facilities in France and Italy. Science and Technology for the Built Environment, 24(5), 492–501. doi:10.1080/23744731.2018.1438664

Novak, V. (2018). The Protection of Masonry Blocks with Using Hydrophobization Before Load Due to Increased. *International Journal on Advanced Science Engineering informatgion Technology, 8*(6). ISSN: 2088-5334.

Rautray, P., Roy, A., Mathew, D., & Eisenbart, B. (2019). Bio-Brick - Development of Sustainable and Cost Effective Building Material. *Proceedings of the Design Society: International Conference on Engineering Design, 1*(1), 3171–3180. doi:10.1017/dsi.2019.324

Saravanakumar, P., Bisher, E., & Aravinndh, R. (2021). Usage of fibre content in hemp as a material in building construction. *IOP Conference Series. Materials Science and Engineering, 1145*(1) doi: https://doi.org/10.1088/1757-899X/1145/1/012057

Seay, B., Adetona, A., Sadoff, N., Sarofim, M. C., & Kolian, M. (2021). Impact of South Asian brick kiln emission mitigation strategies on select pollutants and near-term Arctic temperature responses. *Environmental Research Communications*, *3*(6), 061004. DOI: https://doi.org/10.1088/2515-7620/ac0a66

Soulios, V., de Place Hansen, E. J., & Peuhkuri, R. (2021). Hygrothermal performance of hydrophobized and internally insulated masonry walls-simulating the impact of hydrophobization based on experimental results. *Building and Environment*, *187*, 107410. doi:10.1016/j.buildenv.2020.107410

Van, Eck, Waltman, L. (2010). Encuesta de software: VOSviewer, un programa informático para el mapeo bibliométrico. *Cienciometría,* 84, 523–538. Doi:https://doi.org/10.1007/s11192-009-0146-3

Zach, J., Hroudova, J., Sedlmajer, M. (2012). Utilization of Alternative Insulation Materials for Thermal Insulating Ceramics Blocks Production. *Advanced Materials Research, 482-484*, 1570–1575 doi: 10.4028/www.scientific.net/AMR.482-484.1570