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The Use of Zeolite Material as a Filtration Media in Waste Treatment: Bibliometric Analysis

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ABSTRACT

This study aims to show the profile of research trends related to zeolite adsorbent material as a filtration medium in waste treatment. The research method used is a literature study with bibliometric analysis. The articles used are 2018-2023 with a total of 287 articles. Keywords used in PoP software are sewage treatment, adsorbent, and zeolite. Article data was analyzed and obtained using Publish or Perish (PoP) software on the Google Scholar database. The results of the following publication trends are represented in the form of graphical visualizations, which are analyzed using VOSviewer software. The focus of this study is the research trend on the effectiveness of using zeolite adsorbent material as a filtration medium in waste treatment. The implications of this study are (1) This finding will provide an empirical basis for the development of the use of zeolite as an adsorbent material; (2) Traceability of data on trends and updates from research on the use of zeolite as an adsorbent material.

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1. INTRODUCTION

The rapid development of industry in Indonesia has caused the waste produced to also increase. Wastewater produced without prior treatment into waterways can degrade water quality and affect aquatic ecosystems and human health. Water quality itself can be seen through the limits of wastewater quality standards according to what is discharged or released into the water media of a business activity. Wastewater treatment can be done by treatment methods such as screening, mixing, flocculation, sedimentation, flotation, filtration, and gas transfer. One way of wastewater treatment is through simple filtration media. These findings can help in understanding how wastewater is treated through simple filtration media using zeolite. The results of this filtration media can be used to improve the quality of good wastewater treatment or meet the requirements of wastewater quality standards. Some examples of research on zeolite use are presented in **Table 1**.

Table 1. Some examples of research on the use of zeolite.

No	Title	Purpose	Results	Reference
1	The use of natural zeolite to remove heavy metals Cu (II), Pb (II) and Cd (II), from industrial wastewater	This study aims to investigate the efficiency of adsorbents of heavy metals from industrial wastewater. The kinetic study indicated the suitability of the zeolite for the removal of Cu^{2+}, Pb^{2+} and Cd^{2+} ions from synthetic wastewater.	The results indicate that the removal efficiency of Cu^{2+} increases from 60% with 1 gram of absorbent to 99% with 10 grams. It also increases from 62% at a 1% initial solution pH to 94% at a pH of 7. The efficiency rises from 90% at 100 rpm agitation speed to 94% at 300 rpm. Additionally, the amount adsorbed increases from 0.5 mg/g at 100 mg/l concentration to 2.1 mg/g at 400 mg/l. Similar trends are observed for the other two heavy metals (Pb^{2+} and Cd^{2+}), showing that the adsorbent's capacity to remove heavy metals is directly proportional to the absorbent mass, initial solution pH, agitation speed, and solution concentration. The highest adsorption rates for Cu^{2+}, Pb^{2+}, and Cd^{2+} ions occurred during the first few hours, followed by a slower adsorption rate.	(Elboughdiri, 2020)
2	Synthesis and characterization of new zeolite materials obtained from fly ash for heavy metals removal in advanced wastewater treatment	The aim of this study was to develop an efficient and inexpensive zeolite adsorbent by utilizing fly ash from coal combustion as the raw material, which can be used for wastewater treatment, especially for removing heavy metals (Cd^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}) from synthetic solutions.	The results of this study indicate that fly ash converted into zeolite material can be used effectively to remove heavy metals from liquid waste. Optimal adsorption conditions, such as contact time, amount of adsorbent, and initial concentration, were successfully identified to achieve maximum heavy metal removal efficiency. In addition, the characterization results of zeolite material showed changes in morphology and crystallinity that supported the adsorption capacity.	(Visa, 2016)

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Table 1 (Continue). Some examples of research on the use of zeolite.

No	Title	Purpose	Results	Reference
3	Utilizing Faujasite-type zeolites prepared from waste aluminum foil for competitive ion-exchange to remove heavy metals from simulated wastewater	The aim of this study was to examine the utilization of aluminum foil waste as a source of alumina in the synthesis of NaY and NaX zeolites, and to evaluate the ion-exchange capability.	The results showed that NaY and NaX zeolites synthesized from aluminum foil had good Si/Al ratio and specific surface area, 2.28 and 1.35 and 476.248 m^2/g and 610.256 m^2/g, respectively. Both zeolites showed affinity to metal ions in the order: Cd(II) > Cu(II) > Hg(II), and the ion-exchange results were in good agreement with the pseudo-second-order kinetic model ($R^2 > 0.96$).	(Jubouri *et al*., 2021)
4	Effect of zeolite media for the treatment of textile wastewater in a biological aerated filter	The purpose of this study was to compare the performance of two laboratory biofilters using natural zeolite and sand media in treating textile wastewater using biological aeration filter (BAF), and to evaluate their effectiveness in reducing COD, nitrogen, and suspended solids.	The results showed that biofilters using natural zeolite were able to reduce COD by 88%, while those using sand were only 75%, at organic loads varying between 1.2 to 3.3 kg COD/m^3/day. Higher nitrogen reduction in biofilters with natural zeolite was due to the NH4+ ion exchange capacity. The number of nitrifying bacteria in the biofilm was higher in natural zeolite than in sand. Both biofilters were able to remove about 97% of suspended solids (SS) at a load of 1–3 kg SS/m^3/day. Pilot-scale biofilters with natural zeolite capable of processing up to 12 m^3/day of textile wastewater were able to reduce about 99% BOD, 92% COD, 74% SS, and 92% T-N with a hydraulic load of 1.83 m^3/m^2/hour.	(Chang *et al*., 2002)
5	Pengaruh Variasi Massa Zeolit pada Pengolahan Air Limbah Pabrik Pakan Ternak melalui Media Filtrasi	The processing of animal feed factory wastewater has been carried out through filtration media by varying the mass of zeolite to determine the effect of variations in zeolite mass on several parameters, namely clarity, TDS value and pH level of animal feed factory wastewater filtrate.	The results of the study showed that the processing of animal feed factory wastewater by varying the mass of zeolite through filtration media can improve the quality of the processed water. In this study, the sample using 600g of zeolite mass had the highest level of clarity, with a TDS value of 844ppm and a pH of 7.8.	(Sumarli *et al*., 2016)

The use of zeolite in the industrial field is often used as an adsorbent because it has a high capacity as an absorbent. Zeolite can separate molecules based on size and configuration from molecules. Possible adsorption mechanisms are physical adsorption (involving Van der Walls forces), chemical adsorption (involving electrostatic forces), hydrogen bonding, and the formation of coordination complexes (Sumarli *et al*., 2016). Several studies have been conducted to develop zeolite as an adsorbent material in the **Tabel 1**.

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This article aims to provide a bibliometric analysis of the literature related to research on the use of zeolite adsorbent material as a filtration medium in waste treatment indexed by the Google Scholar database. Recent studies on bibliometric use are well documented in **Table 1**. Then, based on previous bibliometric research and the author's research on previous bibliometrics as shown in **Table 2,** the following authors present a review of the use of zeolite adsorbent material. The novelty of this work is that it provides a bibliometric review highlighting keyword evolution, collaboration between authors, the most cited articles, and sources published in leading journals regarding the use of zeolite adsorbent materials.

Table 2. Previous research on bibliometric analysis.

No	Title	Topic	Reference
1	A Bibliometric Review of Adsorption Treatment with an Adsorbent for Wastewater	This review used several software programs including Microsoft Excel to process the data, and VOSviewer to analyze the bibliographic mapping. This review showed that many researchers of adsorbents, such as activated, carbon, graphene-based, metal-organic frameworks (MOFs), and graphene-based materials can be used to treat large volumes of wastewater, such as tea waste, dyes, or soybean waste.	(Hardyanti *et al*., 2023)
2	Cation Exchange of Natural Zeolites: Worldwide Research	This work aims to identify studies' cognitive structure based on the cation exchange	(Morante-Carballo *et al*., 2021)
3	A bibliometric analysis of permeable reactive barrier enhanced electrokinetic treatment for sustainable polluted soil remediation	This study aims to conduct a bibliographical analysis related to electrokinetic remediation coupled with permeable reactive barriers for heavy metal contaminated soil and to examine the effect of using various types of reactive barrier materials and their placement on the pollutant's removal in the soil.	(Budihardjo *et al*., 2021)
4	Research trend of metal-organic frameworks: a bibliometric analysis	A bibliometric analysis based on the related articles in the Science Citation Index Expanded database was conducted to gain insight into global trends and hot issues of metal-organic frameworks (MOFs).	(Wang & Ho, 2016)

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5	Pengaruh Variasi Massa Zeolit pada Pengolahan Air Limbah Pabrik Pakan Ternak melalui Media Filtrasi	The processing of animal feed factory wastewater has been carried out through filtration media by varying the mass of zeolite to determine the effect of variations in zeolite mass on several parameters, namely clarity, TDS value and pH level of animal feed factory wastewater filtrate.	The results of the study showed that the processing of animal feed factory wastewater by varying the mass of zeolite through filtration media can improve the quality of the processed water. In this study, the sample using 600g of zeolite mass had the highest level of clarity, with a TDS value of 844ppm and a pH of 7.8.	(Sumarli *et al.*, 2016)

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2. METHODS

This research is a literature study to determine research trends in the use of zeolite adsorbent material as a filtration medium in waste treatment. An illustration of methodological design stages related to bibliometric analysis in research is shown in **Figure 1**.

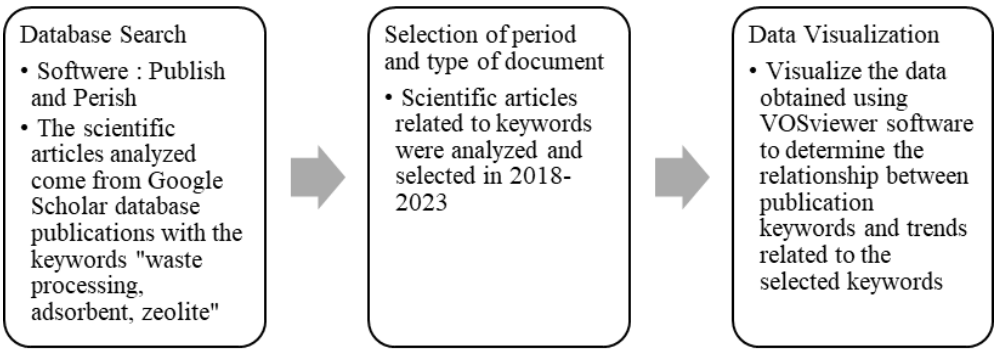

Figure 1. The methodological framework of the study.

2.1. Database Search

The scientific articles analyzed came from Google Scholar database publications with the keywords "sewage treatment, adsorbents, zeolite" in related article searches in 2018-2023. Article search is done using Publish or Perish software. Data collection resulted in 287 research articles on the use of zeolite adsorbent material as a filtration medium in waste treatment. The articles are then imported into Microsoft Excel and saved in comma-separated value (*.csv) and RIS formats.

2.2. Data Visualization

The scientific articles analyzed came from Google Scholar database publications with the keywords "sewage treatment, adsorbents, zeolite" in related article searches in 2018-2023. Article search is done using Publish or Perish software. Data collection resulted in 287 research articles on the use of zeolite adsorbent material as a filtration medium in waste treatment. The articles are then imported into Microsoft Excel and saved in comma-separated value (*.csv) and RIS formats.

2.3. Data Analysis

At this stage the data that has been stored in a comma-separated value format (*.csv) and visualized will be analyzed using Ms. Excel to obtain the results of research developments per year, authors with the most research, countries, and relationships between authors and other authors, as well as countries with other countries. At this point, clusters derived from visualization results are also examined.

3. RESULTS AND DISCUSSION

3.1. Publication Trends

The findings are based on the number of articles published in the Google Scholar database from 2018 to 2023. There are 287 articles related to the use of zeolite adsorbent material as a filtration medium in waste treatment. **Figure 2** illustrates the decline and rise in research growth over the past five years. The largest increase in publication growth occurred in 2019

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as many as 61 publications (21.25%). While 2023 seems to be the lowest publication growth with 23 publications (8.01%). The number of publications on particle technology and CFDs fell to 54 (18.81%), 59 (20.55%), 49 (17.07%), and 41 (14.28%) for the publication years 2022, 2021, 2020, and 2018 respectively.

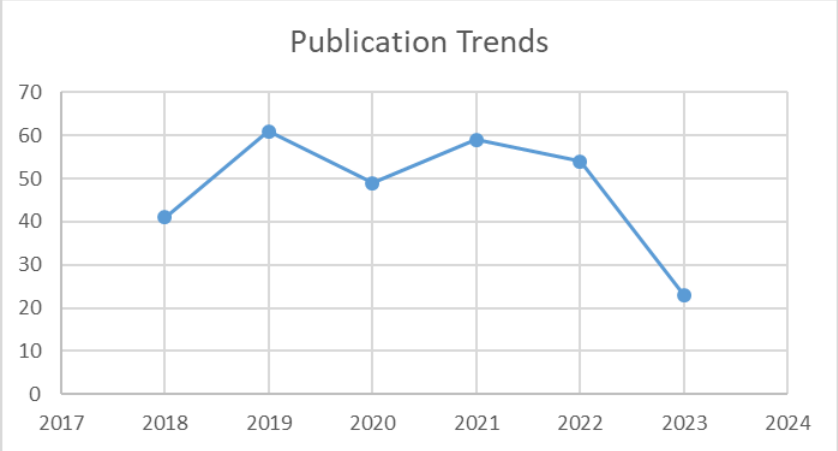

Figure 2. Number of documents published for the keyword "sewage treatment, adsorbents, zeolite".

3.2. Co-authorship Analysis of Author

The author's visualization of the most active research on the use of zeolite adsorbent material as a filtration medium in waste treatment is shown in **Figure 3**. A total of 17 authors participated in the related study. There are different colors, representing different groups. Cluster 1 is represented by a red circle, consisting of 4 authors, while Cluster 2 consists of 3 authors, represented by a green circle. Cluster 3 is marked with a blue circle, consisting of 5 authors. Cluster 4 represented by a yellow circle, consists of 3 authors. Finally, clusters 5, 6, and 7 represent light blue colors comprising 1 item. The size of the circle represents the number of article documents. In other words, the greater the number of papers, the larger the circle. As shown on the map, Mayangsari (green circle), Setiawan (orange circle), and Sugiarto (purple circle) are considered the most prolific authors in related studies.

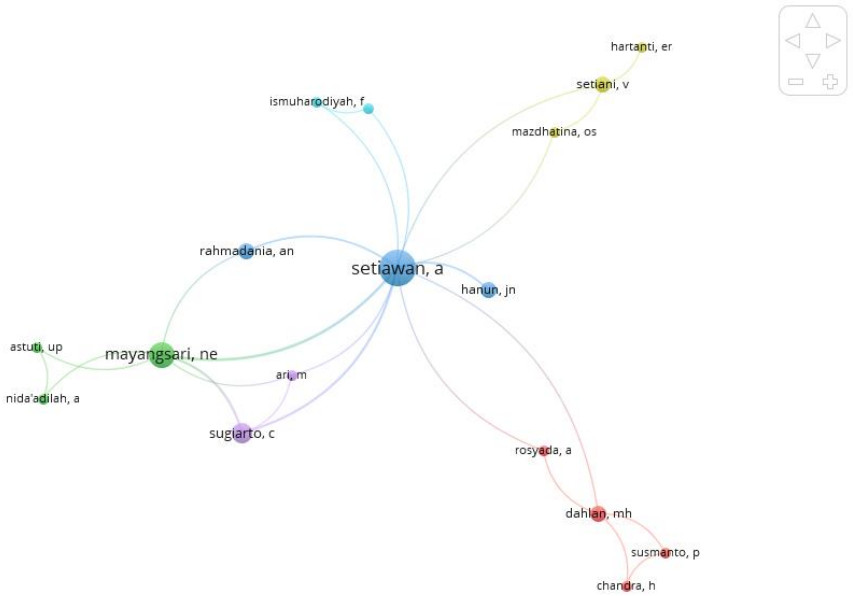

Figure 3. Co-authorship analysis of authors.

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3.3. Co-authorship Analysis of Author

In this study, the author will visualize using a software called VOSviewer. This software will help process data so that it can become an image visualization based on the focus of mapping. The use of VOSviewer to construct and visualize bibliometric networks (Perkasa, 2022). VOSviewer can display bibliometric maps in three different ways: network visualization, overlay visualization, and density visualization.

Figure 4 shows a visualization of the relationship between keywords in a publication published in the Google Scholar database. The color difference in **Figure 4** shows that there are five clusters, namely blue, green, red, yellow, and purple color clusters. Publication's closely related keywords will usually be placed close to each other and marked with the same color line. Based on Figure 4, the keywords Zeolite are shown in red and are closely related to publications on filtration, environment, water treatment, and liquid waste treatment.

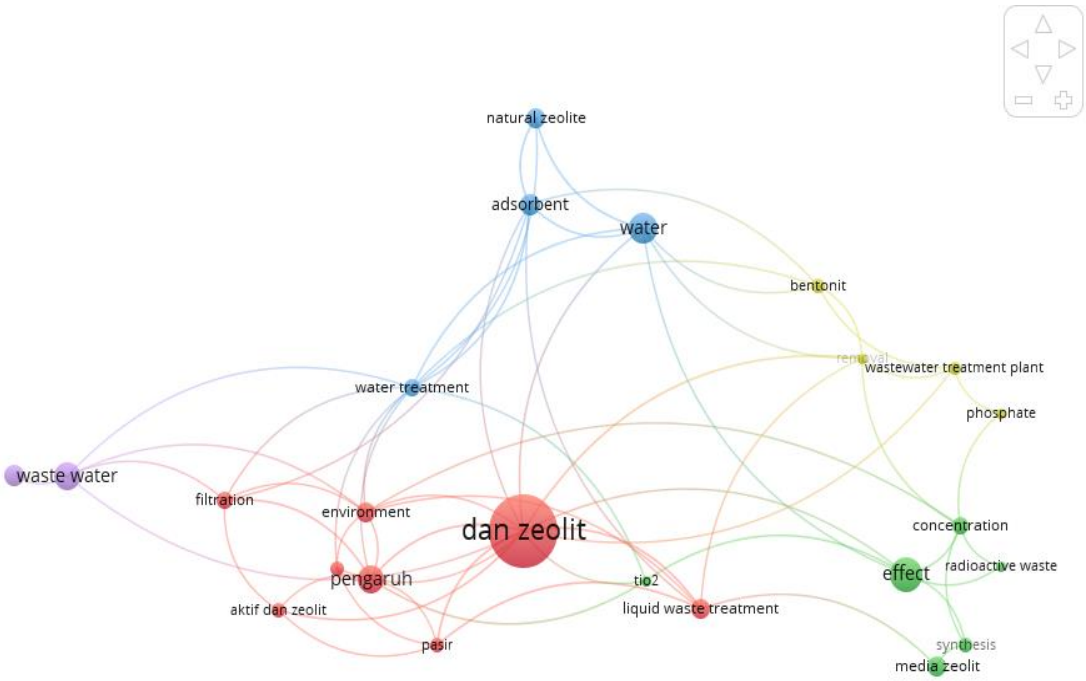

Figure 4. Network visualization.

Figure 5 shows the level of novelty in the publication keyword through the color gradation from purple to yellow. **Figure 5** with keywords for recent publications zeolite, adsorbent, and filtration. In the picture, you can see the spread of trends in 2016-2020. Several keywords are seen close together in his publications such as zeolite, adsorbent, and liquid waste treatment which show trends in 2019-2020. The zeolite that shows a trend in mid-2019 that is adjacent to adsorbents.

Figure 6 shows the relationship density between keywords covered in the same area. The bold color shows a very close relationship between these keywords. The information obtained from **Figure 6** shows that the keyword Zeolite has the closest relationship with adsorbents and wastewater. This shows that the research trend of zeolite adsorbent materials is closely related.

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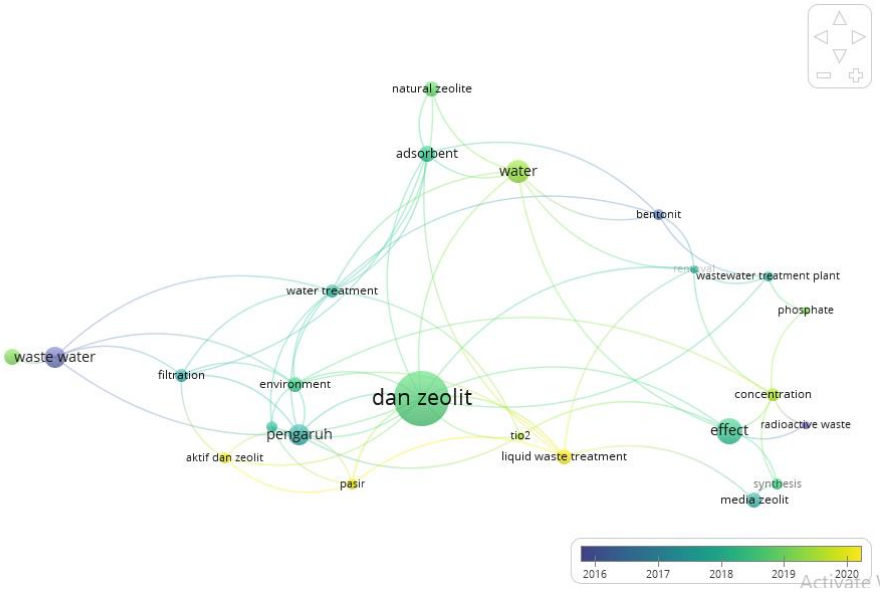

Figure 5. Overlay visualization.

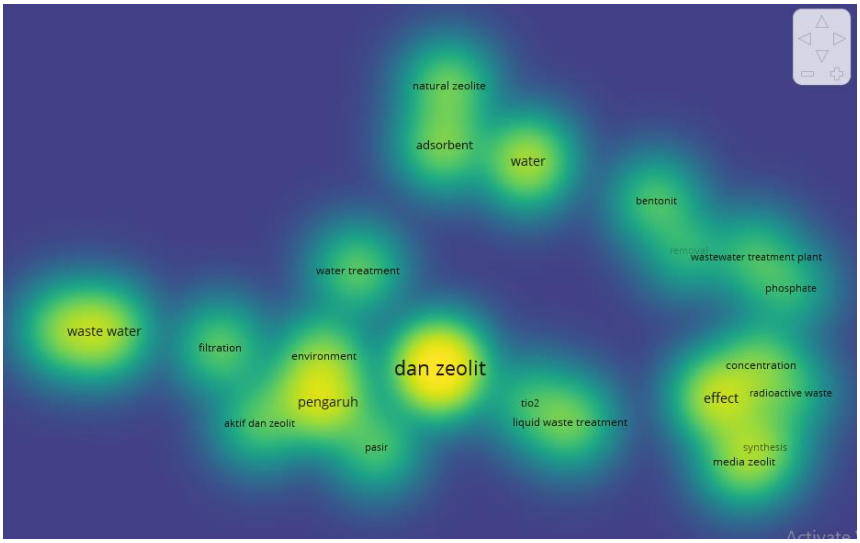

Figure 6. Density visualization.

4. CONCLUSION

Based on the findings obtained, articles with research on zeolite adsorbent materials, especially in journals indexed by Google Scholar, are important. This is evidenced by the results of publication trends and research classified as still very rare with the highest year in 2019 reaching a total of 61 publications (21.25%). The results of the top citation analysis showed the highest scientific articles with 23 citations in 2018. Analysis of the author's visualization shows that the author named Setiawan is the most prolific writer in this topic area. The results of network visualization analysis show that the most frequently appearing keyword is "zeolite" and the least frequent keyword is "sand". The latest related research in 2020 focused on "liquid waste treatment". Furthermore, the results of density analysis showed that the keywords "zeolite" had the closest relationship with "adsorbent" and "wastewater". This research is expected.

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5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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