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Bibliometrics: Analysis of the Development of Desalination Membranes in the Past Decade to 2022

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Abstract
Purpose: This study uses a bibliometric method to computational mapping analysis with VOSviewer to look at how chemical particle desalination membrane research has evolved.
Methodology: By using the publish or perish reference manager tool, the Google Scholar database was queried for the article data. By using the phrase "Chemistry Particle Desalination Membrane" the search is directed by the title and abstract of the article. There were 1024 items that were thought to be pertinent. The research period considered for the study is the most recent ten years of Google Scholar-indexed articles (2012 to 2022).
Results: The findings showed an upward trend in the number of papers on desalination membranes. In desalination membrane research, there are 5 clusters and 5 topics that are frequently discussed. These are Cluster 1: Treatment (number of links 52, total link strength 99, accurness 65), Cluster 2: Composite (number of links 34, total link strength 49, accurness 40), Cluster 3: Nanofiltration (number of links 42, total link strength 92, accurness 52), Cluster 4: Desalination performance (number of links 39, total link strength 93, (number of links 34, total link strength 75, accuracy 38).
Limitations: The limitation of this research wass focused on the development of desalination membranes in the last 10 years using bibliometric analysis.
Contribution: This study can provide an explanation that serves as a foundation for knowledge about the development of desalination membrane.
Keywords: *Bibliometric, Computational mapping analysis, Chemistry Particle Desalination Membrane, VOSviewer, Publish or Perish.*
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1. Introduction

Water treatment technology using membranes has been widely used by the industrial sector because the separation process can be carried out continuously, low energy requirements, can take place at room temperature, does not cause degradation of the separated substances because of the non-destructive and environmentally friendly nature of the membrane (Xu et al., 2020). The separation process in membrane technology can occur due to an impulse in the form of pressure differences, electric fields, or concentrations. Based on the size of the particles that can be separated, the separation technology using membranes is classified into 3, namely Microfiltration, Ultrafiltration, and Nanofiltration.

Good water treatment techniques are needed to maintain the quality and availability of clean water. One of the innovations in water treatment that can be developed to meet water needs is through seawater treatment (almost 97% of the world's water) using desalination technology with membrane filtration(Okamoto & Lienhard, 2019). This membrane technology has potential for seawater desalination applications with the ability to reject up to 100% salt (Kusworo et al., 2021).

Desalination is the process of separating salts (multivalent molecules and ions) and minerals in water through a semipermeable membrane with the help of pressure. Water purification using membrane desalination technology takes place with minimum energy when compared to other technologies. The use of this technology also has more advantages such as, easy to use, effective, done without the addition of chemicals and requires relatively lower costs (Lusiana et al., 2020). The membrane as the main component must have certain characteristics, such as good mechanical properties, good durability, minimal pollution, antifouling and high permeability (Ravi et al., 2020). Desalination membrane technology has great potential in water treatment, so the research and development of this technology continues to increase from year to year. Analysis of the development of desalination membrane technology can be carried out using bibliometric analysis methods.

Bibliometric analysis is a powerful tool for understanding the growth and prospects of research areas. Bibliometric strategies have been used to examine the evolution of research fields, recognize the relationship between logical developments and strategic change, and identify evolving interdisciplinary collaborations. Bibliometrics has become a standard tool for science policy and research management in recent decades. All compilations of significant scientific indicators, relying mostly on published statistics and citations and other bibliometric techniques. Bibliometric analysis offers in-depth quantitative and statistical scientific insight into methods for making decisions on policy issues. Comprehensive bibliometric analysis can be performed using various online databases (eg, Scopus, Google Scholar, Pub Med and Web of Science). In addition, various software such as Citespace, Bibexcel, Publish or Perish, Ucinet, Gephi, Pajek, VOSviewer, and Science of Science (Sci2) can provide illustrative data representation and mapping (Goel et al., 2021). In this study, a bibliometric analysis of desalination membranes will be carried out using software called Perish Publish and VOSviewer with a database from Google Scholar in past 10 years.

2. Literature review

2.1 Membrane Technology

Membrane technology has evolved and is now widely used in the separation and purification of water. The membrane is generally defined as a porous medium in the form of a thin layer with semipermeable properties that allow certain species to pass through (Rahmaniyan et al., 2021). The particle size of the compound and the pore size of the membrane are used to separate species through the membrane, with particles larger than the membrane pores being retained on the membrane surface. The retentate, or part of the mixture that does not pass through the membrane, and the permeate, or part of the mixture that does pass through the membrane, are the results of the separation. The driving force for mass transfer on the membrane can be differences in concentration (C), pressure (P), temperature (T), or electric potential (E) (Zahirifar et al., 2018).

2.2 Desalination

Water desalination is the separation of dissolved minerals (including salt) from seawater, brackish water, or treated wastewater (Saleem & Zaidi, 2020). Distillation, ion exchange, freeze desalination, and membranes are some of the basic techniques for separating salt and other dissolved solids (Subramani & Jacangelo, 2015). Membrane desalination technology is the use of a semipermeable membrane to isolate salt and achieve salt-water separation. Water desalination technologies that use membranes, such as reverse osmosis and nanofiltration, can be used (Anis et al., 2019). According to the driving force, pressure membrane water desalination technology (RO and NF) has the advantages of relatively high energy efficiency, low operating pressure, a high rejection rate for divalent salts, and is environmentally friendly when compared to other salt separation technologies (Homaeigohar & Elbahri, 2017). Reverse osmosis is the most effective technology for producing drinking water from seawater at the moment. Water is pressed against a semipermeable membrane during reverse osmosis desalination, allowing water to pass through while salt is retained. A high-pressure pump will press the feed water into the membrane to supply it. A high-pressure pump will press the feed water into the membrane to supply pressure and push the water through the membrane, so a higher pressure is required to treat water with a higher salt concentration (Okamoto & Lienhard, 2019).

2.3 Bibliometric

Bibliometrics is a tool for determining objective publication data, which is frequently used as performance data and can assist in completing the tasks mentioned. Its basic features can be considered highly mathematically and statistically, or they can be rendered understandable and transparent to nonmathematicians. Opposition to and reservations about gathering data on research performance stem primarily from people who do not understand the method and fear it as manipulation. As a result, it is critical not only to make bibliometrics understandable and transparent, but also to reveal its limitations and identify alternatives (Husaeni & Nandiyanto, 2022). Cole and Eales developed the first bibliometric analysis. The authors investigated which books on human anatomy were published between 1550 and 1860 in 1917 (Ball, 2018).

On the other hand, Bibliometrics is a set of quantitative methods for analyzing academic literature and patents. Meanwhile, using keywords, the bibliometric method can describe distribution patterns within a given topic, field, institute, or country, as well as assess development trends or future research orientations. The basic idea behind bibliometrics is to quantify people's and institutions' academic output. A second step involves drawing qualitative conclusions from the figures and values. Bibliometrics is one method for accomplishing this (Hassan et al., 2020). The bibliometric method is an indirect approach that deduces academic quality from quantification of academic output and publications (Al Husaeni & Nandiyanto, 2021). Aside from traditional publications, there are a slew of other quantifiable factors that can be used to assess academic performance and quality, such as the number of final projects supervised (doctoral theses, postdocs, etc.), the amount of external funding raised, the number of pending patents, the number of exhibitions and visitors, appointments on relevant national and international committees, the number of students enrolled per chair or professor, and the extent and number of publications (Ball, 2018).

3. Experimental Procedure

The article data used in this study was based on research from publications that have been published in Google Scholar indexed journals. We selected Google Scholar in this study because the Google Scholar database is an open source. To obtain research data, a manager reference application was used, namely Publish or Perish. Publish or Perish software was used to conduct a literature review on our chosen topic. Google Scholar is a product of the search engine giant, Google. Google Scholar Indonesia is called Google Scholar which is focused on finding references for academics. With this Google Scholar, academics will get scientific references, such as journals and scientific publications which of course have been validated.

The research was carried out through several stages:

1) Collection of publication data using the publish or perish application
2) Processing of bibliometric data for articles that had been obtained using the Microsoft Excel application
3) Computational mapping analysis of bibliometric publication data using the VOSviewer application
4) Analysis of the results of computational mapping analysis

The article data search on Publish or Perish is used to filter publications using the keyword "Chemsitry; Particle; Membrane; Desalination" based on the publication's title requirements. The papers used were published between the years of 2012 and 2022. 1024 papers were obtained in September 2022. The articles that have been collected and match the criteria for this study's analysis were then exported into two file types: comma separated value format (*.csv) and research information systems (.ris). VOSviewer was also be used to visualize and evaluate trends using bibliometric maps. VOSviewer was employed to create 3 variations of mapping publications, namely network visualization, density visualization, and overlay visualization based on the network (co-citation) between existing items. When creating a bibliometric map, the keyword frequency was set to be found at least 5 times. Therefore, obtained 78 terms and keywords that are less relevant were removed.

4. Results and Discussion

4.1 Publication and Data Research

The results of bibliometric analysis using perish software with the keywords chemistry, particles, membranes, and desalination can be seen in table 1 and graph 1. The number of publications on desalination membranes from 2012 to 2022 reached 1024 publications related there are 10 out of 5866 terms, and 98 that meet the threshold criteria. The development of research on membrane desalination increases every year, where in 2021 is the peak number of publications or research on desalination membranes. This is because the problems of water pollution and water quality deterioration arose, while people's living standards improved, so that the water quality could not meet the requirements. In such circumstances, the research and development of membranes become hotspots, owing to the superior performances of various membrane separation technologies for water treatment., Research on water treatment continues to increase every year. The peak was in 2020 where there were 164 papers on the development and application of desalination membrane.

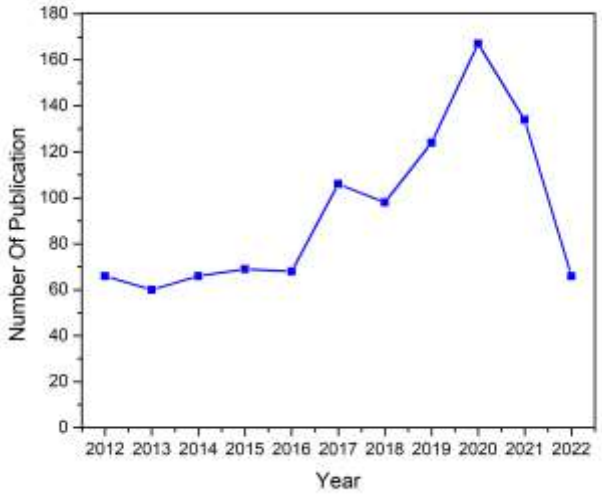

Figure 1. Graph of Number publications on 2012-2022

The data was obtained in the form of article metadata consisting of the author's name, title, year, journal name, publisher, number of citations, article links, and related URLs. Table 1 shows some examples of published data used in the VOSviewer analysis of this study. The data samples taken were the 10 best articles that had the highest GS Rank. The number of citations from all articles used in this study is 853, the number of citations per year is 167.78, the number of citations per author is 224, the average author in the articles used is 4.3.

Research on desalination membranes has been published in various international journals which have a high index (Q1). Table 2 shows that Elsevier publisher is a publication portal that publishes the most desalination membrane research and development, reaching 634 out of 1024 publications obtained through perish publish software. This shows that this research area is very useful for life now and in the future, besides that this can also be used as a reference for research development.

Table 1. Number of publications on 2012-2022

Year	Number of Publication
2012	66
2013	60
2014	66
2015	69

2016	68
2017	106
2018	98
2019	124
2020	167
2021	134
2022	66
Total	**1024**

Table 2. Top 10 Of Publication Desalination Membran

No	Author	Tittle	Publisher	Cites	Rank	Refrance
1	T Tong, AF Wallace, S Zhao, Z Wang	Mineral scaling in membrane desalination: Mechanisms, mitigation strategies, and feasibility of scaling-resistant membranes	Elsevier	124	1	Tong et al., 2019
2	A Malakian, SM Husson	Understanding the roles of patterning and foulant chemistry on nanofiltration threshold flux	Elsevier	18	2	Malakian et al., 2020
3	H Ma, X Chen, S Mohammed, Y Hu, J Lu, ...	A thermally reduced graphene oxide membrane interlayered with an in situ synthesized nanospacer for water desalination	pubs.rsc.org	9	3	Ma et al., 2020
4	MM Motsa, BB Mamba, A D'Haese, EMV Hoek, ...	Organic fouling in forward osmosis membranes: The role of feed solution chemistry and membrane structural properties	Elsevier	131	4	Motsa et al. 2014
5	GJ Doornbusch, JE Dykstra, PM Biesheuvel, ...	Fluidized bed electrodes with high carbon loading for water desalination by capacitive deionization	pubs.rsc.org	134	5	Doornbusch et al., 2016
6	J Wu, AE Contreras, Q Li	Studying the impact of RO membrane surface functional groups on alginate fouling in seawater desalination	Elsevier	70	6	Wu et al., 2014
7	M Ding, W Shi, L Guo, ZY Leong, A Baji, ...	Bimetallic metal–organic framework derived porous carbon nanostructures for high performance membrane capacitive desalination	pubs.rsc.org	81	7	Ding et al., 2017
8	Z Liu, Z Yang, X Huang, C Xuan, J Xie, H Fu, ...	High-absorption recyclable photothermal membranes used in a bionic system for high-efficiency solar desalination via enhanced localized heating	pubs.rsc.org	95	8	Liu et al., 2017

9	J Wu, KR Zodrow, PB Szemraj, Q Li	Photothermal nanocomposite membranes for direct solar membrane distillation	pubs.rsc.org	102	9	Wu et al., 2017
10	D Li, H Wang	Smart draw agents for emerging forward osmosis application	pubs.rsc.org	89	10	Li & Wang., 2013

Publication number 5 in table 2 "Fluidized bed electrodes with high carbon loading for water desalination by capacitive deionization" is the best publication when viewed from the number of citations, where the journal has been cited as many as 134 times, this shows that the journal has high quality and trust.

Tabel 3. Publisher portal and number of publications indexed Q1 on desalination membrane research

No	Publisher	Number Of Papper
1	Springer	28
2	Elsivier	634
3	Nature	3
4	Reserachgate	5
5	Taylor and francis	8

Table 3 and Figure 2 are data analysis of VOSviewers which shows the total number of clusters in the study is 5 clusters. The relationship between one term and another is shown in each existing cluster. Labels are given to each term with colored circles (figure 2). Cluster 1 is depicted as red with 28 items, cluster 2 is depicted in green with 17 items, cluster 3 is depicted in blue with 12 items, cluster 4 is depicted in yellow with 11 items, and cluster 5 is depicted in purple with 10 items. Cluster in VOSviewrs analysis is a random description or grouping of related words.

Table 4. Cluster of biblioetric analyzed in chemistry particle desalination membrane

No	Cluster	Item
1	Cluster 1	Addition, Adsoprstion, Colloidal Particle, Deposisition, Forward Ormosis, Fouling, Influence, Membrane Fouling, Membrane Material, Membrane Process, Memebrane Property, Membrane Surface Changer, Membrane Technology, Osmosis, Pore Size, Presence, Pressure, PVDF Membrane, Recent Advance, Role, Silica Partikel, Small Particle, Solution Chemistry, Treatment, Ultrafiltration, Wastewater, Wastewater Treatment, Zeta Potential
2	Cluster 2	Challenge, Composition membrane, Desalination Application, Efficiency, Gas Separation, Graphine oxide, Incorporatation, Inorganic Particle, Membrane Performance, Mixed Matrix Membrane, Nano Particle, Polyamide Membrane, Polymeric Membrane, Synthesis, TiO, Water Flux, Water Purification,
3	Cluster 3	Characterization, Impact, Interfacial Polymerization, Membrane Chemistry, Membrane Structure, Nano, Nanofiltration, Nanofiltration, Membrane, NF Membrane, Particle Size Distribution, Preparation, Thin Film Nanocomposite,
4	Cluster 4	Desalination Performance, FO Membrane, MOF, MOF Particle, Osmosis Membrane, TFC, TFC Membrane, TFN, TFN Membrane, Thin Film, Thin Film Composite Membrane
5	Cluster 5	Brackish Water, Capacitive Deionization, Carbon, Carbon Nanotube, Comparsion, Desalination Plant, Order, Reverse Osmosis, Reverse Osmosis Membrane, RO Membrane

The round size in the mapping of Figure 2 shows the number of word accuracy that appears in this study, the larger the size, the more the number of occurrences of the word in each study. The size of the label circle shows a positive correlation with the occurrence of the term in the title and abstract.

the size of the label indicates how often the keyword is mentioned, the larger the size of the label means the more often the keyword is mentioned.
The mapping visualization analyzed in this study consists of 3 parts: network visualization (see Figure. 3), density visualization (see Figure. 4), and overlay visualization (see Figure. 5).

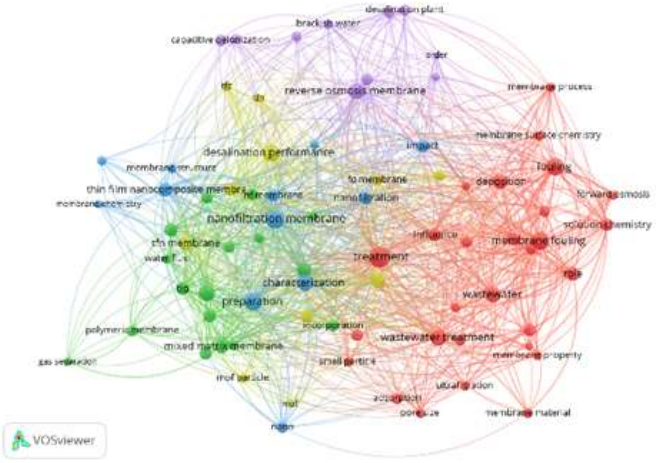

Figure 2. Network visualization of Chemistry Particle Membran Desalination Keyword

Overlay Visualization which explains the history of research with the span of the year studied. Figure 3 shows the overlay visualization of the chemistry particle of desalination membrane, it can be seen that the reverse osmosis keyword appears in the blue circle, meaning that research on reverse osmosis has been mostly carried out in the range of 2017 to mid-2018. Every year there are always developments in research that aims to improve previous research. Seawater desalination using the reverse osmosis membrane method has drawbacks, so a development using a desalination membrane was carried out in the middle of 2019 until now. The development of research on the performance of desalination, nanofiltration membranes, and waste water treatment using MOF as a filler or modifier for polymer base membranes began to be carried out in the middle of 2019. Eventhough the research about MOF as a filler membrane still. However, research on MOF as a membrane filler is still few. therefore, publications about MOF as a filler for desalination membrane have a great opportunity to publish.

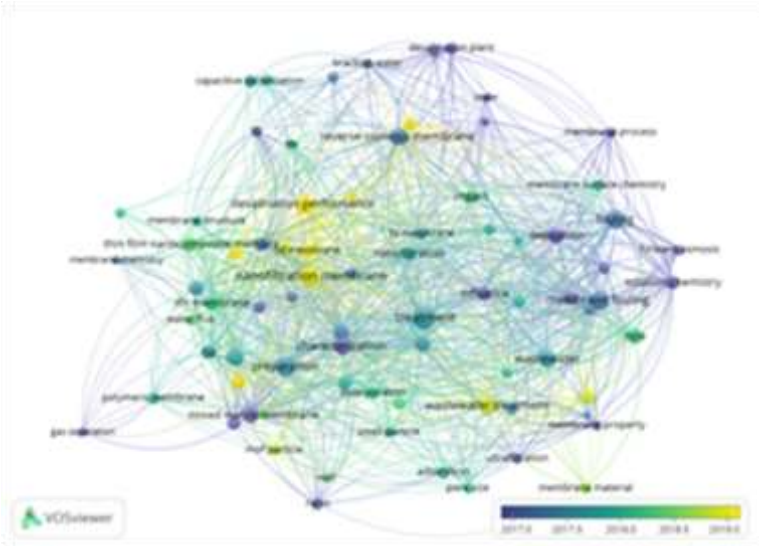

Figure 3. overlay visualization of Chemistry Particle Membran Desalination Keyword

Density Visualization explains the level of depth of research that has been carried out. It can be seen in figure 4. From the picture it can be seen that there are different colors in each area. The yellow color is an area of research development that has often been carried out over the past 10 years, such

as; membrane fouling, nanofiltration, characterization, treatment, desalination, mix matrix membrane. This means that the research is widely explored by researchers to get optimal results.

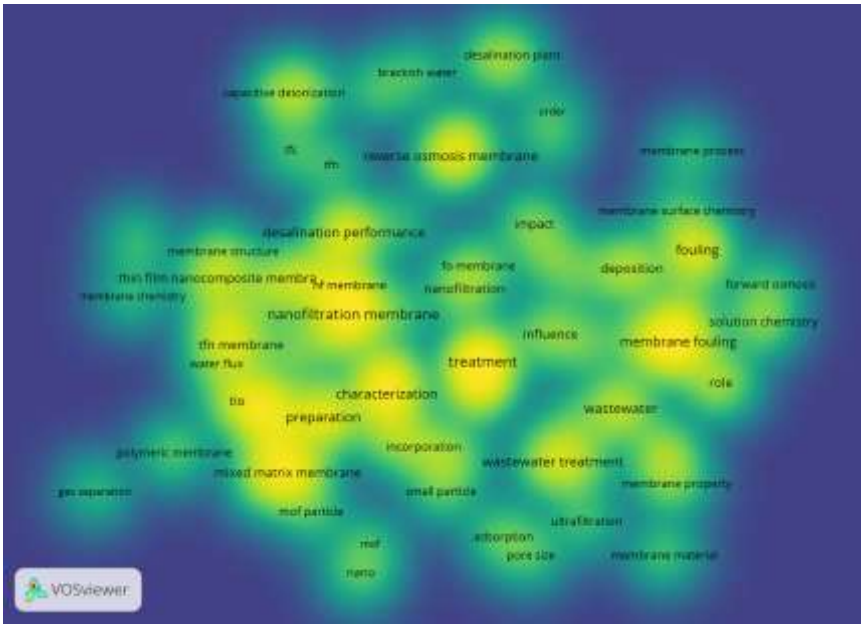

Figure 4. density visualization of Chemistry Particle Membran Desalination Keyword

5. Conclusion

Based on Bibliometric Analysis, it can be concluded that the numbers of published papers on membrane water treatment technology grew rapidly in recent years, indicating that researchers have paid increasing attentions to the application of membrane separation technologies in the field of membrane desalination. Treatment (Cluster 1), Composite membranes (Cluster 2), Nanofiltration (Cluster 3), Desalination performance (Cluster 4), and Reverse Osmosis are five terms that often arise and are discussed in membrane desalination research. The topic of treatment is at the center of research on desalination membranes, this shows that there are still many gaps that must be developed for desalination membrane treatment. Based on the results of the mapping of the collected article data, it can be seen that the keywords "Chemistry Particle Desalination Membrane" are still rarely used in research.

Limitation and Suggestion

This research is limited to the analysis of research developments related to desalination membranes in general in the last 10 years using the bibliometric method so that a deeper exploration is needed. For the next research, this bibliometric analysis can be carried out more specifically regarding the type of membrane and its modifiers, especially MOFs and GO, as well as the composite mapping related to each keyword that needs to be further elaborated.

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