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Bibliometric overview of carbon and particulate matter control and emissions.

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SUMMARY

This research presents a bibliometric overview of the state of the art around the world regarding carbon emission and control of particulate matter, focusing on keywords, connection networks between author, countries, and quantitative and temporal analysis of publications. The method used was based on the features of the software Vosviewer version 1.6.15, and data extraction for processing of the Scopus database resulting in a sample of 102 papers between the years 2010 and 2020. The results show that research on the topic is still recent and there is no scientific homogeneity in the approaches, they also s how that oriental researchers are the ones with more connection networks and although researchers in general are not very connected, the general used keywords have many connections, with emphasis on the term "particle (of particulate matter)" most used in average in 2018. China has 3 lines of research: 1. passive removal through plants like sea lettuce but with little influence; 2. removal using technology such as washing filters and technological Nano; 3. technological with coating made of metallic materials capable of capturing carbon.
The western, in general, led by American research, uses passive solutions, by removing pollutants with different types of plants and seeking to find value for the tons of carbon removed by the plants.

KEYWORDS: Removal. Pollutants. Efficiency.

1. GUIDELINES

Air pollution and gas emissions are extremely relevant issues with respect to sustainable economic development. According to COP25, between 2016 and 2019, global banks have invested around 1.9 trillion dollars in fossil fuels. 71% of global emissions come from 100 companies in the oil, gas and coal industries (Carbon Disclosure Project 2017).

Greenhouse gases (GHG), when not controlled, contribute to global warming, which in turn interferes with the planet's ecosystems natural processes. According to the 2018 Intergovernmental Panel on Climate Change (IPCC) report, with an increase of just 35.6 °F in temperature, almost all corals would cease to exist, and heat waves, forest fires, coastal regions floods, increased cases of dengue and malaria would be more frequent. Increases in temperature facilitate the concentration of pollutants in cities, inhibiting winds to disperse them (Oliveira S.T. 2013).

Some countries do not have geo-biophysical resources for removing CO2 from the atmosphere. Bioenergy with Carbon Capture and Storage (BECCS) can be an option for these countries to achieve targets in carbon emissions reduction. This technique enables negative emissions and the removal of the emitted carbon (Fajardy M. et al. 2020).

The more consumer a city is the more carbon it will emit. Understanding global consumption demands is key to control carbon emissions. Next, based on reliable information on the pattern of carbon emissions, on a global scale, it is possible to develop more efficient air quality control act ions (Andrew Sudmant et al. 2018).

For example, significant improvements in air quality and in the control of gas emissions can be achieved through planting urban trees and forests. Plant foliage is capable of removing tons of carbon from the atmosphere each year (Nowak et al. 2018).

Improvements in human health through planting trees has been a topic of interest and knowledge to researchers for a long time, as we can see that according to Tiwary et al. (2009), who carried out a study in London, in an area of 10 x 10 km^2, covered with 25% of trees and concluded that two deaths and two hospitalizations can be avoided each year in these conditions.

Some plants and trees species can remove more carbon from the atmosphere than others. There are species capable of removing other types of contaminants, including certain categories of acids (Jeongeun Ryu, et al. 2018).

Particulate matter carried in the air is harmful to humans and trees can remove particles from the atmosphere, improving the quality of human life (Xu et al. 2018).

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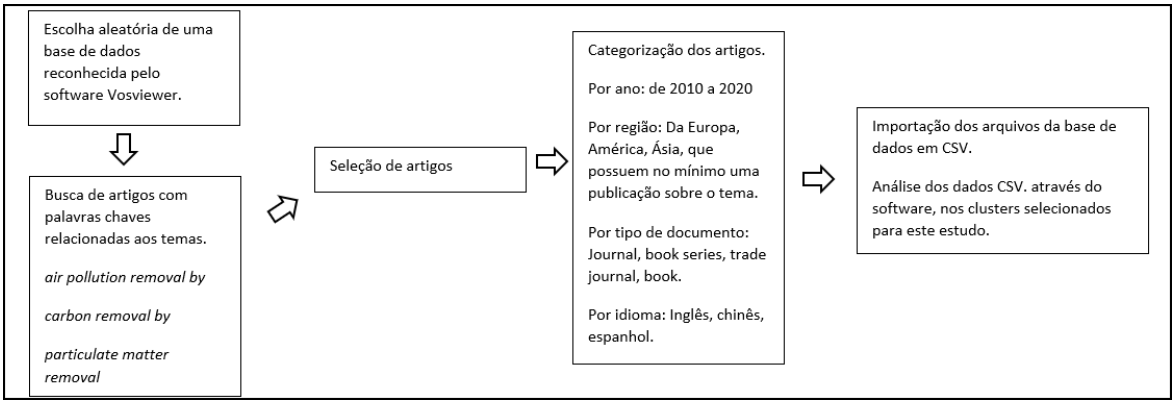
2. OBJECTIVE

Despite the scientific literature explaining forms of reducing emissions or removing carbon excess and particulate matter from the atmosphere, it can be said that such forms are still recent. Hence, this paper seeks to provide an overview of such researches, based on a bibliographic survey, with scientific bases, to point out which strategies are being used to minimize the problems related to climate change. To do so, an investigation was carried out on countries and authors around the globe with more relevant researches on carbon and particulate matter.

3. METHODOLOGY

For the systematic review of the state of the art on the emission and control of carbon and particulate material, three types of analysis were carried out involving countries, keywords, authors, and co-authors based on the following criteria:

Image 1: Schematic of the methodology.



Source: THE AUTHOR HIMSELF, 2020.

As outlined (Image 1), the first step of the study consisted in choosing a database which would be compatible with the bibliometric software VOSViewer version 1.6.15, thus, Scopus (Elsevier) database was randomly defined.

VOSViewer "*Visualization of Similarities Viewer*" is a software developed by the Dutch researchers Nees Jan Van Eck and Ludo Waltman. Easy to use, it analyses co-authored bibliometric data, keywords, co-citation among others.

The software creates a similarity matrix in the sample and generates a data map based on its algorithms, where each similarity extracted from the sample becomes part of a *"cluster"* (group), which is also identified by colors.

The software shows the distance between the nodes (circles) in the target network of the analysis, the further one node is from the other the less intense their relationship is, the closer the more related between each other, and the greater the thickness of the line connecting the circles (*"links"*) the more intense their relationship is. (van Eck & Waltman, 2014).

Afterwards, a systematic search was carried out in Scopus database for papers containing in the body of the text the terms "air pollution removal by", "carbon removal by", "particulate matter removal". Selection filters available in Scopus database were applied to categorize papers by year,

region, type of document, and language. The search with no filters brought approximately 2,200 documents and with the filters 102 documents.

Among the 102 documents found, only a few countries had at least 1 (one) document published between 2010 and 2020, they are: USA, China, Brazil, France, United Kingdom, Belgium, Canada, Colombia, Hungary, Italy, Mexico, Spain, Japan, South Korea, Australia, Iran, Taiwan, Poland, Singapore, Luxembourg, Germany, Bermuda and Holland, which became the focus of the analysis.

Also, the selection only included the documents published in English, Chinese, and Spanish, in the categories: "Journal, book series, trade journal and book".

Subsequently, the 102 documents found with these characteristics were exported in CSV.excel format with the following information: "citation information", "bibliographical information", "abstract & keywords", "include references".

With this base it is possible to point out:

(I) The countries with more publications, the countries with an average of recent publications between the years 2015 and 2020 and their connection networks.
(II) The authors with more publications and citations, the average of recent publications between the years 2012 and 2018 and their connection networks.
(III) The co-occurrence of the most used keywords in the 102 articles, which of them were used more often between the years 2016 and 2018 and their connection networks.

4. RESULTS AND DEBATE.

4.1 CO-AUTHORSHIP BY COUNTRY.

This analysis facilitated the understanding of the connections among countries in this research area. Besides this, it indicates what are the countries that are in the edge of knowledge with more publications (van Eck & Waltman, 2014).

In image 02, it is possible to check how the co-authorship networks by country relate to each other. The circumference size is directly related to the number of published papers. The colors represent groups - "*clusters*" - which indicate how researches support each other. That is, the distance between the circles represents proximity or distance, in relation to the lines of research between countries. USA and China leading with more publications and Brazil and Hungary with fewer publications and no relationship with the other countries in the sample.

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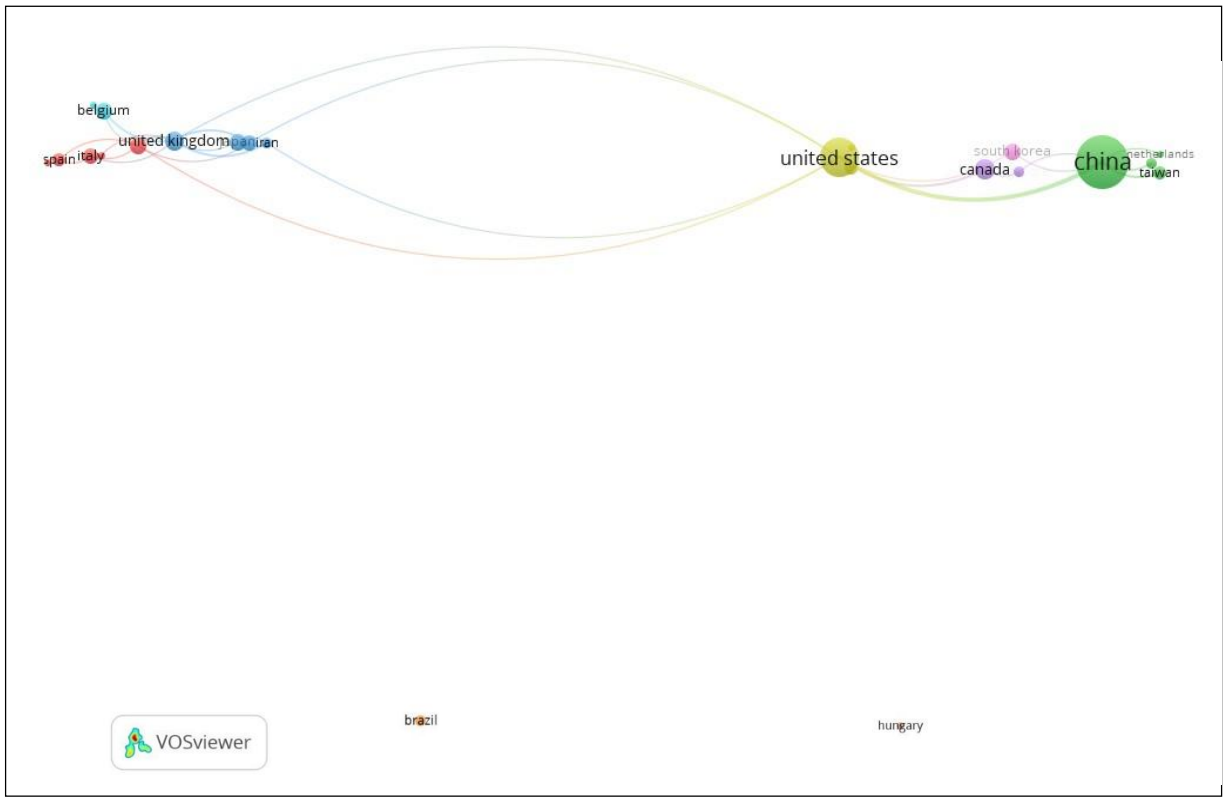
Image 02: Co-authorship network map by country.



Source: THE AUTHOR HIMSELF, WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER, 2020.

The data in image 02 show with respect to countries that China has the largest number of publications, however the USA has been the most cited country as seen in table 01, being between the European Union and the Eastern, but closer to Eastern countries, we can also see that Brazil and Hungary are isolated in their researches with no network connections.

The USA and the East, especially China, with a certain proximity in the line of reasoning aiming at removing the pollutants emitted into the atmosphere.

Plant foliage is capable of removing tons of carbon from the atmosphere each year (Nowak et al. USA 2018). Nano-fibrous cellulose air filters are efficient in removing particulate matter to clean the atmospheric air, they can be washed and reused (Zhang. Et al. China 2020). Different species of plants remove different types of air contaminants (Jeongeun Ryu, et. al. South Korea 2018).

However, while China mostly seeks technological alternatives, the US look for using nature itself in favor of improving air quality. This does not mean that there are no Chinese researchers exploring passive alternatives to reduce air pollutants, but that there is research on both facets within the sample.

Sugarcane bagasse biomass can be burned and transformed into energy; this biomass contains less carbon than fossil fuels (Fajardy M. et al. Holland 2020). Increases in temperature facilitate the concentration of pollutants in cities, inhibiting winds to disperse them (Oliveira S.T. Brazil 2013).

From this perspective, there is a certain separation from Sino-American thinking, where, on the one hand, there is the search for burning fewer polluting fuels as a solution and on the other hand just a perception that the increase in temperatures inhibit the action of the winds in pollutants dispersion.

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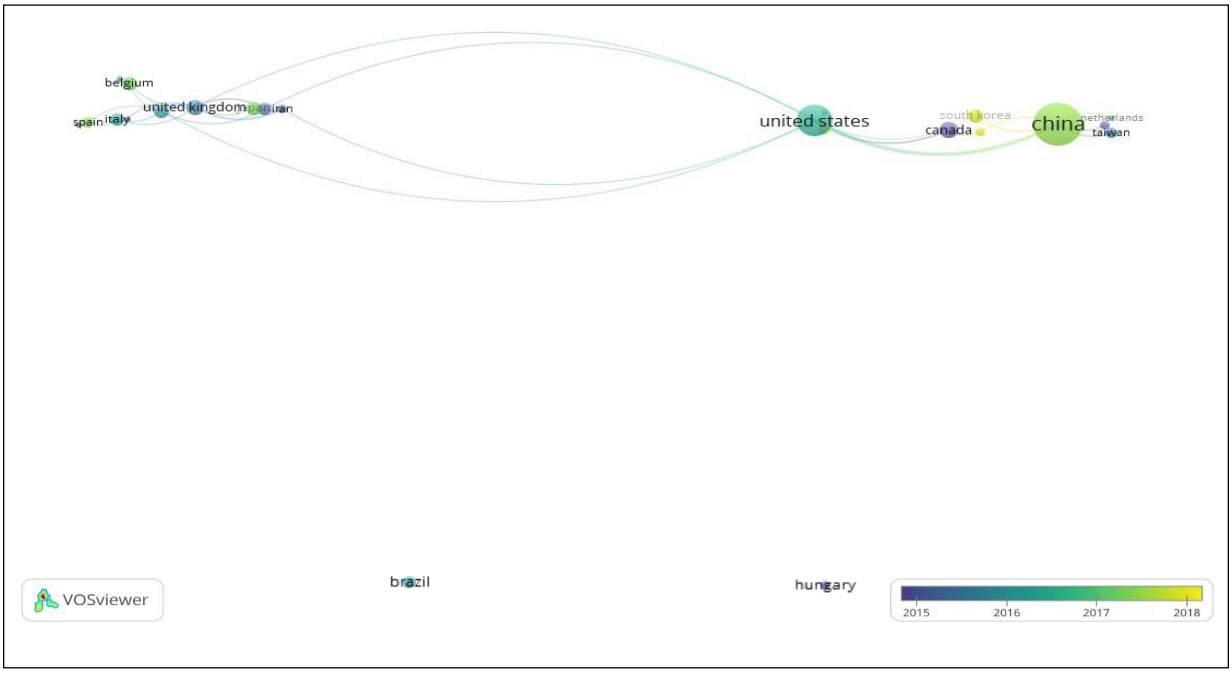
In Image 3, there is a demonstration, among the co-authorship networks, of the countries with the most recent publications. Yellow represents current publications. In chronological sequence, green and finally blue, representing countries with older publications within the sample. The results show the average year of publication and not the exact year.

Image 03: Co-authorship network maps by year.



Source: THE AUTHOR HIMSELF WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER, 2020

The studies below show some characteristics of the researches carried out over time, portraying a part of the map in Image 03, where researchers in the United Kingdom, Brazil, China, the USA and South Korea present the time scale of some studies, again the lack of connection networks in Brazil in relation to other countries is noteworthy.

In 2009, there were already publications in the United Kingdom reporting the existing links between the amount of air pollutants removed by trees and the decrease in deaths from respiratory diseases (Tiwary et. al. 2009). In 2014, in Brazil it was observed that winds contribute to the dispersion of pollutants, but high temperatures can influence the actions of the winds and, consequently, concentrate pollutants in warmer regions (Oliveira S.T. 2013).

Air quality is affected by plants, they dispose and disperse pollutants and dust (Yeng Lin et al. 2014). Another eastern study states that 17 species of trees found in Beijim can remove and accumulate particulate material in their leaves (Xu et al. 2018). In addition to removing pollutants from the atmosphere, and improving air quality, it is possible to monetarily quantify the value of tons of carbon removed by trees (Nowak et al. USA 2018). Ulvas also known as "*Sea lettuce*" found in all oceans, can remove tons of nitrogen, phosphorus, and carbon every year, in addition to contributing to the improvement of air quality in coastal regions, and being edible (Kim et al. Korea S. 2018)

In table 01, the number of documents published by country is indicated in the column "*Documents*", the number of citations of the respective country' documents is mentioned in the column "*Citations*", and the strength of the connection or links that the document has within the

sample is shown in the column "*total link strength*".

Taking into account at least 1 document per country and at least 05 citations per country. China leads with the largest number of publications with 48 documents and then the USA with the highest number of citations: 797.

Table 01: Documents and citations.

Verify selected countries

Selected	Country	Documents	Citations	Total link strength
☑	united states	26	797	20
☑	china	48	585	17
☑	united kingdom	6	82	11
☑	australia	4	32	7
☑	france	5	174	7
☑	iran	2	26	6
☑	belgium	5	79	4
☑	canada	7	164	4
☑	italy	4	71	4
☑	japan	5	26	3
☑	spain	3	6	3
☑	taiwan	3	79	3
☑	colombia	3	41	2
☑	hong kong	2	22	2
☑	poland	1	41	2
☑	singapore	2	10	2
☑	south korea	5	12	2
☑	bermuda	1	11	1
☑	germany	1	5	1
☑	luxembourg	1	17	1
☑	netherlands	1	36	1
☑	brazil	2	30	0
☑	hungary	1	17	0

Source: THE AUTHOR HIMSELF WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER 2020.

Even though China is the country with the largest volume of publications in this sample, there is a general interest among researchers, including some Chinese, in exploring passive ways of improving air quality that meets the American thinking identified in this sample, which places the documents published by the USA in agreement with different researchers from different countries.

The European study on plant Barriers as a passive method for improving air quality and American studies on carbon removal from tree leaves end up meeting this idea and creating biases. (E. Podhajska et al. 2020). Korean and Chinese interest in growing sea lettuce as a strategy to sequester carbon and other pollutants is also seen as a passive solution (Kim et al. 2018)

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Sugarcane plantations in Brazil also contribute to removing carbon from the atmosphere (Fajardy M. et al. Holland 2020). In this respect, the Dutch study creates a bias with the strategies for removing carbon and contaminants by plants.

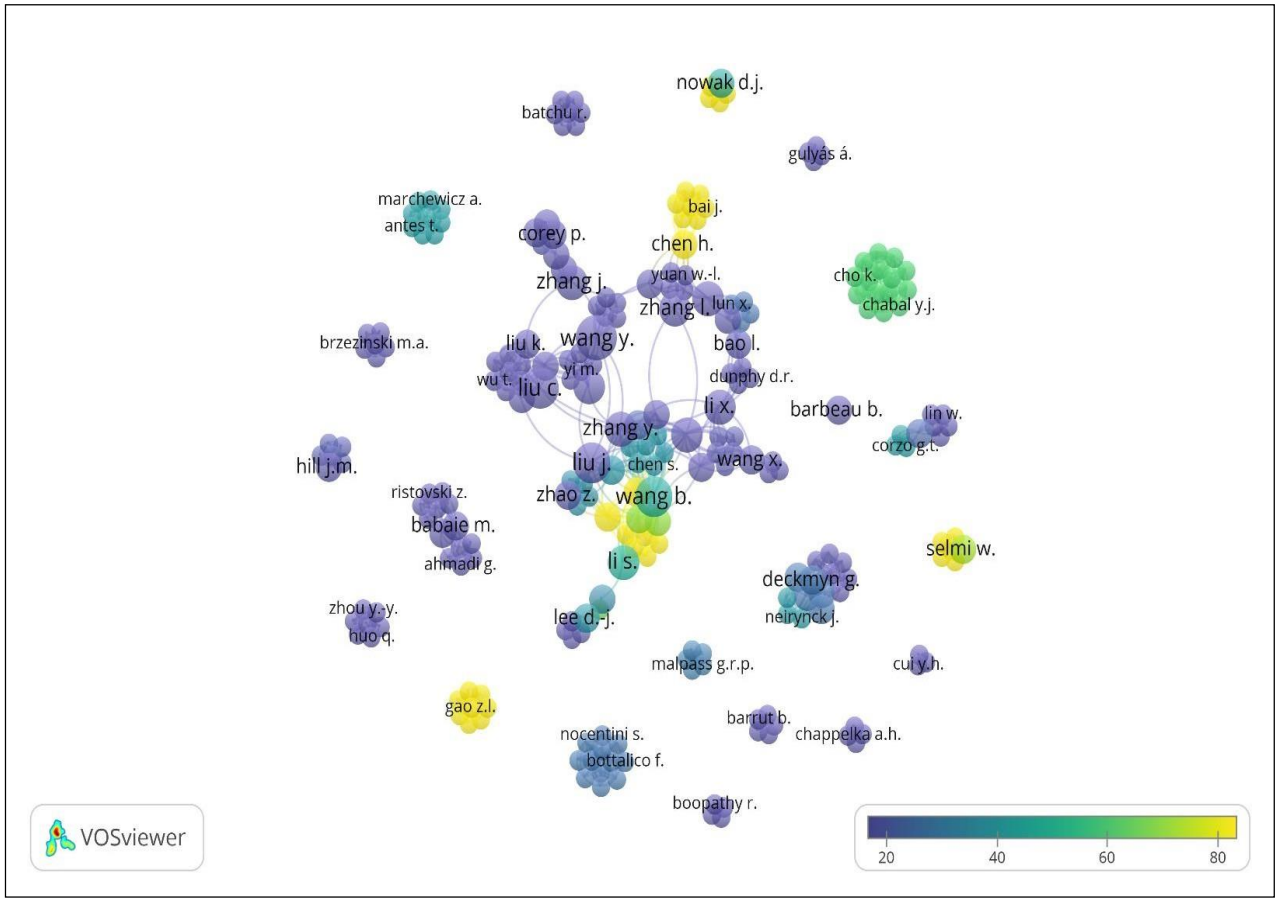
4.2 AUTHORS AND CO-AUTHORS ANALYSIS.

Image 04 indicates the most cited authors and co-authors within the sample taking into account a minimum of 10 citations per person and the main connection networks between them.

The lines represent the connection between the authors/co-authors network. The 28 identified *"clusters"* are represented by colors. The colors represent the most cited authors; yellow authors and co-authors with more citations - on average 80 citations in the sample, then green on average 40 and 60 citations and lastly, blue indicating the least cited authors, with an average of 20 citations.

In this case, the size of the circles is not related to any other information.

Image 04: Most cited authors and co-authors network



Source: THE AUTHOR HIMSELF WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER, 2020.

It is possible to observe in image 04 that authors Nowak d.j. Gao Z.L. and Selmi W. are often cited, but in their "*Clusters*", and they do not have many connection networks with the East, for

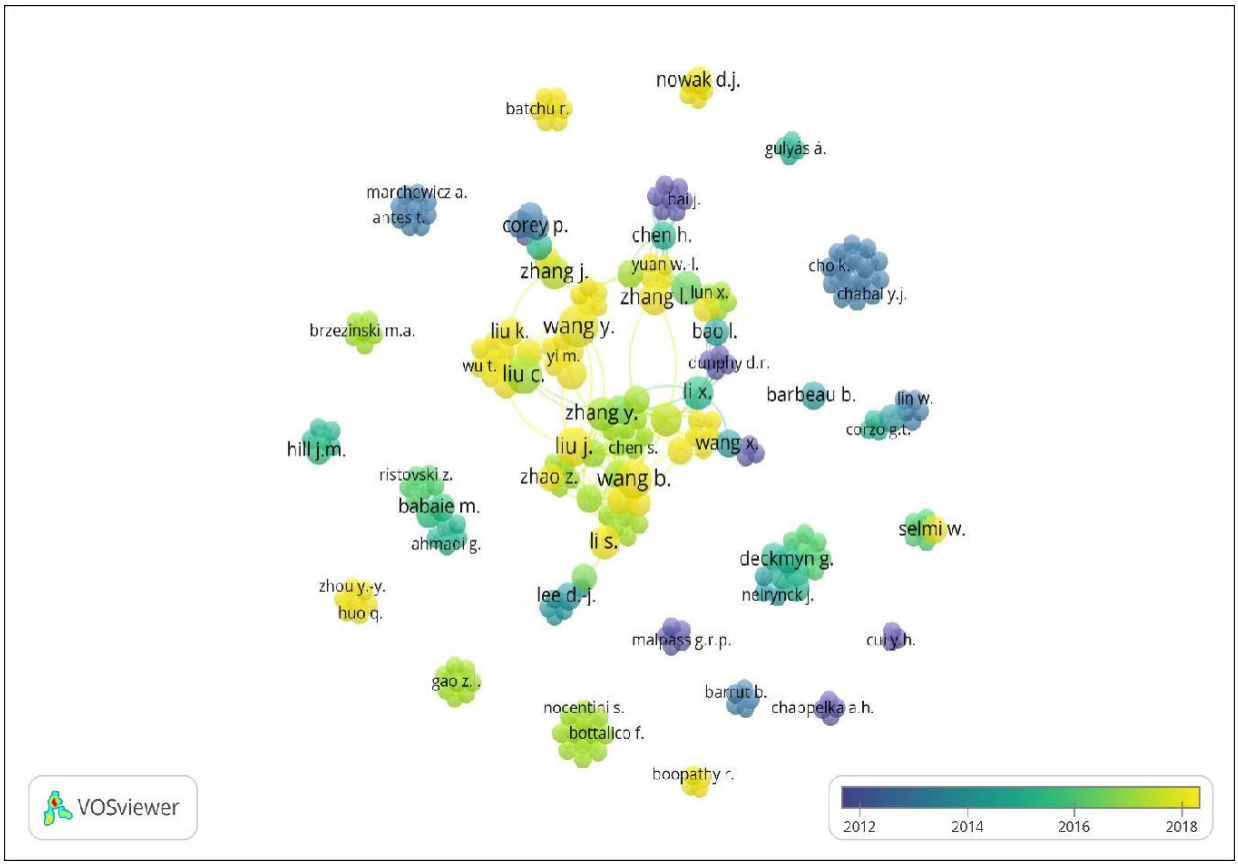
example, in the European study on plant Barriers as a passive method for improving air quality, American studies are cited 08 times. (E. Podhajska et al. 2020).

The most cited studies in the east and with the most prominent connection networks in China are the ones by researcher Chen H. in a line of research focused on nanostructures with carbon removal capacity (Chen H. et al. 2020) and researches on metallic coating materials capable of capturing carbon (Zhao Z. et al. 2017).

Image 05 shows authors and co-authors with more recent researches by the average year of publication.

The authors and co-authors represented by yellow have more recent works, on average in 2018, after, those represented by green cited on average between the years 2014 and 2016 and in blue, authors with less recent published articles, on average in the year 2012.

Image 05: Network of authors and co-authors with more recent works



Source: THE AUTHOR HIMSELF WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER, 2020.

Among the most cited authors and co-authors on average between 2016 and 2018, in yellow there are researches focused on passive carbon removal and environmental valuation through plants, and in this "*cluster*" following this bias there are authors and co-authors Nowak DJ, Tiwary, Arroyave Maya, Mc. Govern, Pasher J. Among the authors and co-authors, in the eastern "*clusters*" with a bias towards technological solutions, there are more citations between 2016 and 2018 of the following authors: Wang B., Zhang, Wang Y, Zhao Z. in technological solutions in the east, but in more isolated researches Zhou Y. with works on metallic and organic materials for coating capable of capturing carbon.

CO-OCURRENCE OF KEYWORDS.

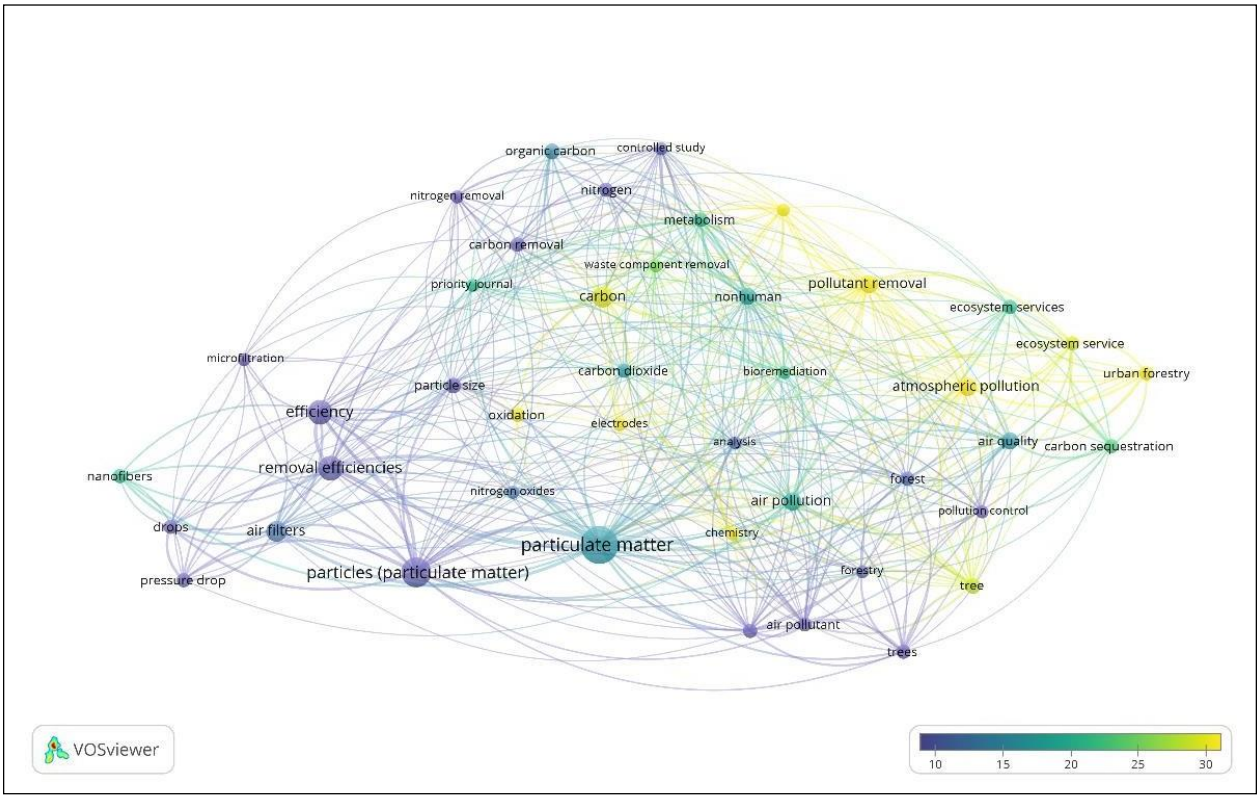
The co-occurrence of keywords happens by the joint occurrence of the word in a group of articles from a database (van Eck & Waltman, 2014).

Image 06 presents the occurrence of the most repeated keywords within the sample. Only 04 "*clusters*" were identified, that is, words that repeat at least 05 times excluding the word "*article*" from this count.

The size of the circumference represents how much the word relates to others, with a strong relationship between the circles when they are closer.

Yellow represents the most used words, on average 30 times, in green, words used on average 20 to 25 times and, in blue words with less occurrences, on average 10 times.

Image 06: Key-words occurrence network



Source: THE AUTHOR HIMSELF WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER, 2020.

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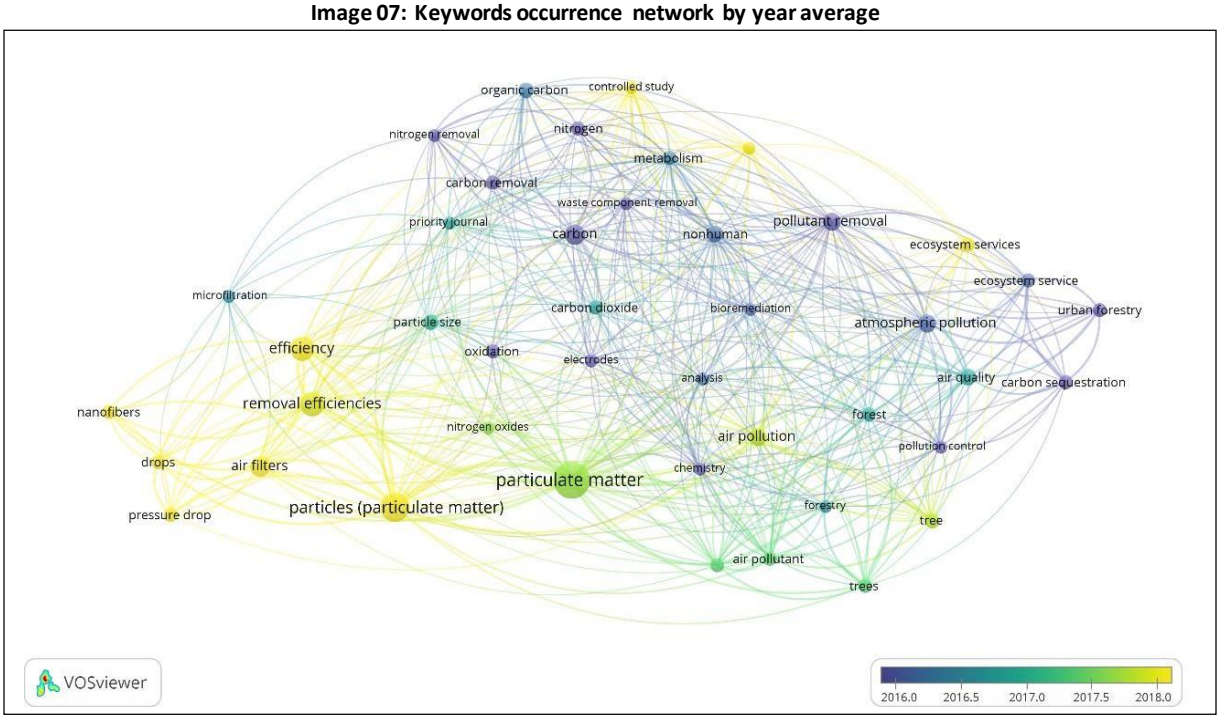
The map in image 06 shows that some words like "*particulate matter and particle (particulate matter)*" are closely related, despite words such as air pollution, urban forests, carbon, among others having been used more often in the sample.

Image 07 presents the occurrence of the most repeated keywords in the average of the years. The size of the circumference represents how much the word relates to others and the closer the circles the stronger their relationship is.

Yellow represents the words used more often in 2018, green the ones in 2017 and blue the ones in 2016.

Image 07: Keywords occurrence network by year average



Source: THE AUTHOR HIMSELF WITH SCOPUS DATABASE TREATED WITH SOFTWARE VOSVIEWER, 2020.

Image 07 shows that the word "Particle of particulate matter" was used more often, on average in 2018, and that it is also a type of word that is very related to several themes in the sample.

5. CONCLUSIONS

After the aforementioned analysis, we conclude that most of the East led by China has 3 lines of research: 1. passive removal through plants such as sea lettuce, but with little influence; 2. removal using technology such as washing filters and technological Nano; 3. technology with metallic materials for coating capable of capturing carbon.

The West, in general, led by American research, aim at passive solutions through the removal of pollutants with different types of plants and seeks to identify value for the tons of carbon removed by the plants.

The analysis of keywords indicates that, although there are several research currents and that they are often not connected by networks, authors, and co-authors in general have used words that are related to each other and have strong connection networks.

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