ISBN: 978-628-95207-8-1. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2024.1.1.1260

Bibliometric Analysis on the Use of Natural Coagulants in the Treatment of Water for Human Use

Carlos Alberto Castañeda Olivera, DSc.[1], Yosilda Rojas Cavero, Eng.[1], and Rita Jaqueline Cabello Torres, MSc.[1]
[1]Professional School of Environmental Engineering, Universidad César Vallejo, Lima, Peru,
ccastanedao@ucv.edu.pe@gmail.com, hasrojas12@gmail.com, and rcabello@ucv.edu.pe

Abstract*– Coagulation tends to be one of the most widely used techniques in the treatment of domestic and industrial wastewater and drinking water; however, its high cost and acquisition tend to be a disadvantage. The present investigation carried out a bibliometric analysis of reference to the use of coagulants of natural origin for the treatment of water for human consumption. For the bibliographic analysis, we worked with the Scopus and Web of Science databases, considering articles and reviews published in the period from January 2011 to September 2021. The co-occurrence and co-citation maps were carried out using the use of VOSviewer software. As a result, 678 investigations were obtained for Scopus and 1273 for Web of Science. For both databases, the subject area with the highest number of publications was "environmental science", and the country with the highest number of publications on naturally occurring coagulants in Scopus was India and in the web of Science China. In addition, it was identified that coagulation and flocculation were the most used technologies for water treatment, with Moringa Oleifera being the natural coagulant with the highest efficiency and with the most studies. Finally, it is concluded that the use of natural coagulants is favorable since they have a low cost and are friendly to the environment.

Keywords*-- natural coagulants, water treatment, drinking water, bibliometric analysis.

I. Introduction

Water is an essential resource for the development of life, water reserves have been decreasing day by day due to the increase in population and industries, and its quality depends clearly on the biological, physical and chemical parameters and their interaction; these parameters must be evaluated in order to decide its specific use [1]. It is worth mentioning that pollution and scarcity of water sources are the main factors affecting social and economic development [2]. Therefore, countries should focus on the application of innovative, economical and feasible techniques.

Water treatment by coagulation removes colloids, bacteria and toxic agents that have a negative effect on living beings; it should be mentioned that the effectiveness of the coagulant in eliminating turbidity depends on the dose of the coagulant and the pH of the aqueous medium [3]. Likewise, this technology is usually relatively inexpensive and promising in water treatment [4], being an important process for water purification [5]. In water purification, the coagulation process removes impurities and turbidity [6].

New technologies and methods of water treatment seek to be environmentally and economically acceptable in order to replace coagulants of chemical or synthetic origin [7].

Plant-based coagulants are an environmentally friendly option because they meet the requirements of environmentally friendly technologies. Currently, studies employed natural extracts as coagulants for water treatment to determine their efficiency [8]. Other research mentions that these coagulants help reduce the consumption of chemicals and mitigate pollution from chemical by-products [9].

The use of natural coagulants shows advantages such as low cost and environmental friendliness [10]. For this reason, it is important to study natural coagulants in order to evaluate their use as a potential alternative to reduce the use of synthetic coagulants. By means of the bibliometric analysis, the aim is to contribute with information on the use of natural coagulants used in water treatment that contributes to the preservation of water resources.

Therefore, the objective of this research was to know the efficiency of natural coagulants used in water treatment. In addition, it seeks to provide a review of the topic of study, identifying the journals with the highest scientific production. Also, to determine the amount of research that studied the efficiency of natural coagulants in water treatment, and the countries with the highest scientific production.

II. Methodology

A. Type of Study and Research Design

The present research presented a quantitative approach and was of an applied type. Quantitative research is characterized by having knowledge of the reality of social phenomena, based on previous research, in order to logically formulate a theory and establish the behavioral patterns of a population [11].

In addition, the work had a non-experimental design and a descriptive and explicative level.

B. Sources of information

Research on natural coagulants used in water treatment was taken into account as sources of information. These research articles and reviews were obtained from the Scopus and Web of Science databases in the period January 2011 - September 2021. Filters such as year, type of document and language were applied for the selection of research.

C. Search Strategy

For the search of documents (articles and reviews), keywords such as "natural coagulant" and "water treatment" were used.

Digital Object Identifier: (only for full papers, inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).
DO NOT REMOVE

The following search string was used: TITLE-ABS-KEY ((natural AND coagulant) AND (water AND treatment)).

After obtaining the documents, a manual review was carried out in order to eliminate research that did not meet the characteristics or study criteria according to the proposed title.

D. *Data Analysis*

The data analysis was carried out using Microsoft Excel to sort the data extracted from the databases (Scopus and Web of Science) and to prepare the tables and figures. VOSviewer software was also used to create the bibliometric networks, co-citation and co-occurrence maps.

II. Results and Discussion

A. *Scientific Papers*

Figure 1 shows the number of research papers obtained and their overlapping. It shows that 678 documents belong to Scopus and 1273 to Web of Science. In the Scopus database, 634 articles and 44 reviews were obtained, and in the Web of Science database, 1207 articles and 66 reviews were identified.

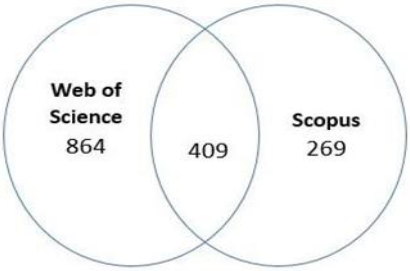

Fig. 1 Overlapping of scientific papers in databases

B. *Types of Scientific Documents*

Figure 2 shows the types of documents used and their respective percentages.

In the Scopus database, 678 documents were used, including articles and reviews, which are represented with 6.5% and 93.5%, respectively. On the other hand, in the Web of Science database it was observed that 5.2% are reviews and 94.8% are articles out of 1273 documents.

Fig. 2 Types of documents: a) Scopus and b) Web of science

C. *Scientific Papers by Year*

Figure 3 shows the number of publications per year in the Scopus and Web of Science databases.

The analysis was performed in order to quantify the trend of publications concerning natural coagulants and their application for water treatment.

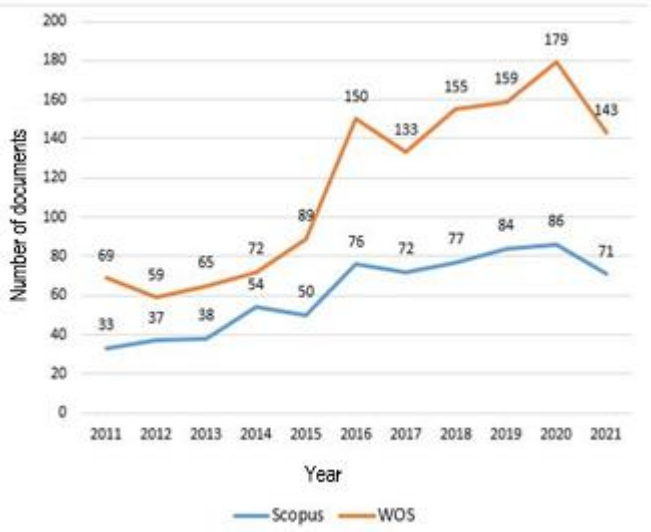

Fig. 3 Number of scientific papers published per year in the Scopus and Web of Science databases

Referring to the Scopus database, it was observed that publications on natural coagulants present an increasing trend in the period 2011 - 2016; however, in the year 2017, the trend of publications tends to decrease, then an increase of publications was observed in the period 2018 - 2021. While, the Web of Science database presents an increasing trend in the period 2011 - 2014, in the year 2015 a decrease of publications is observed; however, in the period 2016 - 2021, the trend of publications goes in an increasing way. All this evidences a great interest of researchers concerning the use of natural coagulants for water treatment.

D. *Analysis of the Number of Publications by Subject Area*

Figure 4 shows the thematic areas with the highest number of publications.

From these figures it was observed that for the Scopus database, the thematic areas with the highest number of publications were Environmental science 35.02%, Engineering with 13.31% and Chemical Engineering with 12.49%. On the other hand, in the Web of Science database, the thematic areas with the highest number of publications were Engineering with 33%, Ecology and Environmental Science with 26% and Water resources with 21%. Thus, it was observed that the thematic areas of science and engineering present a greater number of research studies on natural coagulants.

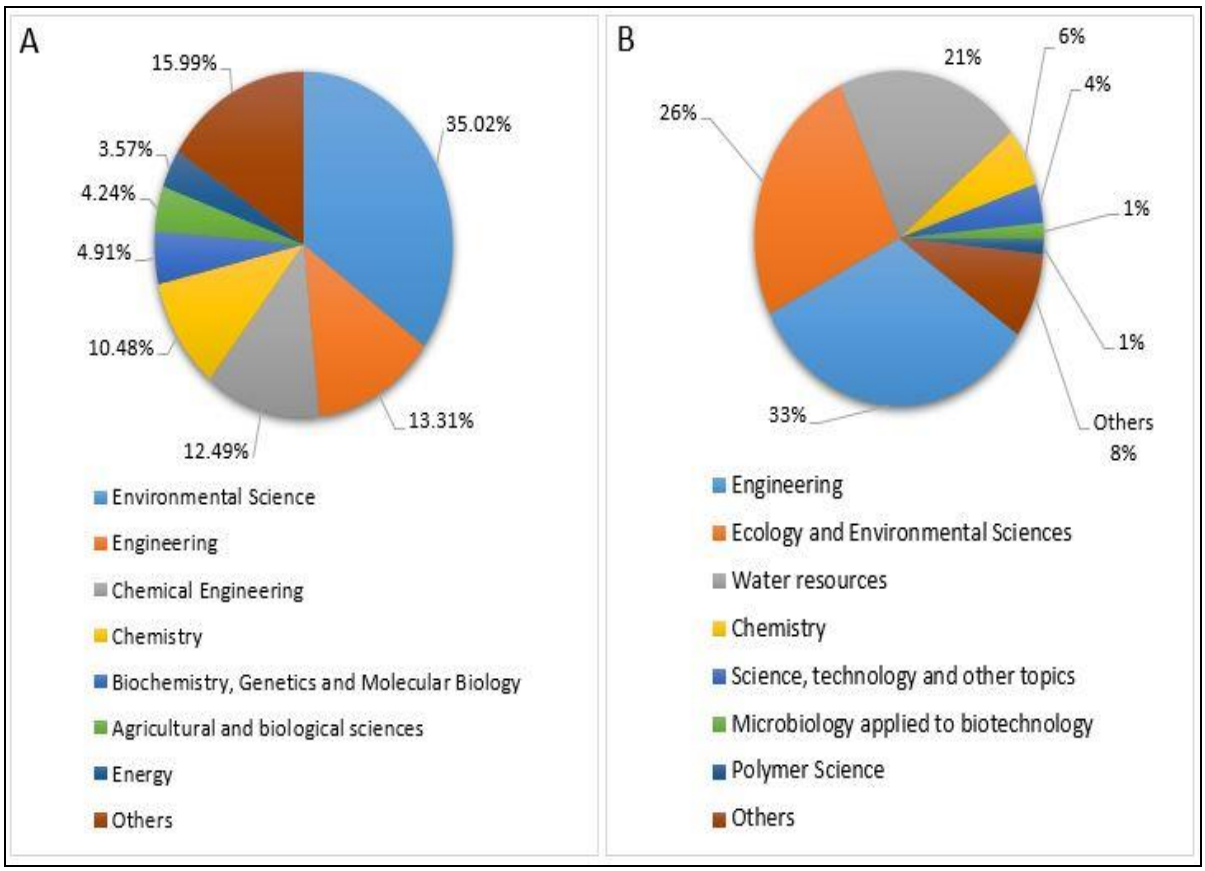

Fig. 4 Publications by thematic area: a) Scopus and b) Web of Science

E. Main journals with the highest scientific production

Figure 5 shows the journals with the highest scientific production. It was concluded that in the Scopus database, the journals with the highest production are "Desalination and Water Treatment" with 59 publications, followed by "Water Research" with 32 publications and "Journal of water process engineering" with 20 publications. Similarly, in the Web of science database, "Desalination and Water Treatment" with 154 publications, followed by "Water Research" with 81 publications and "Separation and Purification Technology" with 64 publications.

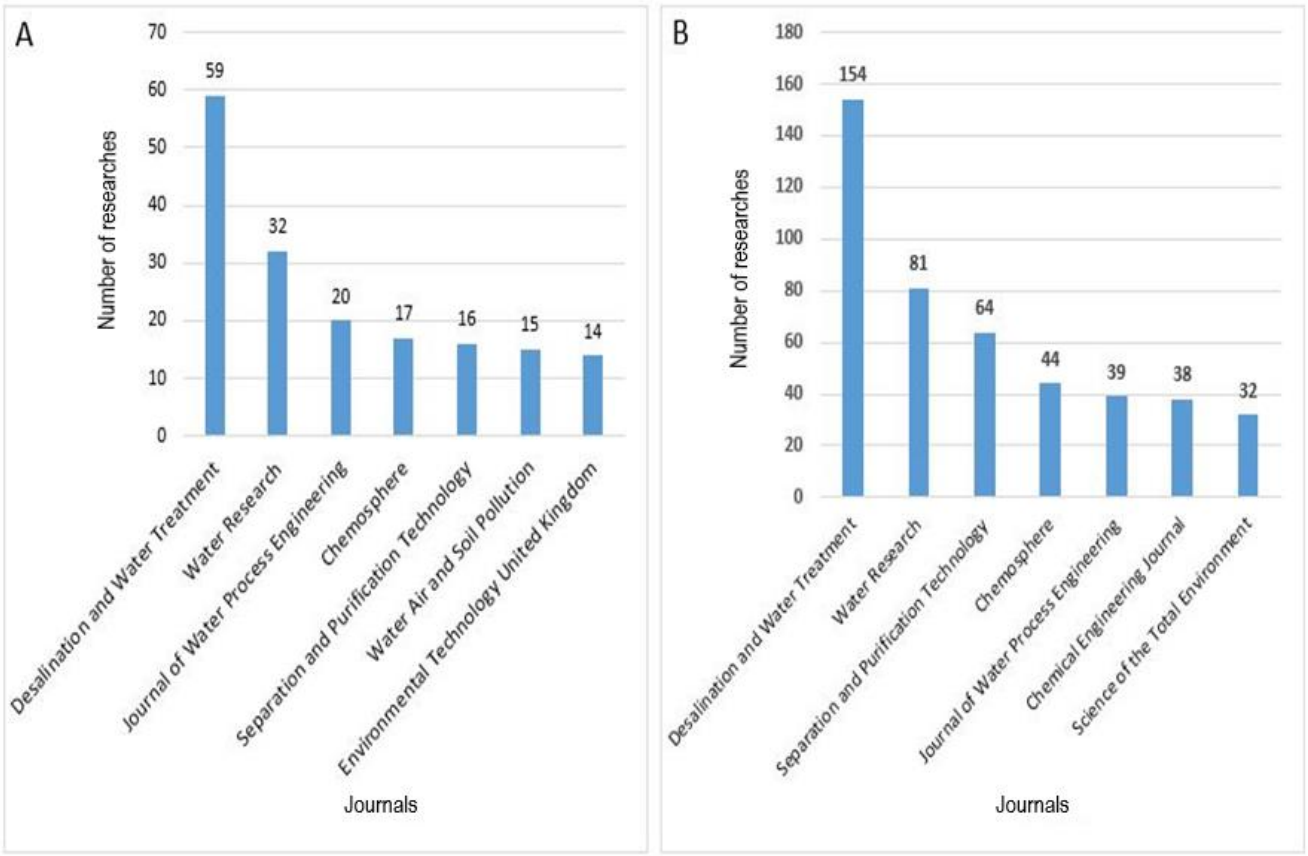

Fig. 5 Journals with the highest scientific production: a) Scopus and b) Web of Science

Ref [12] in a bibliometric analysis study on Moringa Oleifera and its multiple benefits and diverse uses, including coagulation. For the study they used the Scopus database, where they identified that the journals with the highest scientific production are "South African journal of botany" with 64 publications, "Acta horticulturae" with 45 publications and "Desalination of water and treatment" with 35 publications.

F. Keyword Trend Analysis

Figure 6 shows the keyword trend, it was observed that in the Scopus database, the keyword with the highest occurrence was "coagulation" with 190 occurrences, followed by "Water treatment" with 105 and "natural coagulant" with 77 occurrences. Likewise, in the Web of Science database, "coagulation" had 301 occurrences, followed by "Water treatment" with 124 and "natural coagulant" with 68 occurrences.

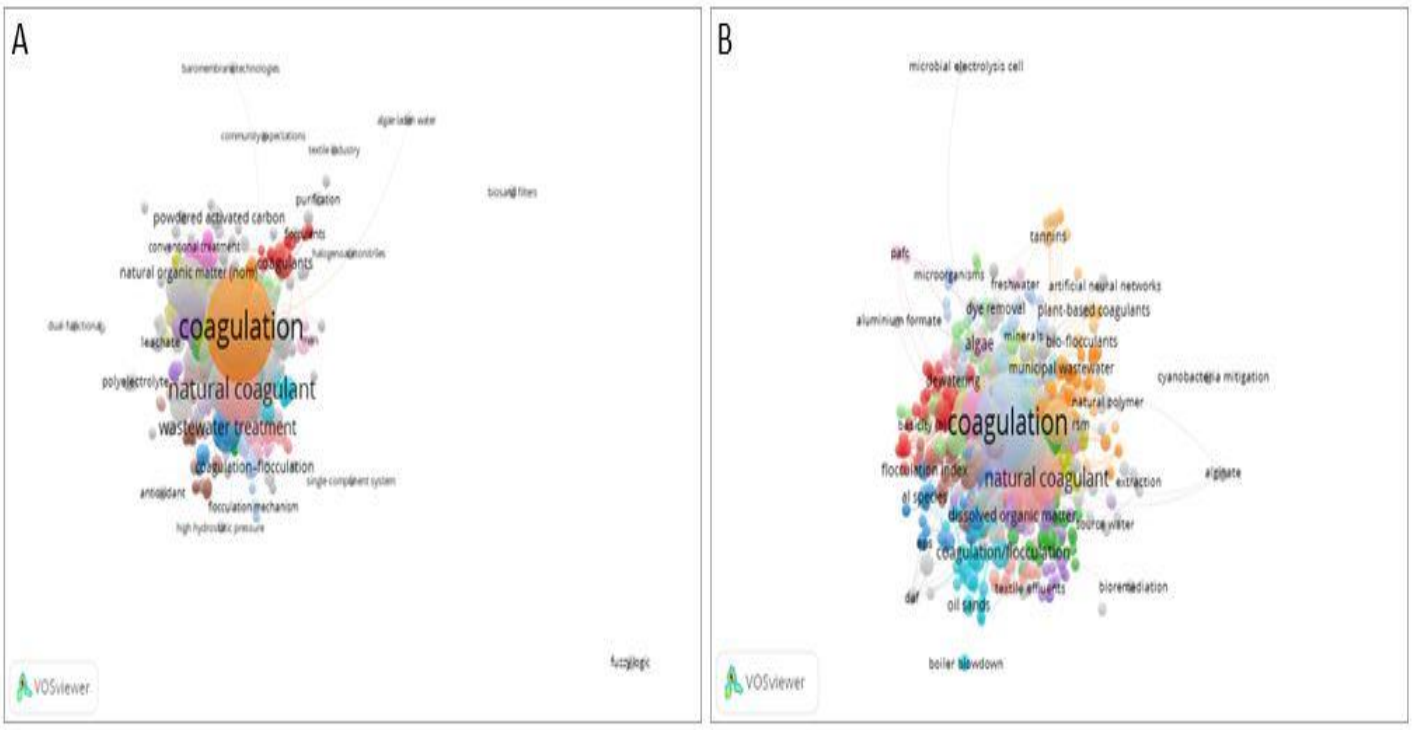

Fig. 6 Keyword trend analysis between 2011-2021: a) Scopus and b) Web of Science

G. Analysis of Scientific Research According to Countries

Figure 7 shows the results of the research regarding publications by country on natural coagulants for water treatment.

It was identified that in the Scopus database, India is the country with the highest scientific production with 94 publications, in contrast to the Web of Science database, which shows that China is the country with the highest scientific production with 531 publications.

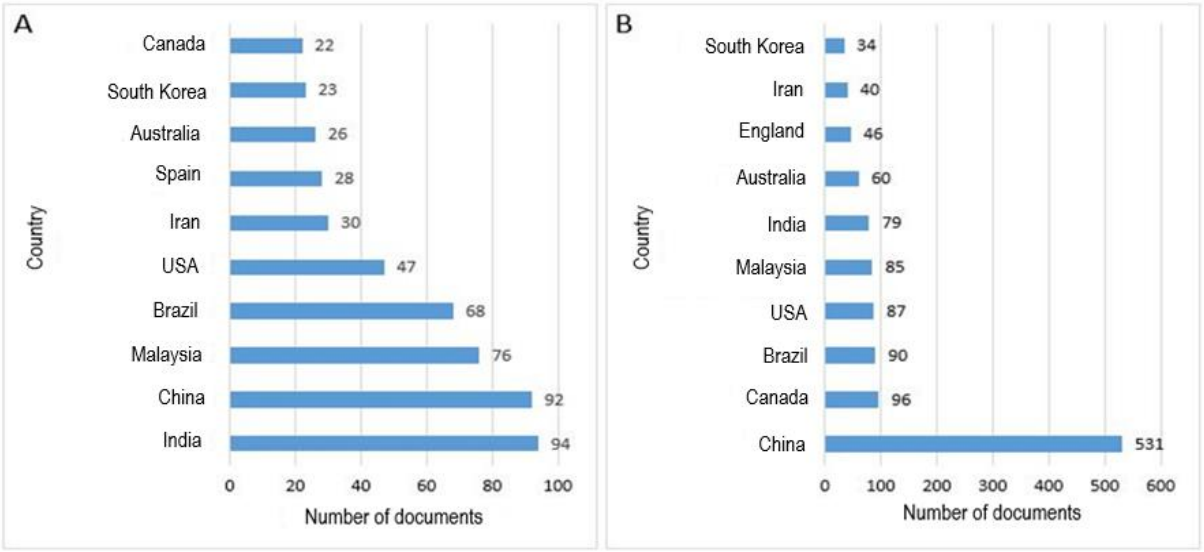

Fig. 7 Research according to countries: a) Scopus and b) Web of Science

Ref [13] conducted a bibliometric analysis of the trends in research on by-products used for water disinfection in the period 1975 - 2018. For this purpose, they used the Scopus database, where they identified that the countries with the highest scientific production are the United States (1405 publications), China (965 publications) and Canada (288 publications).

H. Analysis of Documents by Author

Figure 8 shows the authors with the highest scientific publications in the period January 2011 - September 2021.

It was observed that in the Scopus database, the authors with the highest scientific production are Bergamasco, Gao and Viera with 25, 13 and 12 publications, respectively. Meanwhile, in the Web of Science database, the authors with the highest number of publications are Gao with 58 publications, Wang with 47 and Yue with 45 publications.

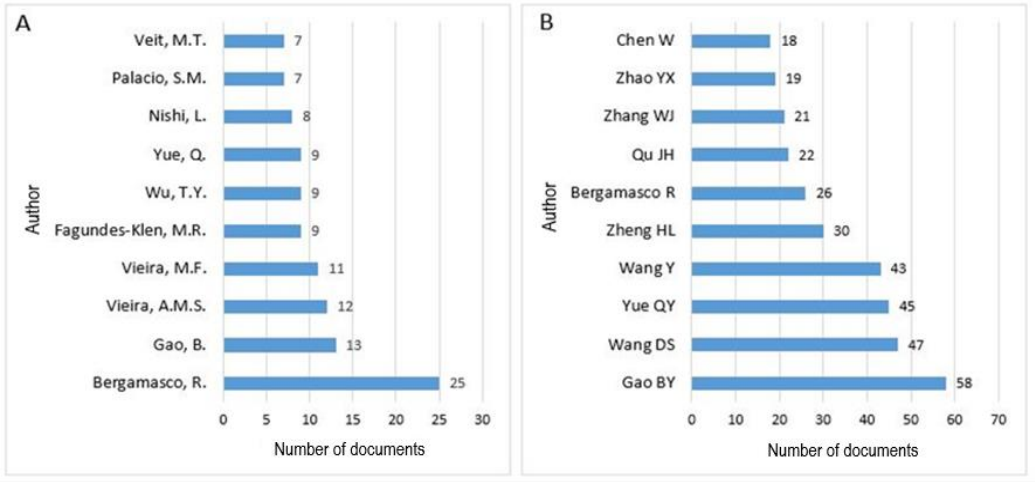

Fig. 8 Documentos por autor: a) Scopus y b) Web of Science

I. Analysis of the Most Cited Authors

Figure 9 shows the most cited authors during the period January 2011 and September 2021.

It was observed that in Scopus, author Wu t.y. was cited 974 times, followed by Bergamasco r. who was cited 681 times and Shack k.p.y who was cited 563 times. In contrast to the Web of Science database, where the most cited author was Gao Baoyu with 702 citations, followed by Wang, Dongsheng with 686 citations and Yue Qinyan with 614 citations.

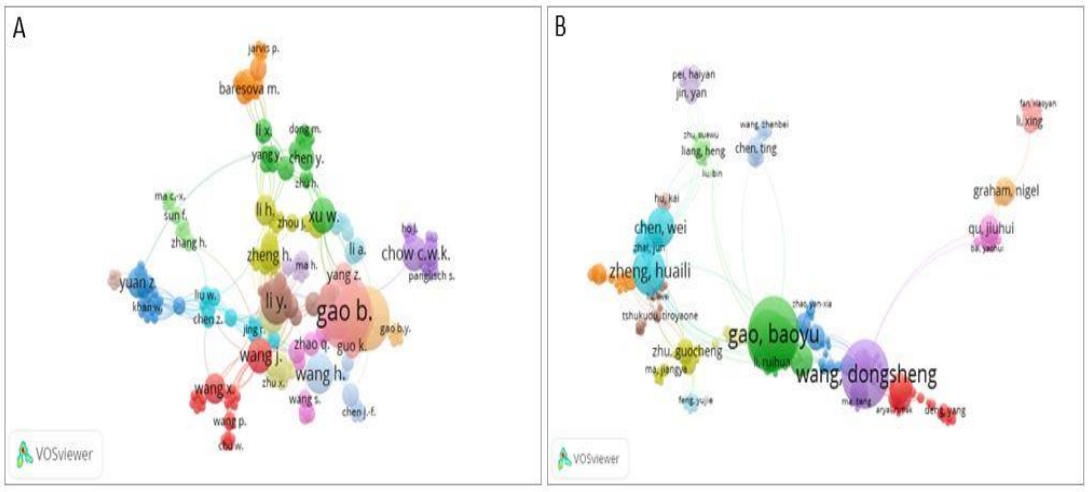

Fig. 9 Network map of the most cited authors between 2011-2021: a) Scopus and b) Web of Science

J. Analysis of Technologies Employed in Water Treatment

Figure 10 shows the technologies used in water treatment. It was observed that for both databases the most used technology in water treatment is coagulation with 74% in Scopus and 63% in Web of Science, followed by flocculation with 16% in Scopus and 25% in Web of Science.

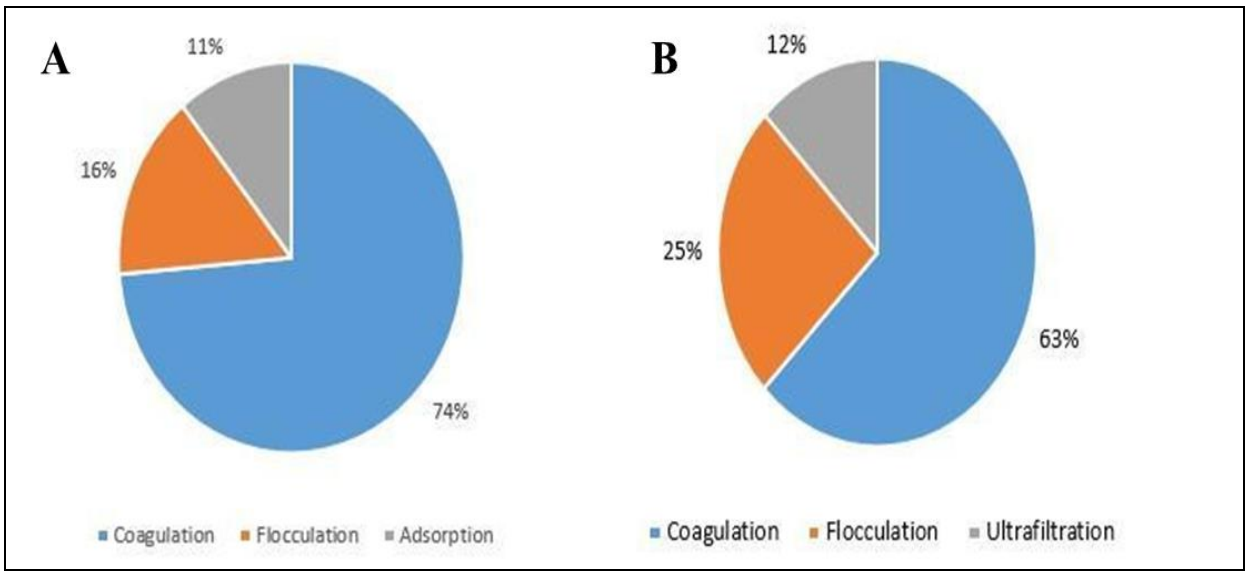

Fig. 10 Technologies used in water treatment: a) Scopus and b) Web of Science

Figure 11 shows the studies that employed various technologies for water treatment over the years. It was observed that in the Scopus database there is an increasing trend in the period 2011 - 2017; however, in 2018 there was a decrease in publications. Subsequently, it was observed that in the period 2019 - 2021 there was an increase in publications related to the topic.

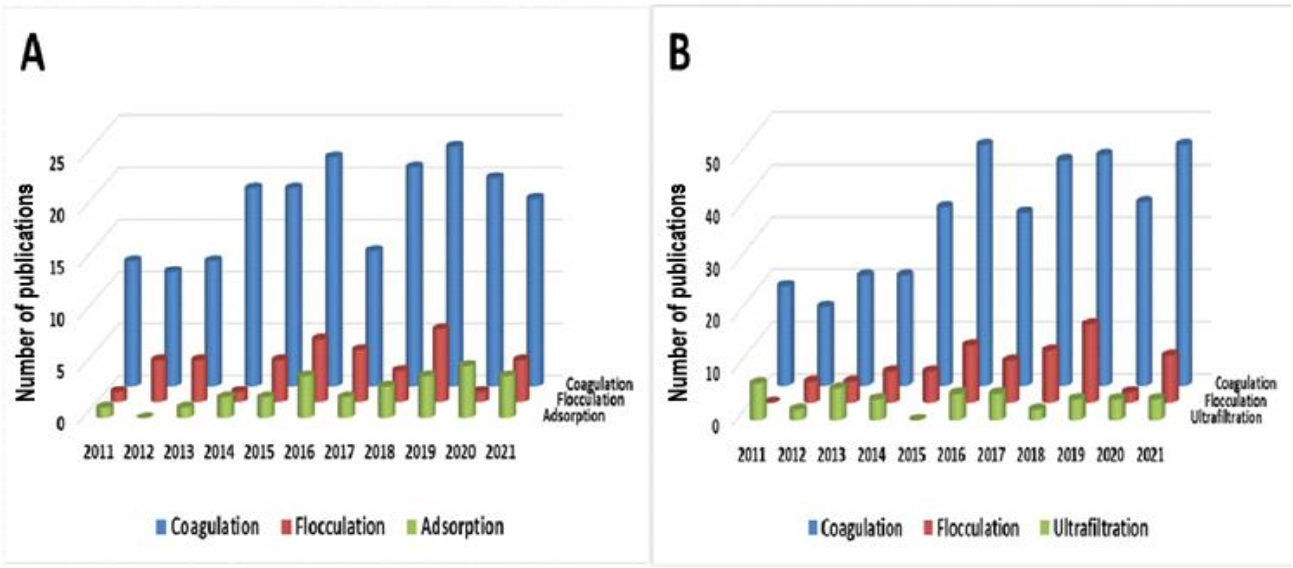

Fig. 11 Techniques used in research according to years: a) Scopus and b) Web of Science

K. Use of Natural Coagulants

Table 1 shows the coagulants of natural origin and the results achieved in each investigation. From the same it was observed that the coagulants achieved results for turbidity removal up to 98.6% and for COD up to 87.19%.

Ref. [14] mention that coagulants obtained from plant derivatives such as Opuntia ficus and Moringa oleifera have been studied and proposed as a friendly and sustainable alternative to synthetic coagulants. Ref [15] conducted a study where they found that coagulants of natural origin generate up to five times less sludge volume than conventional coagulants, and are also environmentally friendly and safe.

TABLE I
NATURAL COAGULANTS AND RESULTS ACHIEVED

Nro.	Natural coagulants	Wastewater type	Results achieved	Author (s)
1	*Moringa (semilla)*	Textile industry	Heavy metals: Cd, Cr and Mn (100%). Turbidity (98.6%), biochemical oxygen demand and COD (11.7%)	[16]
		Palm oil manufacturing effluent	Suspended solids (99.2%), chemical oxygen demand and BOD (52.5%)	
2	*Ocimum basilicum (albahaca)*	Landfill Leachate	Basil with alum as an additive: COD (64.4%) and color (77.8%)	[17]
3	*Médula de plátano*	Polluted river water	Turbidity (98.5%), COD (54.3%), suspended solids (96.03%)	[18]
4	*Opuntia ficus*	Textile effluents	Effluents from washing clothes (jeans); COD (64.77%) and turbidity (91.26%). Efluents from fabric dyeing factories: COD (87.19%) and turbidity (93.62%).	[19]

According to the studied research, Moringa oleifera has a high efficiency as a coagulant. According to Ref. [20], Moringa oleifera seeds possess coagulant properties since it has proteins that have a similar performance to cationic polyelectrolytes, and it is a renewable product, with low toxicity and guarantees turbidity removal. Similarly, Ref. [21] mention that Moringa oleifera seed receives greater attention being used in the treatment of sources such as textile wastewater, dyes, concrete, palm oil mill effluent water, drinking water, domestic wastewater, among others.

IV. CONCLUSIONS

The bibliometric analysis showed that coagulants of natural origin are efficient in water treatment, obtaining percentages of up to 99% in turbidity removal. In addition, they have low costs and are environmentally friendly, making them a safe option.

- It was identified that the number of documents on scientific research on the use of natural coagulants was 678 in Scopus and 1273 in WoS, obtaining a total of 1951 documents.
- The journals with the highest scientific production on natural coagulants for Scopus were "Desalination and water treatment" with 59 publications and "water research" with 32 publications. For the WoS database, the journals with the highest scientific production were "Desalination and water treatment" with 154 publications and "water research" with 81 publications.
- The country with the highest number of scientific publications in Scopus was India (94 publications). However, in WoS, the country with the highest number of scientific publications was China (531 publications).
- The most widely used coagulant is Moringa oleifera seed due to its high tannin content, demonstrating high efficiency with turbidity removal values of 98%.

ACKNOWLEDGMENTS

The authors would like to thank "Investiga UCV" of the Universidad César Vallejo for financial support for the publication of this research.

REFERENCES

[1] P. Vasistha and R. Ganguly, "Water quality assessment of natural lakes and its importance: An overview," *Mater. Today Proc.*, vol. 32, pp. 544–552, Jan. 2020, doi: 10.1016/J.MATPR.2020.02.092.

[2] A. J. Varkey, "Purification of river water using Moringa Oleifera seed and copper for point-of-use household application," *Sci. African*, vol. 8, p. e00364, Jul. 2020, doi: 10.1016/J.SCIAF.2020.E00364.

[3] A. Nath, A. Mishra, and P. P. Pande, "A review natural polymeric coagulants in wastewater treatment," *Mater. Today Proc.*, vol. 46, pp. 6113–6117, Jan. 2021, doi: 10.1016/J.MATPR.2020.03.551.

[4] A. H. Jagaba *et al.*, "Sustainable use of natural and chemical coagulants for contaminants removal from palm oil mill effluent: A comparative analysis," *Ain Shams Eng. J.*, vol. 11, no. 4, pp. 951–960, Dec. 2020, doi: 10.1016/J.ASEJ.2020.01.018.

[5] G. Prabhakaran, M. Manikandan, and M. Boopathi, "Treatment of textile effluents by using natural coagulants," *Mater. Today Proc.*, vol. 33, pp. 3000–3004, 2020, doi: 10.1016/j.matpr.2020.03.029.

[6] B. I. Gandiwa, L. B. Moyo, S. Ncube, T. A. Mamvura, L. L. Mguni, and N. Hlabangana, "Optimisation of using a blend of plant based natural and synthetic coagulants for water treatment: (Moringa Oleifera-Cactus Opuntia-alum blend)," *South African J. Chem. Eng.*, vol. 34, pp. 158–164, Oct. 2020, doi: 10.1016/J.SAJCE.2020.07.005.

[7] N. Chaibakhsh, N. Ahmadi, and M. A. Zanjanchi, "Use of Plantago major L. as a natural coagulant for optimized decolorization of dye-containing wastewater," *Ind. Crops Prod.*, vol. 61, pp. 169–175, Nov. 2014, doi: 10.1016/J.INDCROP.2014.06.056.

[8] N. A. Oladoja, "Headway on natural polymeric coagulants in water and wastewater treatment operations," *J. Water Process Eng.*, vol. 6, pp. 174–192, Jun. 2015, doi: 10.1016/J.JWPE.2015.04.004.

[9] M. G. Antov *et al.*, "Common oak (Quercus robur) acorn as a source of natural coagulants for water turbidity removal," *Ind. Crops Prod.*, vol. 117, pp. 340–346, Jul. 2018, doi: 10.1016/J.INDCROP.2018.03.022.

[10] J. Dotto, M. R. Fagundes-Klen, M. T. Veit, S. M. Palácio, and R. Bergamasco, "Performance of different coagulants in the coagulation/flocculation process of textile wastewater," *J. Clean. Prod.*, vol. 208, pp. 656–665, Jan. 2019, doi: 10.1016/J.JCLEPRO.2018.10.112.

[11] R. Hernández S., C. Fernández C., and M. del P. Baptista L., *Metodología de la investigación*, 6 Ed. México: McGRAW-HILL, 2014.

[12] T. T. George, A. O. Obilana, A. B. Oyenihi, and F. G. Rautenbach, "Moringa oleifera through the years: a bibliometric analysis of scientific research (2000-2020)," *South African J. Bot.*, vol. 141, pp. 12–24, Sep. 2021, doi: 10.1016/J.SAJB.2021.04.025.

[13] Y. Tang *et al.*, "Bibliometric review of research trends on disinfection by-products in drinking water during 1975–2018," *Sep. Purif. Technol.*, vol.

241, p. 116741, Jun. 2020, doi: 10.1016/J.SEPPUR.2020.116741.
[14] B. U. Okoro, S. Sharifi, M. A. Jesson, and J. Bridgeman, "Natural organic matter (NOM) and turbidity removal by plant-based coagulants: A review," *J. Environ. Chem. Eng.*, vol. 9, no. 6, p. 106588, Dec. 2021, doi: 10.1016/J.JECE.2021.106588.
[15] S. Y. Choy, K. M. N. Prasad, T. Y. Wu, M. E. Raghunandan, and R. N. Ramanan, "Utilization of plant-based natural coagulants as future alternatives towards sustainable water clarification," *J. Environ. Sci.*, vol. 26, no. 11, pp. 2178–2189, Nov. 2014, doi: 10.1016/J.JES.2014.09.024.
[16] T. C. Shan, M. Al Matar, E. A. Makky, and E. N. Ali, "The use of Moringa oleifera seed as a natural coagulant for wastewater treatment and heavy metals removal," *Appl. Water Sci.*, vol. 7, no. 3, pp. 1369–1376, Jun. 2017, doi: 10.1007/S13201-016-0499-8/TABLES/3.
[17] M. A. Rasool, B. Tavakoli, N. Chaibakhsh, A. R. Pendashteh, and A. S. Mirroshandel, "Use of a plant-based coagulant in coagulation–ozonation combined treatment of leachate from a waste dumping site," *Ecol. Eng.*, vol. 90, pp. 431–437, May 2016, doi: 10.1016/J.ECOLENG.2016.01.057.
[18] B. Kakoi, J. W. Kaluli, P. Ndiba, and G. Thiong'o, "Banana pith as a natural coagulant for polluted river water," *Ecol. Eng.*, vol. 95, pp. 699–705, Oct. 2016, doi: 10.1016/J.ECOLENG.2016.07.001.
[19] M. T. F. De Souza *et al.*, "The use of a natural coagulant (Opuntia ficus-indica) in the removal for organic materials of textile effluents," *Environ. Monit. Assess.*, vol. 186, no. 8, pp. 5261–5271, May 2014, doi: 10.1007/S10661-014-3775-9/METRICS.
[20] D. F. S. Silva, L. G. Speranza, L. Quartaroli, R. B. Moruzzi, and G. H. R. Silva, "Separation of microalgae cultivated in anaerobically digested black water using Moringa Oleifera Lam seeds as coagulant," *J. Water Process Eng.*, vol. 39, p. 101738, Feb. 2021, doi: 10.1016/J.JWPE.2020.101738.
[21] P. Vega Andrade, C. F. Palanca, M. A. C. de Oliveira, C. Y. K. Ito, and A. G. dos Reis, "Use of Moringa oleifera seed as a natural coagulant in domestic wastewater tertiary treatment: Physicochemical, cytotoxicity and bacterial load evaluation," *J. Water Process Eng.*, vol. 40, p. 101859, Apr. 2021, doi: 10.1016/J.JWPE.2020.101859.