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Literature Review

Architecture Science Field Position in Dew and Fog Harvesting Research: A Bibliometric Analysis

Muhammar Khamdevi[1]*, Matius MLT[2]
[1]Architecture Department of Universitas Matana, [2]Physics Department of Universitas Matana
*m.khamdevi@gmail.com

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ABSTRACT

Passive dew and fog harvesting is currently a topic that has begun to develop since the issue of climate change and the water crisis hit the world. Even though this topic is not new, its development has been very intense lately by many researchers from various disciplines. However, this topic has not yet become a major topic of conversation in the architecture science. Therefore, this bibliometric research was carried out, to see the development of passive fog and dew harvesting research related to architectural science. At the same time to see opportunities for positions that can be filled by researchers and architects to contribute and collaborate on this topic. The database used is from Lens based on ten keywords related to the topic of dew and fog harvesting. The dataset is then processed in Microsoft 365 Excel and VOSviewer to obtain a scientific mapping which will be interpreted afterwards. The results of this study indicate that there are positions that can be filled and there are still opportunities that can be researched on this topic by architectural scientists, particularly in relation to context, locality, community, sustainability, biomimetics, bioinspiration, and low technology.

Keywords*: fog harvesting, dew harvesting, atmospheric water harvesting, bibliometric, architecture.*

Office:
Departement of Architecture
Matana University
ARA Center, Matana University Tower
Jl. CBD Barat Kav, RT.1,
Curug Sangereng, Kelapa Dua, Tangerang, Banten, Indonesia

ABSTRAK

Pemanen embun dan kabut pasif saat ini merupakan topik yang mulai berkembang sejak isu perubahan iklim dan krisis air melanda dunia. Walau sebenarnya topik ini bukan hal yang baru, namun perkembangannya sangat intens akhir-akhir ini oleh banyak peneliti dari berbagai disiplin. Namun topik ini belum menjadi perbincangan utama di dunia aritektur. Oleh karena itu, penelitian bibliometrik ini dilakukan, untuk melihat perkembangan penelitian pemanen embun dan kabut pasif yang berhubungan dengan keilmuan arsitektur. Sekaligus untuk melihat peluang posisi yang bisa diisi oleh para peneliti dan arsitek untuk berkontribusi dan berkolaburasi pada topik ini. Basis data yang digunakan adalah dari Lens berdasarkan sebelas kata kunci yang berhubungan dengan topik pemanen embun dan kabut. Dataset tersebut lalu diolah pada Microsoft 365 Excel dan VOSviewer untuk mendapatkan pemetaan ilmiah yang akan diinterpretasikan setelahnya. Hasil penelitian ini menunjukkan ada posisi yang bisa diisi dan masih ada peluang yang bisa diteliti pada topik ini oleh peneliti-peneliti keilmuan arsitektur, terutama sekali kaitannya dengan konteks, lokalitas, komunitas, keberlanjutan, biomimetik, bioinspirasi, dan teknologi rendah.

Kata Kunci: pemanenan kabut, pemanenan embun, pemanenan air atmosfer, bibliometrik, arsitektur.

INTRODUCTION

Water scarcity is one of the consequences of global climate change, including its quantity and quality (Ling, 2021). This has been a concern stated in the UN's Sustainable Development Goal 6 since 2015 (Van Vliet et al., 2021). This water crisis will threaten the energy supply, food security, economic and financial sectors (Chakkaravarthy, 2019). This will have an impact on security and sustainability in drought-stricken, high-population, and socio-economically unstable areas (Singh et al., 2014). The attention of architecture science to this issue - especially on the theme of green buildings - so far only focused on how to reduce water use, did not on water conservation (Weeks, 2013).

Because of this issue, many researchers have conducted research on the harvesting of water from the sea and air (Cassauwers, 2022). Since around 2000, there have been many studies on the harvesting of atmospheric water, especially from dew and fog. Dew harvesting technology relies on a condensation process, either passively or actively. While fog harvesting technology uses traditional approaches, biomimetics, and bioinspiration. Both technologies were developed on a small or large scale (Jarimi et al., 2020). Currently, there are many dew and fog collectors that still have inefficient design, especially collector building for large-scale use (Suau, 2010 and Beysens, 2012). Is there a position in the scientific field of architecture in research on this topic? What contribution can the scientific field of architecture make to research on this topic?

This study aimed to explore the trend of research publications on this topic by using scientific mapping in the form of bibliometric analysis. Bibliometric analysis was used to summarize a large amount of data with a wide review coverage and large datasets that cannot be reviewed manually. This analysis would display the state of the intellectual structure and trends of a topic or scholarship (Donthu et al., 2021). This research utilized scientific publications collected from the Lens database randomly from various disciplines based on certain keywords. Microsoft 365 Excel version 2212 and VOSviewer analyzed the dataset through some purification or filtering to produce some mapping visualizations. These maps would describe the network patterns of publication data, which will be interpreted later. That way, the scientific field of architecture could determine its position and opportunities in this research today and in the future.

RESEARCH METHOD

This study used the Lens search engine without limiting the time of publication to obtain broader literature data on the topic of dew and fog harvesting. Lens provided a database of scientific works that is quite complete, easy to access, open, free of charge, and without institutional accounts. However, some mapping visualizations in VOSviewer were not available for data from Lens, such as in co-citation analysis and co-authorship analysis for organizational units and countries.

Microsoft 365 Excel version 2212 served to provide a descriptive analysis of the years, types of publications, sources, and countries from collected publications without processing the Lens dataset through the inclusion, exclusion, and extraction stages, due to large data. In addition, it also provided additional visualization in subsequent analyses.

The data search identified scientific publications related to the topic of dew and fog harvesting using the following keywords: "Dew Catcher" OR "Dew Collector" OR "Dew Collection" OR "Dew Harvesting" OR "Dew Condenser" OR "Dew Condensation" OR "Fog Catcher" OR "Fog Collector" OR "Fog Collection" OR "Fog Harvesting". This was because the terms in the research topic of dew and fog harvesting were very diverse, so these ten keywords were used to obtain more varied data. The ten keywords were found in previous searches manually. The resulting dataset was then saved in .csv format, then converted into .xlsx format.

Inclusion and Exclusion

Datasets that have been collected from search engines did not go through an inclusion and exclusion process before being inputted into VOSviewer. This process was carried out after the dataset is inputted into the VOSViewer to get a more suitable and more adequate mapping visualization. VOSviewer would provide settings for limiting the minimum amount of data in an

item.

Data Extraction

As with the inclusion and exclusion process, data extraction was done in VOSviewer. VOSviewer would suggest the largest set of connected items. Even so, this VOSviewer recommendation would be considered for the purposes of effective and efficient visualization.

Analysis

The extracted data was visualized by VOSviewer and Microsoft 365 Excel version 2212. Lens dataset analysis that could be processed by VOSviewer was selected according to the needs of more efficient and effective visualization and interpretation. Citation analysis used the sources and the names of the authors. Co-occurrence analysis used author keywords. Co-authorship analysis used the names of the authors.

Citation analysis would present the relationship between publications and the most influential publications. Co-occurrence analysis was carried out to describe the mapping of the relationship between the keywords of the research topic. Meanwhile, co-authorship analysis showed the relationship between the authors (Donthu et al., 2021). The discussion would end with content analysis. Content analysis was used to get clearer insights, especially in publications related to architecture in dew and fog harvesting research.

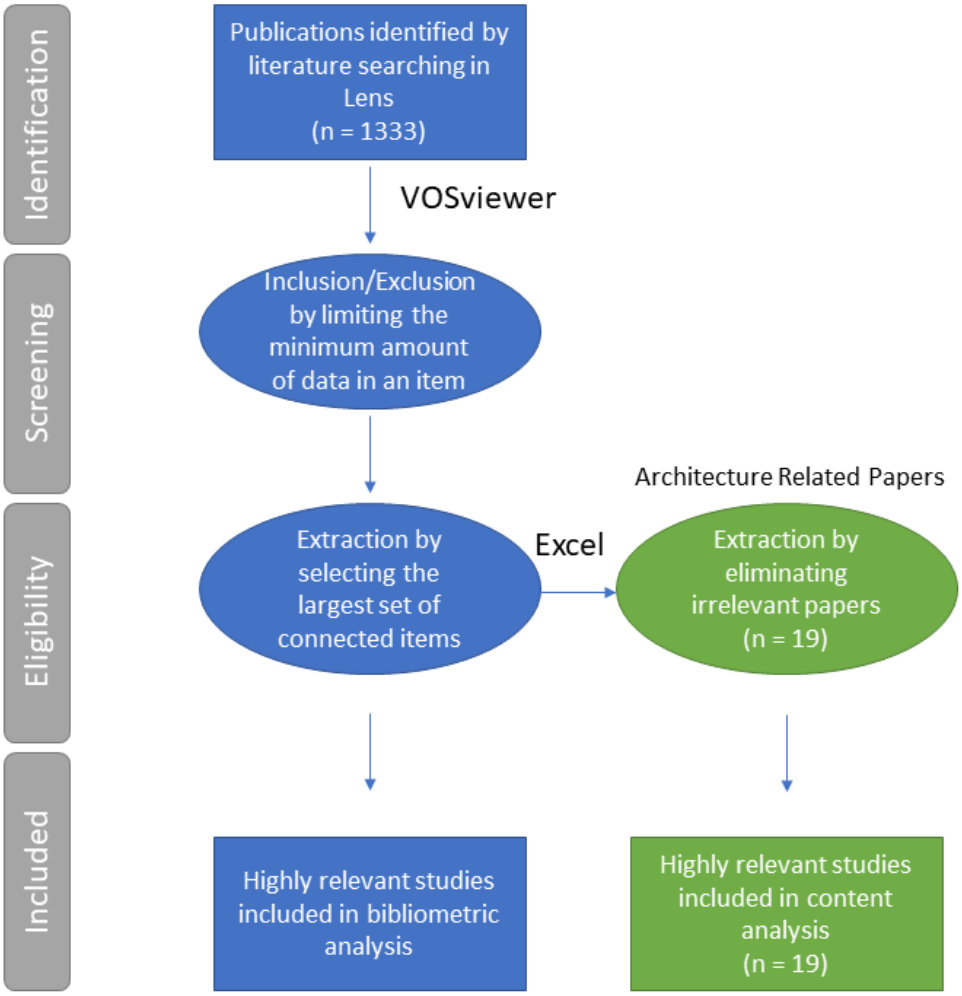

Figure 1. Flow Diagram of Literature Selection for Bibliometric Analysis
Source: Author, 2023

RESULT AND DISCUSSION

The collection of publications from the Lens search engine yielded 1,333 publications. This dataset was then processed in Microsoft 365 Excel Version 2212 to analyze the data descriptively in the form of visualization diagrams. Moreover, Lens also provided some analytic diagrams that can be used to this paper for descriptive analysis. This study used bibliometric analysis, so this dataset was not cleaned manually because the number was too large, and the scope was too broad. So empty data was ignored. For co-occurrence, co-authorship, and citation analyses, datasets were processed in the VOSViewer by inclusion-exclusion and extraction processes, then generated scientific mappings showing the meshes of interrelationships of items to one another.

Descriptive Analysis

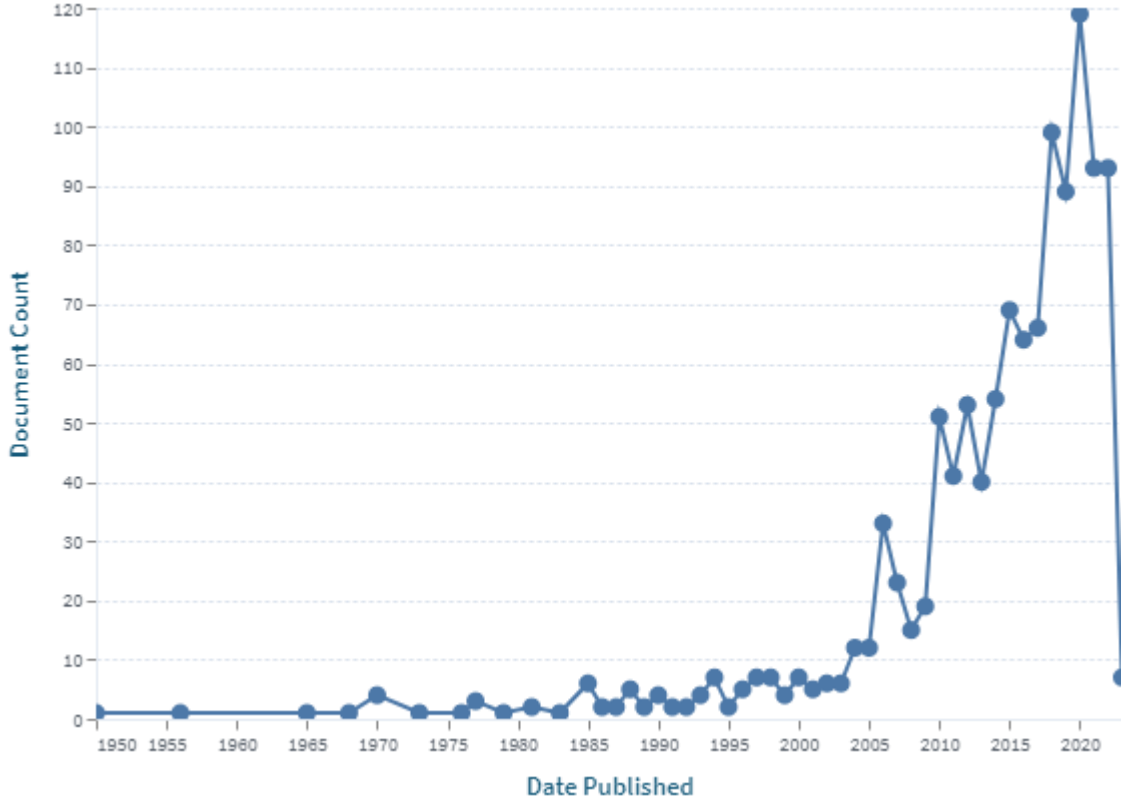

Figure 2. Publication Trends on Dew and Fog Harvesting Research
Source: Lens.org, 2023

From the dataset collected, there were 178 publications whose year is not filled in. But this was ignored, using the filled data. In the diagram in Figure 2, publications related to the topic of dew and fog harvesting began in 1938. Around the 1980s there was an increase in the frequency of publications. This seemed to be in line with the use of the terms global warming and climate change which were gaining popularity at the time, even though studies on this matter had existed before (Shaftel, 2016). However, since the 2000s, publication trends on this topic have increased significantly. At the same time, climate change issues were becoming important discussions and are experiencing increasing use (Joo et al. 2015).

The most active author who produced the largest documents was Daniel Beysens, with 31 documents (see Figure 3). With him, Lei Jang, and Zhiguang Guo made papers above 20. Yongmei Zheng, Girja Sharan, Robert S. Schemenauer, Jin Kawakita, Pilar Cereceda, and Marc Muselli made papers above 10.

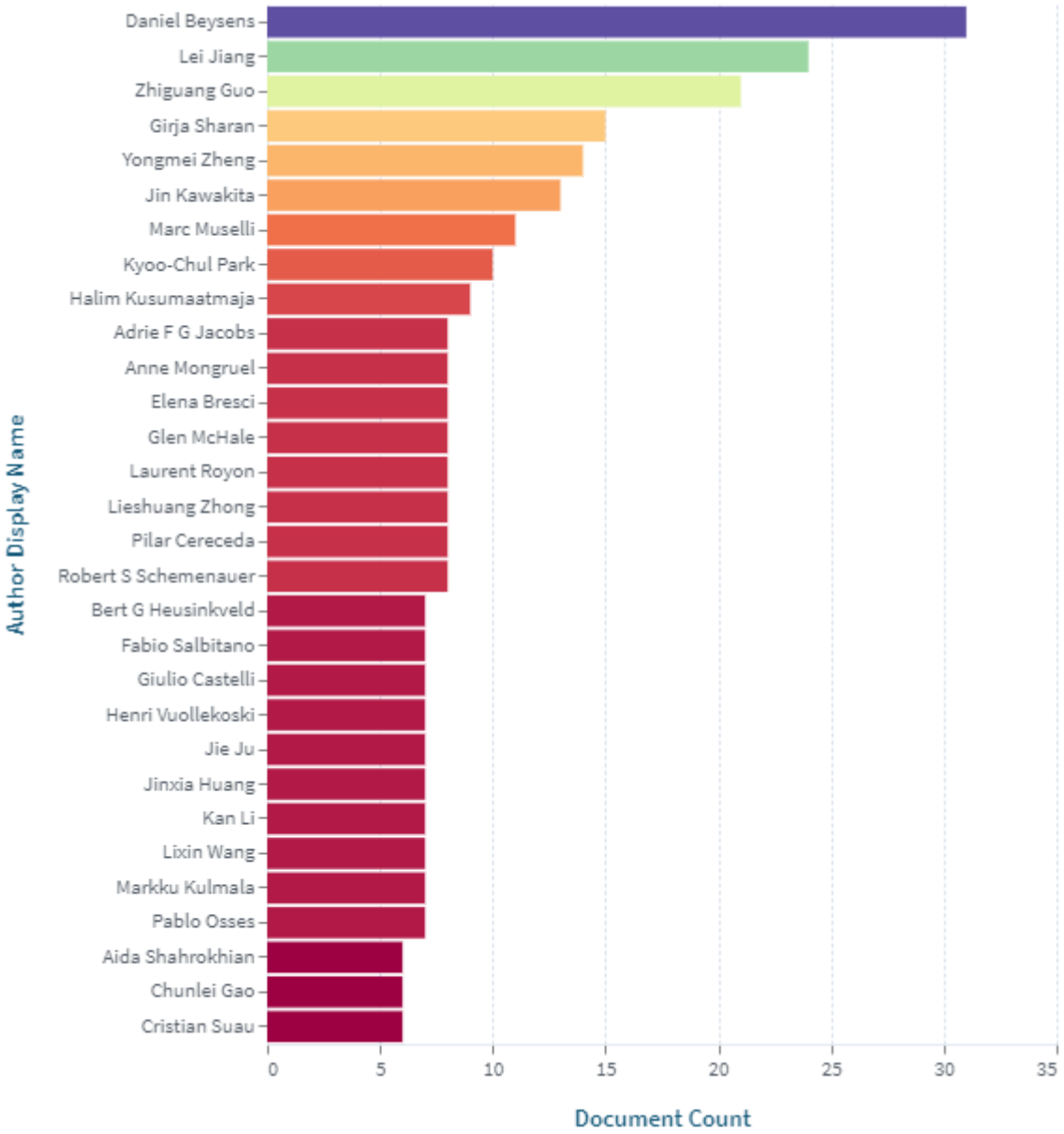

Figure 3. Most Active Authors
Source: Lens.org, 2023

Based on the collected dataset, there were 234 publications whose publication type was not filled in, 420 publications whose publication source was not filled in, and 702 publications where the name of the author's country was not filled in. Based on the available dataset, the most common type of publication was journal articles (see Figure 4). Only a few publications have been presented at scientific conferences and seminars.

The sources that published this research topic were very diverse, where ACS Applied Materials & Interfaces was the most chosen source (see Figure 5). This indicated more publications conducting research on the theme of materials and their surfaces related to this research topic. The countries that publish the most topics discussed were from the United States and the United Kingdom (Figure 6). This was most likely because the most popular publications recorded on the Lens database for this topic are in English, while only a few publications in other languages are used, so they received less global recognition.

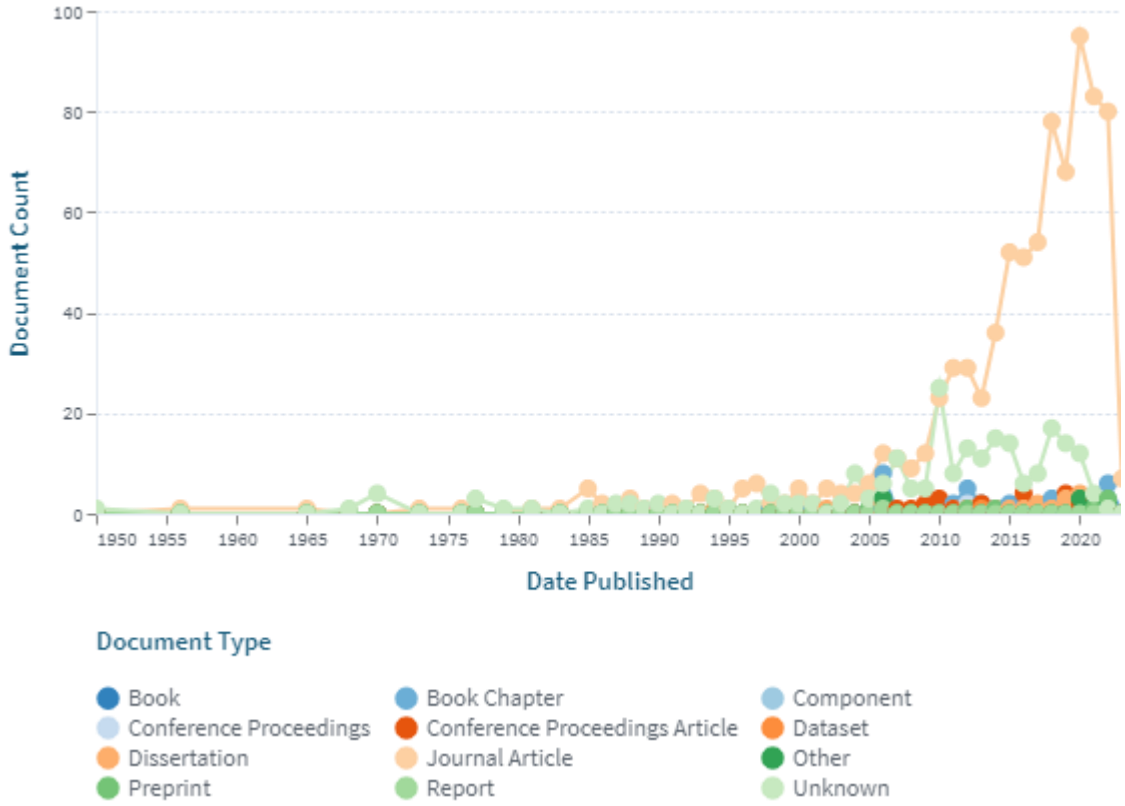

Figure 4. Publication Types on Dew and Fog Harvesting Research
Source: Lens.org, 2023

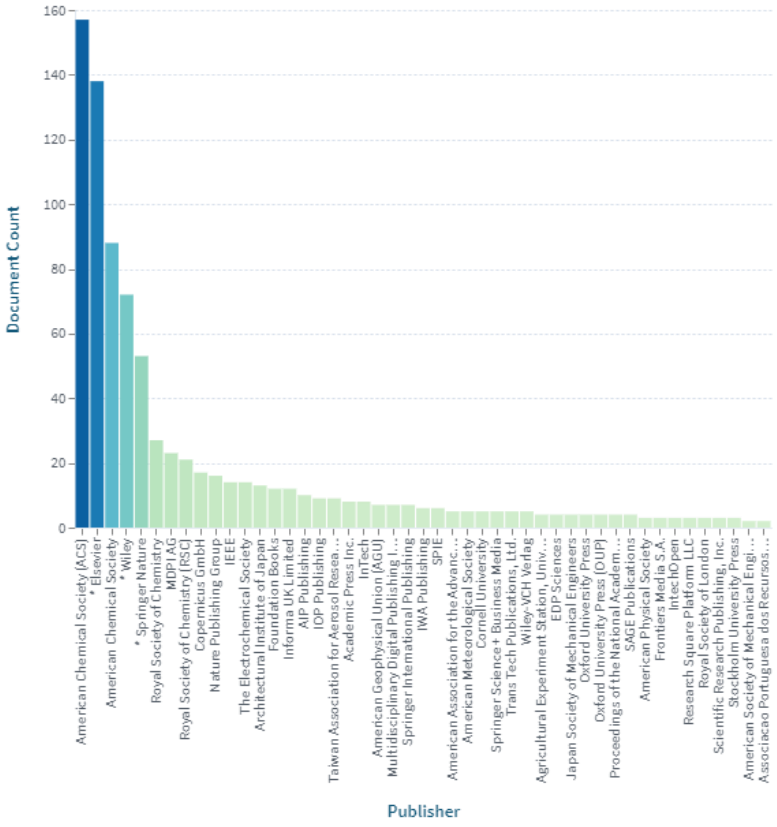

Figure 5. Publication Sources on Dew and Fog Harvesting Research
Source: Lens.org, 2023

Figure 6. Countries Origin of Authors on Dew and Fog Harvesting Research
Source: Author, 2023

Citation Analysis

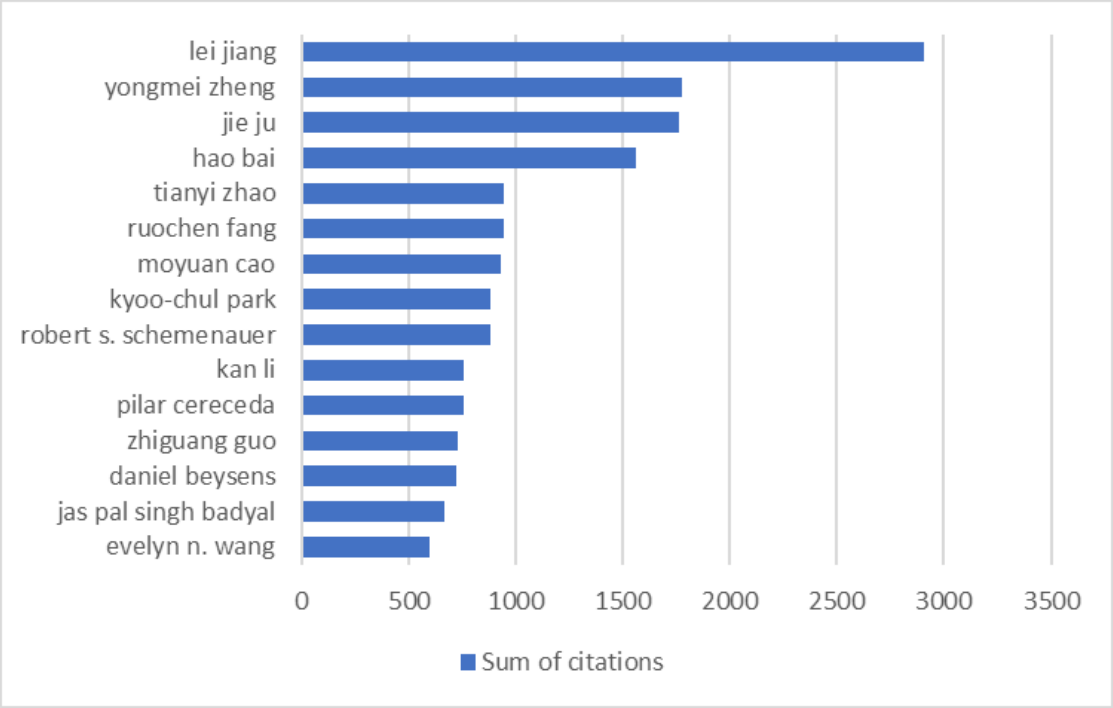

Figure 7. Most Cited Authors on Dew and Fog Harvesting Research
Source: Author, 2023

Papers by Lei Jang were the most cited among others, had 2,904 citaions. Yongmei Zheng, Jie Ju, and Hao Bai had citations above 1,000. Tianyi Zhao, Ruochen Fang, Moyuan Cao, Kyoo-Chul Park, Robert S, Shemenauer, Kan Li, Pilar Cereceda, Zhiguang Guo, Daniel Beysens, Jas Pal Singh Badyal, and Evelyn N. Wang respectively had citations above 5,00 (see Figure 7).

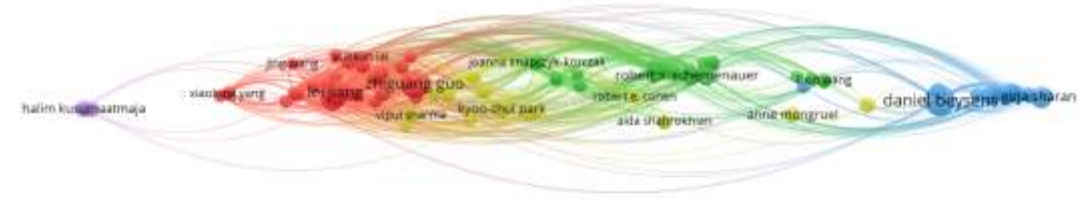

Figure 8. Citation Network on Publication Authors with 5 Clusters after Going through the Inclusion and Exclusion Process with a Minimum Number of Five Documents from an Author the Extraction Process by Selecting the Largest Set
Source: Author, 2023

The first citation analysis was performed on publication authors on dew and fog harvesting research topics using VOSviewer. The inclusion and exclusion process were carried out by determining the minimum number of documents from an author, namely 5. From this process, 92 items were produced. From a number of these items were extracted based on the largest set, with a total of 84 items, 5 clusters with a linkage of 1,430 and a total linkage strength of 7,132 (see Figure 8). In the blue cluster, the most influential authors were Beysens. Schemenauer was the most influential writer on the green cluster. Meanwhile, the author who was very influential on the yellow cluster is Park, the red cluster was Guo, and the purple cluster was Kusumaatmaja.

The most cited source among others was ACS Applied Materials & Interfaces. With it, Langmuir and Journal of Materials Chemistry had citations above 1,000. Advanced Functional Materials, Atmospheric Research, and Nanoscale had citations above 500. Scientific Reports, Applied Surface Science, Advanced Materials Interfaces, ACS Nano, Journal Colloid and Interface Science, Sensors, Journal of Hydrology, Colloids and Surfaces, and Chemical Engineering had citations above 100 (see Figure 9). There were no sources from Architecture on the top fifteen. AIJ Journal Technology and Design - the only source from architecture science - had 0 citation on Dew and Fog Harvesting Research.

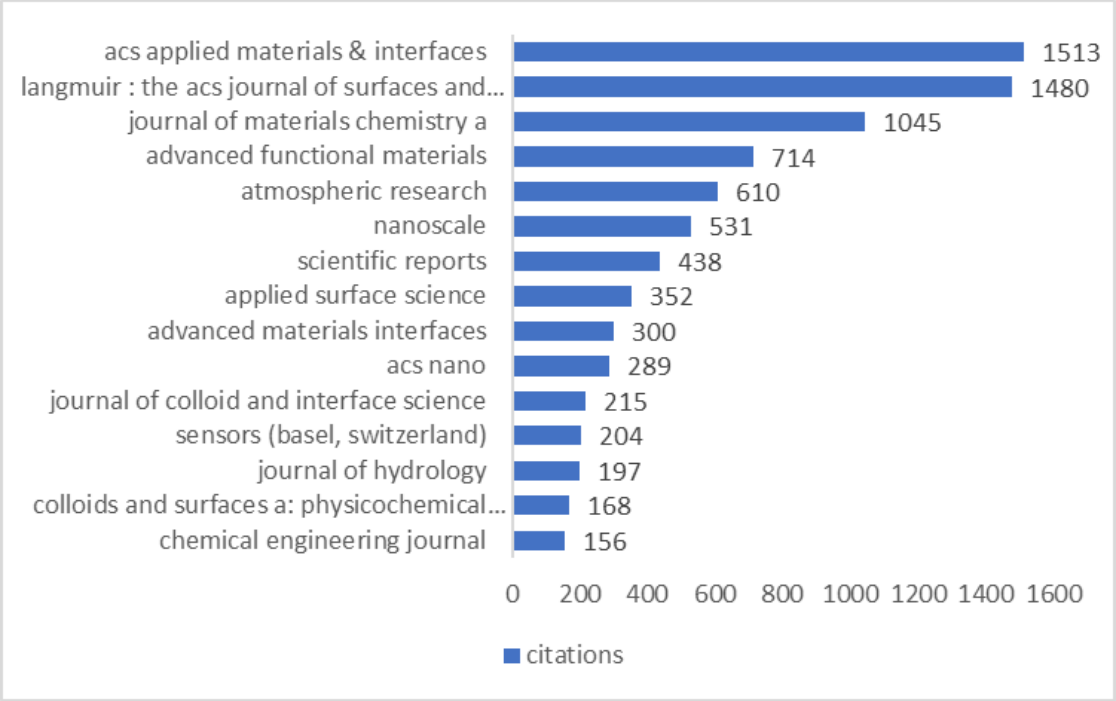

Figure 9. Most Cited Sources on Dew and Fog Harvesting Research
Source: Author, 2023

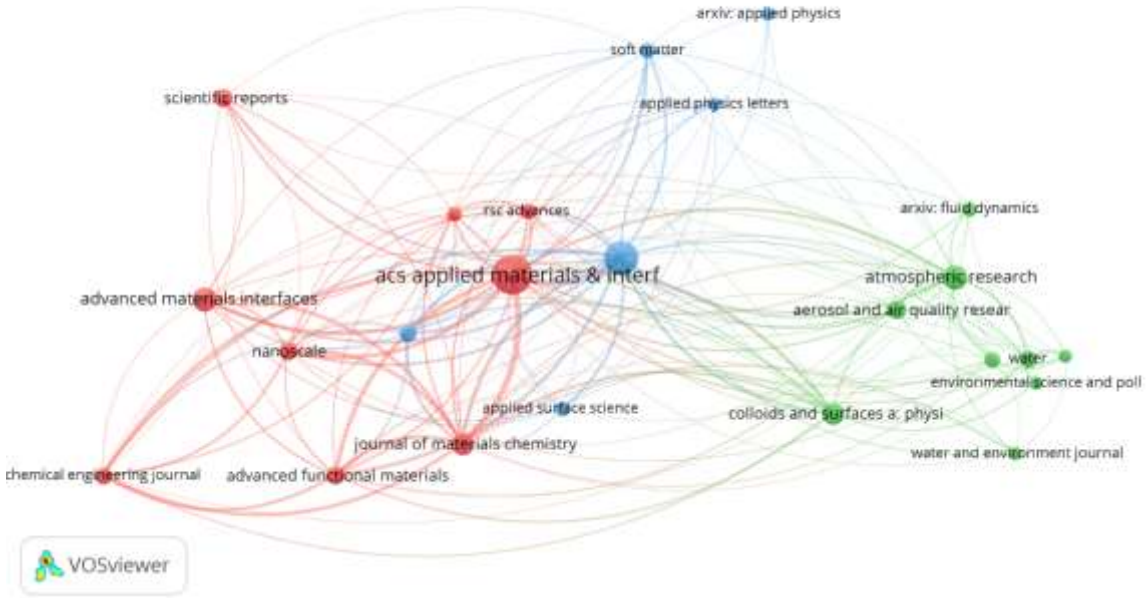

Figure 10. Citation Network on Publication Sources with 3 Clusters after Going through the Inclusion and Exclusion Process with a Minimum Number of Five Documents from a Source and the Extraction Process by Selecting the Largest Set
Source: Author, 2023

The second citation analysis was carried out on publication sources. The inclusion and exclusion process were carried out by determining the minimum number of documents from a source, namely 5. From this process, 33 items were produced. From a number of these items were

extracted based on the largest set, with a total of 24 items, 3 clusters with a linkage of 170 and a total linkage strength of 1,169 (see Figure 10). The most influential source in the red cluster was ACS Applied Materials and Interface, the blue cluster was Langmuir: The ACS Journal of Surfaces and Colloids, and the green cluster was Atmospheric Research. From this analysis, the sources were dominated by materials and surface studies, especially in the red and blue clusters. Meanwhile, the green cluster had a focus on air and water research, which might be an opportunity for sources of publication for architectural scholars but in the form of multidisciplinary research. At first glance, journals on architectural science seemed to be absent from the network. The only journal that publishes architectural scientific research, even related to the research topic of dew and fog harvesting, was the AIJ Journal of Technology and Design, but it did not pass the extraction process because it was not included in the largest set selected by VOSviewer.

Co-Occurrence Analysis

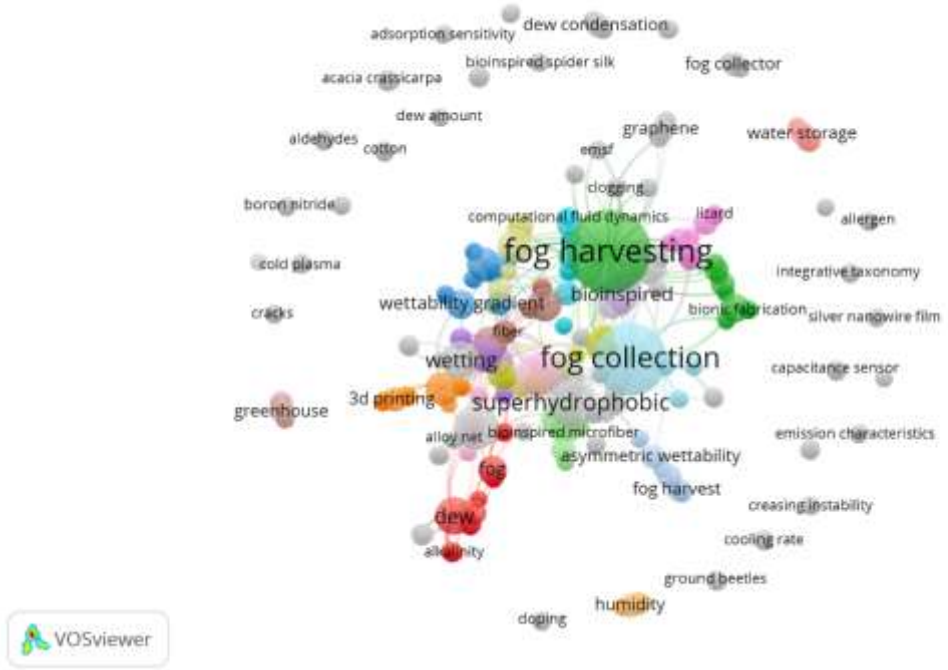

Figure 11. Keywords Co-Occurrence Network Produces 59 Clusters after Going through Inclusion and Exclusion Process with Minimum Number of One Occurrence of a Keyword
Source: Author, 2023

Co-occurrence analysis was performed on author keywords using VOSviewer. During the inclusion and exclusion process by determining the minimum number of occurrences of a keyword once, 497 keyword items were obtained. Of these, 59 clusters were formed with 1,464 linkages and a total strength of 1,493 linkages (see Figure 11).

VOSviewer suggested extraction by selecting the largest set of linked items of 313 items. The extraction yielded 32 clusters with 102 linkages and a total strength of 1,054 linkages (see Figure 12). However, the number of clusters was still too large because the keywords are too diverse.

Then the number of occurrences of a keyword was increased to 2. The result was 55 items. Of the total keyword items, 16 clusters were formed with 146 linkages and a total linkage strength of 175 (see Figure 13).

By going through an extraction process by selecting the largest set of connected items of 55, the number of clusters became 11 with a linkage of 146 and a total linkage strength of 175 (see Figure 14). These results are considered sufficient to be analyzed interpretively.

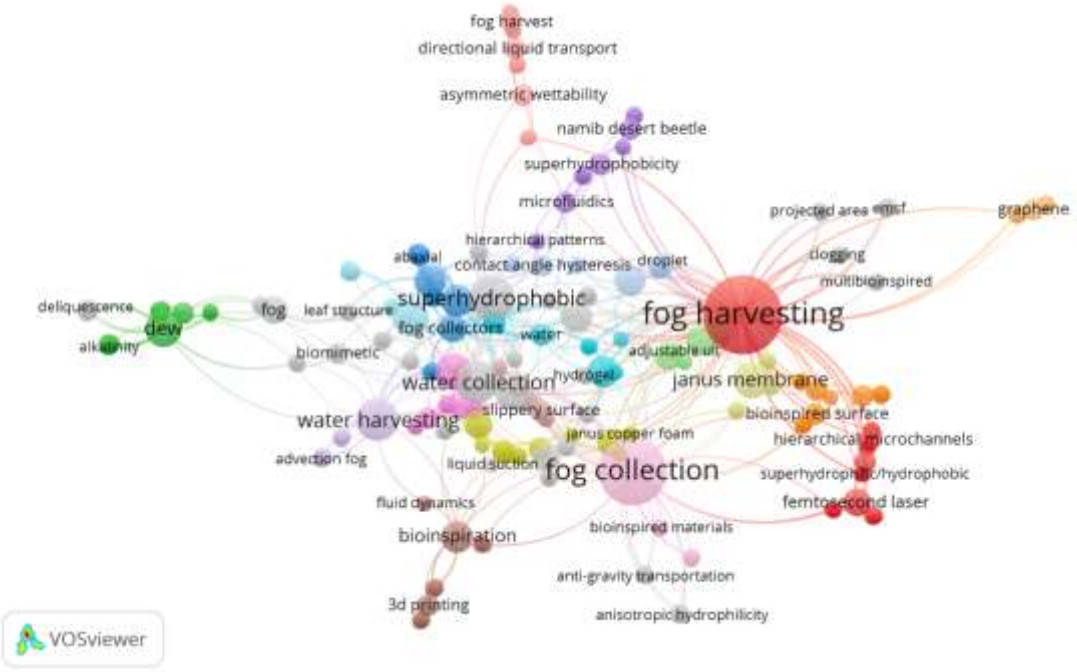

Figure 12. Keywords Co-occurrence Network Produces 32 Clusters after Going through the Extraction Process by Selecting the Largest Set of Linked Items
Source: Author, 2023

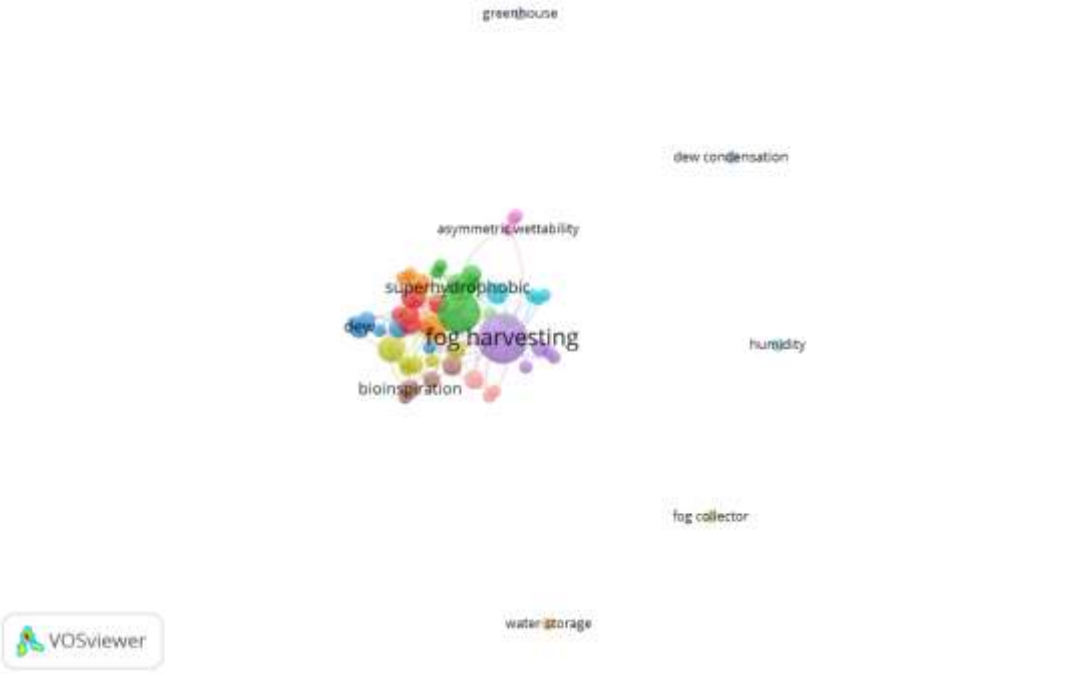

Figure 13. Keywords Co-Occurrence Network Produces 16 Clusters after Going through Inclusion and Exclusion Process with Minimum Number of Two Occurrences of a Keyword
Source: Author, 2023

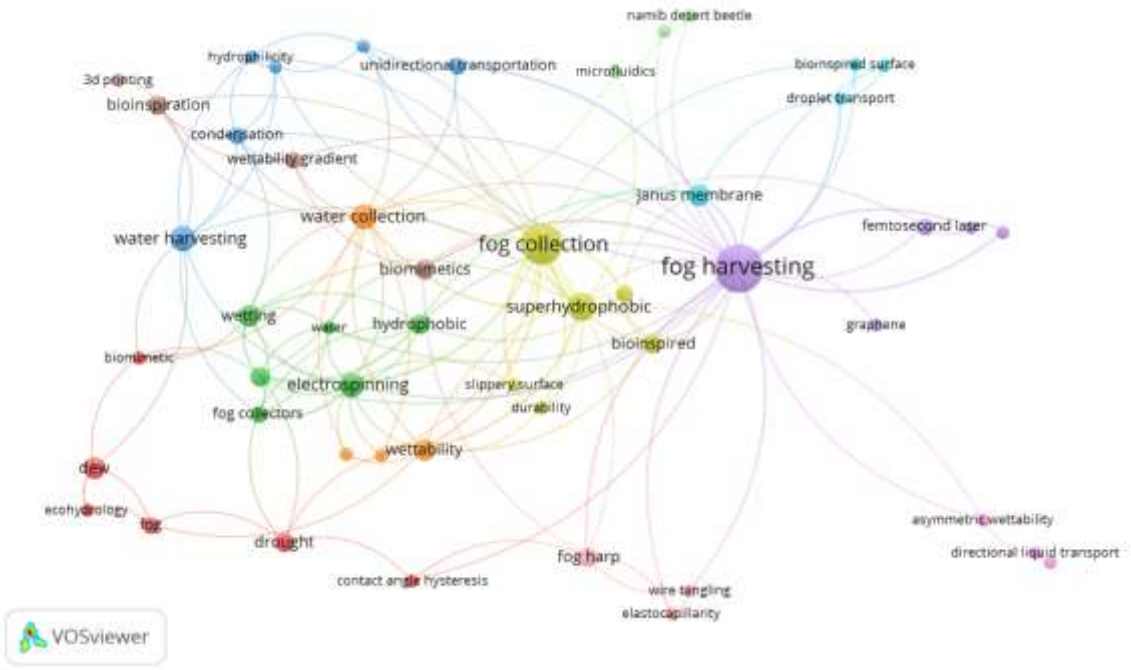

Figure 14. Keywords Co-Occurrence Network Produces 11 Clusters after Going through the Extraction Process by Selecting the Largest Set of Linked Items
Source: Author, 2023

From the eleven clusters, the research focus of each cluster could be formulated. The red cluster focused on studies on dew and fog. The green cluster focused on micro and nanofiber materials for fog collection. The blue cluster focused on dew water harvesting methods and designs. The yellow cluster focused on bioinspiration methods on the fog collection surface. The purple cluster focused on the fog harvesting method and design. Orange cluster focused on the fetal membranes. The light blue cluster focused on the combined dew and fog collection method. The chocolate cluster focused on biomimetic and bioinspiration designs. The pink cluster focused on asymmetric wet ability studies of fog harvesting. The dark red cluster focused on the studies and designs of the fog harp. And the dark green cluster focused on material surface superphobicity studies.

In the research focus clusters that were formed, the scientific field of architecture had opportunities to contribute to research focus clusters with a design approach. The research focus clusters were the dew water harvesting method and design cluster, the fog harvesting method and design cluster, the biomimetic and bioinspiration design cluster, and the fog harp design and studies cluster. However, at first glance, the focus of research with a design approach was more dominated by research on material and surface design. So, it could be considered that there was a research gap on the research topic of dew and fog harvesting for research in the scientific field of architecture. This would probably be seen more clearly in subsequent analyses.

Co-Authorship Analysis

Co-authorship analysis was conducted among publication authors on the research topic of dew and fog harvesting using VOSviewer. The inclusion and exclusion process were carried out by determining the minimum number of documents from an author, namely 5. From this process, 92 author items were produced which were divided into 28 clusters with 155 linkages and a total linkage strength of 582 (see Figure 15). When extracted, the number of items and clusters became too small, and the largest set consisted of research focuses on materials and surfaces only. Then the previous data were used in this analysis.

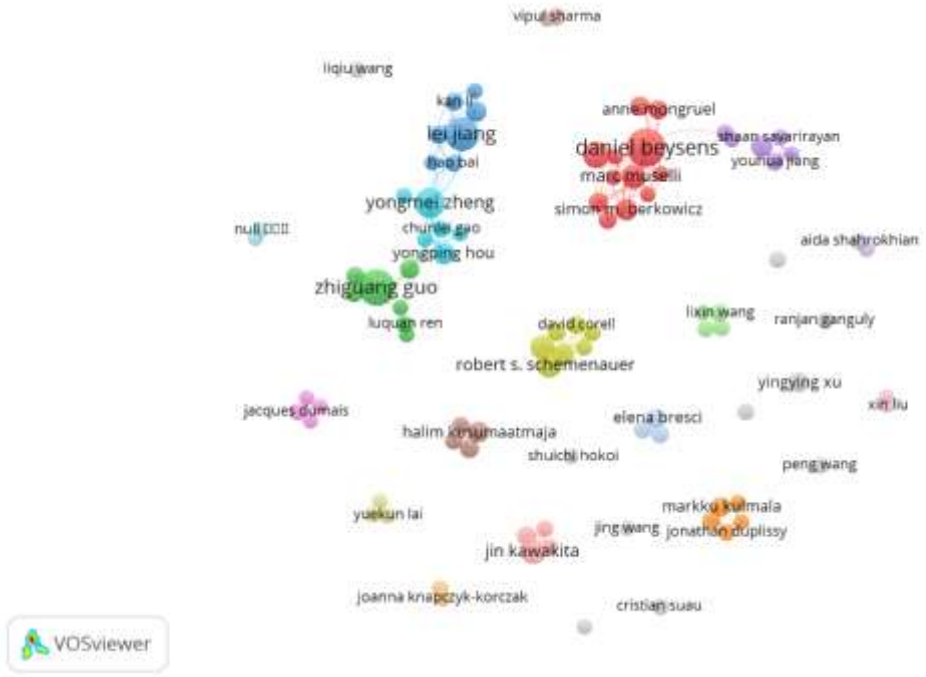

Figure 15. Co-Authorship Network with 11 Clusters after Going through Inclusion and Exclusion Process with Minimum Number of Five Documents from an Author
Source: Author, 2023

There were 2 largest sets in this co-authorship analysis. The first largest set consisted of blue, light blue, and green cluster, that focused on fog harvesting materials and surfaces with traditional, biomimetics, and bioinspiration approach. The second largest set consist red and purple cluster, that focused on dew and fog harvesting materials and architecture. Apart from that, the yellow clusters respectively focused on dew and fog collector design.

Tabel 1. Authorship Clusters and Most Occurring Authors on the Topic of Dew and Fog Harvesting Research

Cluster	Most Occurring Author	Research Focus
Red Cluster	Beysens	Materials and Architecture for Dew Harvesting
Green Cluster	Guo	Fog Harvesting Materials Surface with Traditional and Biomimetic Approach
Blue Cluster	Lei Jiang	Fog Harvesting Material Surfaces with Traditional and Bioinspired Approach
Yellow Cluster	Schemenauer	Dew and Fog Collector Design as Water Resource
Purple Cluster	Kyoo-Chul Park	Fog Harvesting on Wires, Fibers, Meshes, and Asymmetric Bump Surfaces
Light Blue Cluster	Yongmei Zheng	Fog Harvesting Materials and Surfaces: Bioinspired Approach
Orange Cluster	Kulmala	Fog Harvesting Material Surfaces Using Micro/ Nanostructures
Brown Cluster	Kusumaatmaja	Droplet Transport on Liquid Surfaces
Pink Cluster	Azeem	Fog Collector Design and Structure
Light Red	Kawakita	Dew Condensation on Galvanic Arrays
Light Green	Kaseke	Fog and Dew as Water Resources in Namib Desert
Dark Blue	Bresci	Fog as Water Resources in Atacama Desert

Dark Light Blue	Undetected	Dew Condensation on Buildings
Cluster	**Most Occurring Author**	**Research Focus**
Dark Orange	Stachewicz	Fog Harvesting Using Micro/ Nanofibers
Dark Brown	Sharma	Bioinspired Structured Surfaces for Dew and Fog Harvesting
Dark Pink	Xiaolong Yang	Superhydrophilic and Superhydrophobic Surfaces for Fog Harvesting
Grey 1	Cristian Suau	Fog Collector Architecture in Atacama Coast
Grey 2	Abualhamayel	Large Fog Collector Design in Saudi Arabia
Grey 3	Badyal	Plants Bioinspired Fog Collector Architecture on the Arid Climate
Grey 4	Jing Wang	Bioinspired Conical Spine Surface Design for Fog Harvesting
Grey 5	Liqiu Wang	Fibers for Fog Harvesting
Grey 6	Peng Wang	Naomaterials and Bioinspired/ Biomimetics Surfaces
Grey 7	Ganguly	Fog Harvesting from Cooling Towers Using Metal Mesh
Grey 8	Abdul-Wahab	Fog Water Collection in Oman
Grey 9	Hokoi	Dew Condensation on Glass Curtain Wall
Grey 10	Yingying Xu	Dew Condesation and Air Quality

Source: Author, 2023

Content Analysis

Tabel 2. Most Occurring Authors on the Topic of Dew and Fog Harvesting Research Related to the Field of Architecture Science

No.	Most Occurring Authors	Documents	Theme	Topic Focus	Product Scale
1	Robert S. Schemenauer	6	Dew and Fog Harvesting	Dew Condenser and Fog Nets Collector Design	Large
2	Daniel Beysens	3	Dew Harvesting	Dew Condenser Materials and Architecture	Small
3	Musaddaq Azeem	2	Fog Harvesting	Fog Collector Design and Structure	Large
4	Cristian Suau	2	Fog Harvesting	Fog Collector Modular Architecture Design	Large
5	David V. Carrera-Villacrés	2	Fog Harvesting	Fog Collector Design Studies	Large
6	Leslie Dodson	2	Fog Harvesting	Fog Nets Collector Design	Large
7	H. I. Abualhamayel	1	Fog Harvesting	Fog Nets Collector Design	Large
8	Danilo Carvajal	1	Dew Harvesting	Roof-Integrated Dew Harvesting	Small
9	Theska Laila de Freitas Soares	1	Dew and Fog Harvesting	Biomimetics and Sustainability	Large

Source: Author, 2023

There were several clusters that focused on dew and fog harvesting research related to the scientific field of architecture (see Table 2). The red cluster was a cluster of related authors, in which authors named Beysens appear a lot. There were three publications written by the author together with other authors related to architecture, namely Sharan et al. (2007), Beysens et al. (2012), and Carvajal et al. (2018). This cluster focused on dew harvesting materials and architecture. The most author appearing in the yellow cluster was Schemenauer. This cluster focused on studies and projects of dew and fog harvesting as a source of water using nets. Together with other authors, Schemenauer authored publications related to architecture, such as: Schemenauer et al. (1989), Schemenauer et al. (1994), Shanyengana et al. (2003), Schemenauer et al. (2004), Carter Gamberini et al. (2007), and Schemenauer et al. (2016). The most author appearing in the pink cluster was Azeem. This cluster focused on the design and structure of the

fog collector. Azeem and other authors produced publications related to architecture, such as: Azeem et al. (2020a) and (2020b).

Moreover, there were several authors that appear in clusters alone (see Table 1). Suau focused on the architecture of modular fog collectors on the Atacama Coast, produced in architecture-related publications such as: Suau (2010) and Suau et al., (2014). Abualhamayel focused on the design of large fog collectors in Saudi Arabia, produced in architecture-related publications in Abualhamayel (2010). In fact, there are still many authors whose research focus related to the scientific field of architecture but were not included by VOSviewer because there were less than 5 documents, such as: Carvajal on Carvajal et al. (2018) with Beysens, Dodson on Dodson et al. (2015) and Qadir et al. (2018), Carrera-Villacrés on Carrera-Villacrés et al. (2017) and Carrera-Villacrés et al. (2020), and Soares on Soares et al. (2017).

From the content of some of these publications provided some highlights. Dew and Fog Harvesting still require an efficient architectural design (Suau, 2010 and Beysens, 2012). Moreover, there are still open explorations of architectural forms with biomimetics and bioinspiration approaches on this topic (Soares, 2017). This research topic related to architecture also met locality, community, and sustainability issues (Dodson et al., 2015 and Qadir et al., 2018).

CONCLUSION

The results of exploring the trend of publications on the topic of dew and fog harvesting achieve the objectives of this research. From the results of the analysis, it can be concluded that the trend of publications on this research topic is starting to develop significantly and opening more and more diverse research opportunities in the future. Currently, the topic is dominated by a research focus on materials and surfaces, but there is still room for architectural scholars to position itself to contribute and collaborate. There are still very few publications related to architectural science initiated by several authors, but in fact it is a starting point at this time and a great opportunity for further research, especially in relation to context, locality, community, sustainability, biomimetics, bioinspiration, and low technology. Moreover, there are opportunities for sources of architectural scientific publications to provide this research topic. And these sources will get more colorful research on topics with new and fresh issues. The results of this bibliometric analysis will be continued to the Systematic Literature Review before moving on to the Narrative Literature Review.

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