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Trends and Developments in Research on Adsorption in Education: Bibliometric Analysis

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ABSTRACT

Adsorption is the process of clumping dissolved substances in a solution by the surface of an adsorbent substance which allows the material to enter and collect in an adsorbent substance. Adsorption is very important for students to be learned at school. This research presents a bibliometric analysis of trends and developments in research on adsorption in education. Bibliometric analysis was used as a method for this research. Article data was obtained from the Scopus database. The analyses were conducted to identify research trends, topic focus, author collaboration patterns, and publication impact in this field. Based on the research results, the development of publications regarding adsorption in education has experienced and fluctuated over the last 5 years (2019-2024). The most publications were in 2020 with the number of publications being 23 documents. In this research, international collaboration was also considered and analyzed as author collaboration and affiliation collaboration.

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1. INTRODUCTION

Adsorption is an important phenomenon in chemistry that has various applications, including in chemistry education (Nisa & Fitriandani, 2023). Adsorption is the process of clumping dissolved substances in a solution by the surface of an absorbent substance which allows the material to enter and collect in an absorbent substance (Sudarmawan et al., 2020; Febrina & Rizki, 2023; Sa'adah, 2022). Both often appear together in a process, so some call it sorption. In Adsorption, there are components called Adsorbent and Adsorbate. Adsorbent is an absorbent substance (Lestari et al., 2021; Gupta et al., 2009), while adsorbate is a substance that is absorbed (Febriani et al., 2022).

The importance of adsorption studies in education, especially chemistry education, is based on the need to teach basic and applicable concepts that can help students understand the chemical processes that occur around them. Previous research has explored various aspects of adsorption, ranging from basic mechanisms to practical applications in the environment and technology (Ratnawati et al., 2010). Apart from that, much research has also been carried out regarding bibliometric analysis as presented in **Table 1**. However, comprehensive literature studies regarding trends and developments in adsorption research in the educational context, especially chemistry education, are still very limited.

Table 1. Previous research on bibliometric analysis and adsorption.

No.	Title	Cited	Year	Ref.
1.	Bibliometric analysis of publications on essential oil-loaded nanoparticles as antibacteria using VOSViewer.	1	2022	Hernawan and Nandiyanto (2022)
2.	Introducing ASEAN journal of science and engineering: A bibliometric analysis study	31	2023	Nandiyanto et al. (2023)
3.	A computational bibliometric analysis of science education research using VOSviewer	16	2023	Maryanti et al. (2023)
4.	Particle size and pore size of rice husk ash on the resin-based brake pads performance: experiments and bibliometric literature review	10	2022	Nandiyanto et al. (2022)
5.	A Bibliometric analysis of nanocrystalline cellulose synthesis for packaging application research using VOSviewer	12	2022	Maulidah and Nandiyanto (2022)
6.	Literature review and bibliometric mapping analysis: Philosophy of science and technology education	37	2023	Al Husaeni and Munir (2023)
7.	Research trends from the Scopus database using keyword water hyacinth and ecosystem: A bibliometric literature review	25	2024	Nandiyanto et al. (2024)
8.	Bibliometric analysis of research development in sports science with vosviewer	18	2023	Al Husaeni (2023)
9.	Bibliometric analysis of briquette research trends during the covid-19 pandemic	36	2022	Al Husaeni (2022)
10.	Computational bibliometric analysis: Can digital transformation improve the quality of islamic learning?	2	2023	Al Husaeni and Rahmat (2023)

The main aim of this article is to analyze trends and developments in research on adsorption in education through a bibliometric approach. This method will allow identifying publication patterns, collaboration networks between researchers, as well as the topics most frequently discussed in the literature (Chusumastuti et al., 2023; Zupic & Cater, 2015; Al Husaeni et al., 2024; Kemeç & Altınay, 2023). By conducting this analysis, we hope to provide

a comprehensive overview of research developments in this area, identify knowledge gaps, and provide recommendations for future research.

Thus, this article will not only enrich our understanding of how adsorption research is developing in education but also contribute to improving the quality of chemistry education itself. It is hoped that this research can become a basis for further research that is more focused and applicable so that it can have a positive impact on the world of education and the chemical industry.

2. METHODS

This research used bibliometric analysis methods. The bibliometric method was used to determine trends and developments in research on adsorption and its relationship with education. There were five stages carried out in this research, namely:

2.1. Data collection

The first stage carried out in this research was collecting article data, which would be processed to obtain results and discussion. This stage was divided into two, namely database selection and keyword determination. The Scopus database was chosen as the place to collect articles to be used. Apart from that, this research used several keywords, including adsorption and education (TITLE-ABS-KEY ("education") AND TITLE-ABS-KEY ("adsorption")).

2.2. Article Selection

The second stage carried out in this research was article selection. The articles used in this research are articles published in the last 5 years, namely from 2019-2024. Apart from that, the articles used are only journal articles in Indonesian and English.

2.3. Bibliometric Analysis

The third stage carried out in this research was bibliometric analysis. VOSviewer and Bibliometrix were used as software to analyze the data. This analysis includes the number of publications and research trends, trending research topics and themes, journal analysis and cited papers, and researcher collaboration. Apart from that, this research also visualizes the collaboration network between authors and keywords that often appear in research.

2.4. Interpretation of Results

The fourth stage carried out in this research was the interpretation of the results. Identify key trends in adsorption research in education, such as the most researched topics, research methods used, and practical applications. In addition, it analyzes the temporal development of research topics and how the research focus changes over time.

2.5. Conclusion

The final stage in this research is to draw conclusions from the research results. The conclusion contains a summary of the main findings from the bibliometric analysis and the interpretation of the results.

3. RESULTS AND DISCUSSION

3.1. Number of Publications and Research Trends

3.1.1. Number of publications regarding adsorption in Education

From the results of searches in the scientific journal database (Scopus), it was found that the number of publications regarding adsorption during the last five years (2019-2024) was 95 documents. **Figure 1** shows the development of the number of publications each year (2019-2024). Based on **Figure 1**, publications regarding adsorption in education have decreased quite significantly in the last decade. The most visible decrease is from 2020 – 2022 with the number of publications each year, namely in 2020 as many as 23 documents, in 2021 as many as 19 documents, and in 2022 as many as 10 documents. However, in the following year, namely 2023-2024, research on adsorption in education will begin to be sought again. This is proven by the number of publications regarding adsorption in education which has increased from the previous year (2022), namely in 2023 the number of publications was 12 articles and in 2024 the same was 12 articles.

The improving number of publications on adsorption in education indicates increased interest and attention from the scientific community towards this topic. In addition, this increase reflects the importance of the adsorption concept in various industrial and environmental applications (Hasan, 2023; Nafisah et al., 2023), which requires a deep understanding from students. This trend can also be attributed to ongoing efforts to develop more effective and innovative teaching methods, such as the use of digital technology and interactive learning approaches.

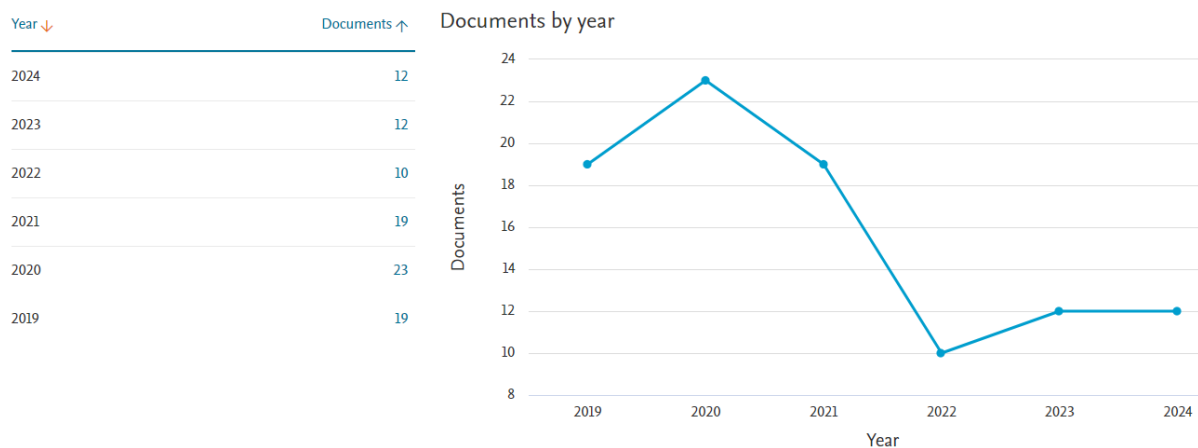


Figure 1. Number of publications.

3.1.2. Geographic distribution

Research on adsorption in chemistry education is spread across various countries, with the highest concentrations in China (12 documents), Indonesia (11 documents), the United States (7 documents), Italy (6 documents), and Brazil (6 documents). Apart from these five countries, several other countries have contributed to the publication of articles regarding adsorption for education. These countries are Malaysia, India, United Kingdom, Germany, Turkey, Slovakia, Saudi Arabia, United Arab Emirates, Ukraine, Taiwan, Spain, Russian Federation, Portugal, Pakistan, Norway, Nigeria, Mexico, Japan, Iraq, Egypt, Canada, Viet Nam, Switzerland, South Korea, Slovenia, Singapore, Romania, Poland, Kazakhstan, Iran, Greece, France, Denmark, Czech Republic, Bangladesh, Austria, Australia, and Algeria. More detailed information is presented in **Table 2**. The number of countries that actively contribute to

publications on adsorption for education shows that this topic has global relevance and importance and encourages international collaboration to improve the quality of chemistry education in various parts of the world.

Table 2. Previous research on bibliometric analysis and adsorption.

Country	Total of Article	Country	Total of Article
China	12	Japan	2
Indonesia	11	Iraq	2
United States	7	Egypt	2
Italy	6	Canada	2
Brazil	6	Viet Nam	1
Malaysia	5	Switzerland	1
India	5	South Korea	1
United Kingdom	4	Slovenia	1
Germany	4	Singapore	1
Turkey	3	Romania	1
Slovakia	3	Poland	1
Saudi Arabia	3	Kazakhstan	1
United Arab Emirates	2	Iran	1
Ukraine	2	Greece	1
Taiwan	2	France	1
Spain	2	Denmark	1
Russian Federation	2	Czech Republic	1
Portugal	2	Bangladesh	1
Pakistan	2	Austria	1
Norway	2	Australia	1
Nigeria	2	Algeria	1
Mexico	2	-	-

3.1.3. Publication type

Based on the results of data collection, publications regarding adsorption for education consist of 4 types, namely journal articles, conference proceedings, book series, and books with each document of each type, namely 65 documents for journals, 25 documents for conference proceedings, 4 documents for books series, and 1 document for book. **Figure 2** shows the number of documents from each type of publication. Based on **Figure 2**, journal articles dominate with around 69% of total publications.

This shows that research related to adsorption in education is more often disseminated through scientific journals. Scientific journals are considered a credible and trustworthy platform for sharing research results (Ginting *et al.*, 2024), especially because of the strict peer-review process that ensures the quality and validity of research findings. In addition, scientific journals usually have a wider readership (Fatmawati, 2020; Björk & Holmström, 2006), allowing researchers to contribute more significantly to the development and dissemination of knowledge in the field of chemistry education.

On the other hand, conference proceedings, book series, and books each contributed less to total publications, with 25, 4, and 1 document, respectively. Even though their contributions are smaller than journal articles, conference proceedings still play an important role in disseminating new ideas and innovations through presentations and direct discussions between researchers. Book series and books, although rarer, offer in-depth and comprehensive contributions that can serve as primary references for educators and researchers. This combination of different types of publications reflects the diversity of ways

of delivering and disseminating research in the field of adsorption for education, as well as the importance of different platforms to meet the needs and preferences of different audiences within the academic community.

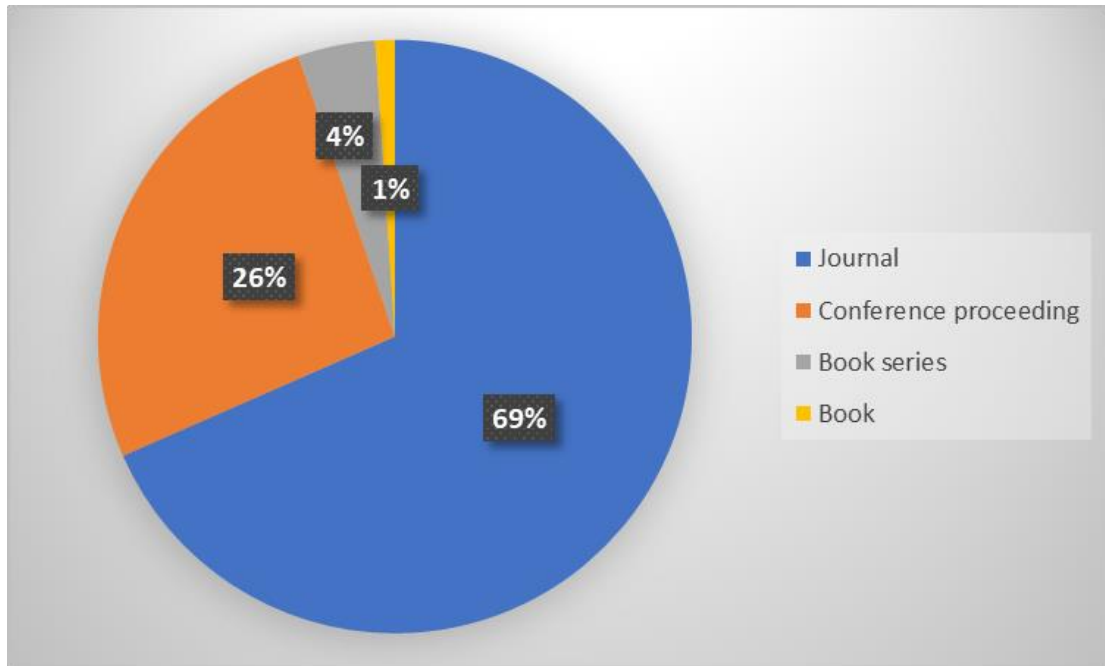


Figure 2. Total publications by source type.

3.2. Trending Research Subject Areas

Table 3 shows the subject areas contained in publications regarding adsorption in education. Based on **Table 3**, Environmental Science is the most widely used subject with a total of 26 documents. This shows that environmental issues play an important role in chemistry education. This reflects the importance of understanding adsorption processes in environmental contexts, such as wastewater treatment, air pollution control, and hazardous waste management. The use of adsorption in these environmental applications emphasizes the practical relevance of chemistry concepts taught in the classroom, which can motivate students to better understand and apply their knowledge in real-world situations.

Table 3. Trending research subject areas.

No.	Subject area	Documents
1.	Environmental Science	26
2.	Chemistry	24
3.	Engineering	21
4.	Physics and Astronomy	20
5.	Chemical Engineering	15
6.	Materials Science	13
7.	Social Sciences	13
8.	Earth and Planetary Sciences	10
9.	Computer Science	9
10.	Biochemistry, Genetics and Molecular Biology	7
11.	Medicine	7
12.	Agricultural and Biological Sciences	6
13.	Energy	5
14.	Pharmacology, Toxicology and Pharmaceutics	5
15.	Decision Sciences	2

Table 3 (Continue). Trending research subject areas.

No.	Subject area	Documents
16.	Mathematics	2
17.	Multidisciplinary	2
18.	Arts and Humanities	1
19.	Business, Management and Accounting	1
20.	Dentistry	1
21.	Immunology and Microbiology	1

3.3. Journal Analysis and Cited Papers

Table 4 shows the articles with the highest number of citations. Based on Table 3, the article "How to calculate adsorption isotherms of particles using two-parameter monolayer adsorption models and equations" by Ragadhita and Nandiyanto (2021) has received many citations with a total of 92 citations over the last five years. This shows a significant influence in the field of chemistry education. This article makes an important contribution by explaining the method for calculating adsorption isotherms using two-parameter models and equations for single layers. This approach is particularly relevant in educational contexts as it provides a simple but effective tool for understanding the basic concepts of adsorption, which are often complex and difficult for students to understand. By providing clear explanations and methods that can be applied in educational settings, this article is a key reference for educators who want to teach this topic effectively. The high number of citations indicates that this paper is of good quality so that many researchers and educators have recognized the value of this contribution (Nugroho, 2022; Judijanto *et al.*, 2024; Tahamtan *et al.*, 2016), making this article an important reference point in development of learning materials and further research in the field of adsorption.

Table 4. Journal analysis and cited papers.

No.	Title	Cited by	Ref.
1.	How to calculate adsorption isotherms of particles using two-parameter monolayer adsorption models and equations	92	Ragadhita and Nandiyanto (2021)
2.	Corrosion inhibition potential of chitosan-based Schiff bases: Design, performance and applications	52	Verma <i>et al.</i> (2021)
3.	Adsorption isotherm of mesopore-free submicron silica particles from rice husk	44	Ragadhita <i>et al.</i> (2019)
4.	Adsorption of dye on carbon microparticles: Physicochemical properties during adsorption, adsorption isotherm and education for students with special needs	36	Maryanti <i>et al.</i> (2020)
5.	Age-related changes in intestinal immunity and the microbiome	33	Walrath <i>et al.</i> (2021)
6.	Urban green transformation in Northeast China: A comparative study with Jiangsu, Zhejiang and Guangdong provinces	30	Fu <i>et al.</i> (2020)
7.	Think and print: 3D printing of chemical experiments	23	Renner and Griesbeck (2020)
8.	Analysis of solar-powered adsorption desalination systems: Current research trends, developments, and future perspectives	22	AlMallahi <i>et al.</i> (2023)
9.	Synthesis of carbon microparticles from red dragon fruit (<i>Hylocereus undatus</i>) peel waste and their adsorption isotherm characteristics	20	Nandiyanto <i>et al.</i> (2020)
10.	LDL Apheresis and Lp (a) Apheresis: A Clinician's Perspective	18	Kayikcioglu (2021)

3.4. Researcher Collaboration

Figure 3 shows several groups of authors. Based on Figure 3, many authors collaborate in small groups rather than working alone. There are several groups consisting of 2 to 11 authors who work together to write a scientific paper. This indicates a strong trend of collaboration among these authors.

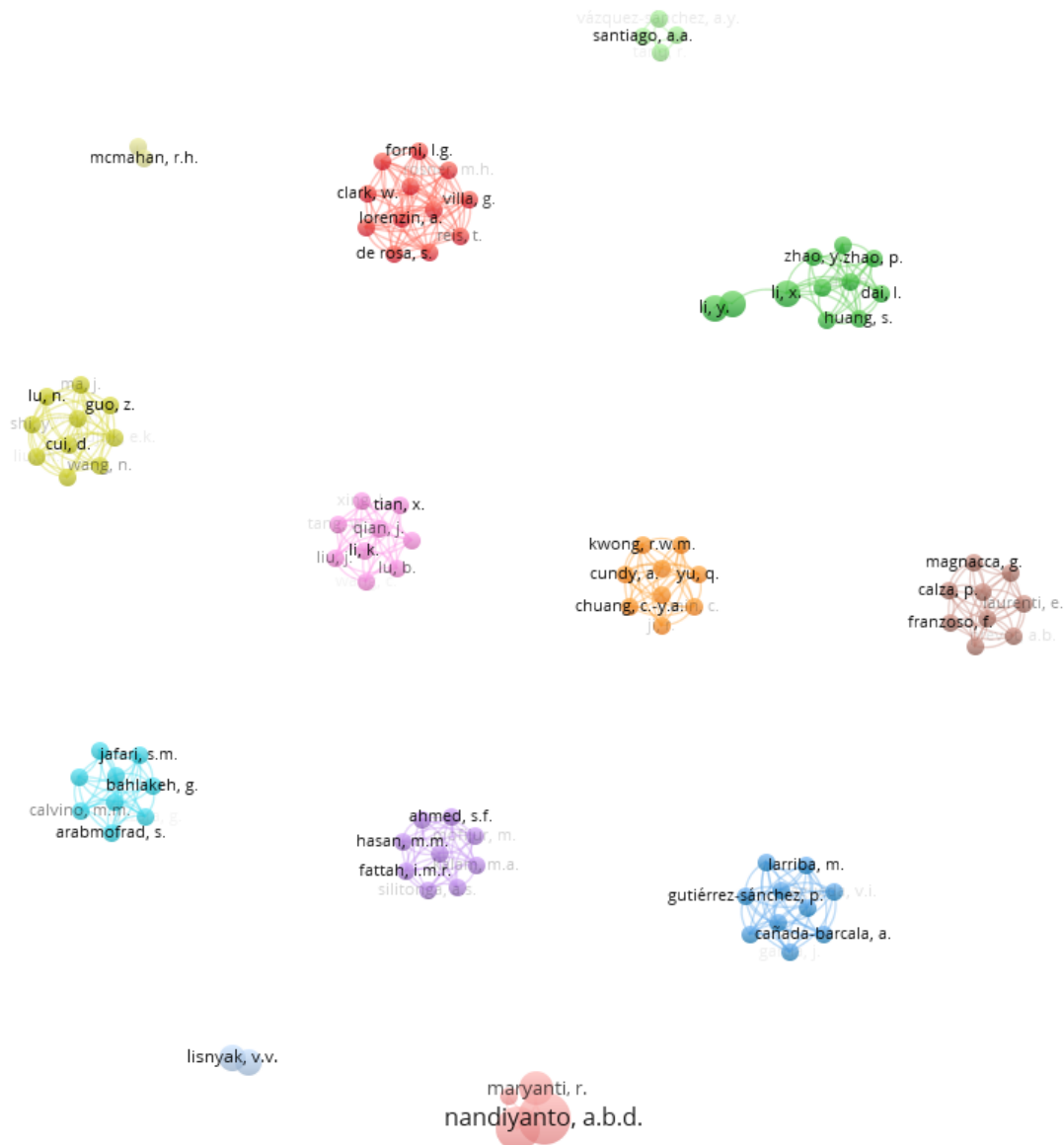


Figure 3. Author-based network visualization.

Figure 3 also shows that collaboration between authors is becoming a common practice in scientific writing today. Such collaborations can provide a variety of benefits, including combining different expertise, improving the quality of research, broadening the scope of methodology, and strengthening the legitimacy of research results. Apart from that, collaboration can also expand the academic networks of these authors, help in obtaining research funding, and increase the impact of their research results.

If we take a sample of 1 cluster from **Figure 3**, namely cluster 1 which is marked in red, we can see that this cluster consists of 4 writers who come from Indonesia. The largest node,

which shows that the author wrote many articles related to adsorption, is Nandiyanto, A. B. D. and his team (See **Figure 4**).

This analysis highlights that in a scientific context, Nandiyanto, A. B. D. has made significant contributions to adsorption research, as an indicator of the size of his nodes in the cluster. The presence of a team from Indonesia in this cluster also shows that there is productive collaboration between Indonesian researchers in this field. This reflects cross-institutional collaboration and possible support from local resources in adsorption research in Indonesia.

More broadly, these observations support the importance of international collaboration in scientific research, where authors from different countries can contribute to global knowledge in a specific field such as adsorption. Such collaborations not only expand the scope of methodologies and resources, but also enable the exchange of ideas and increased expertise among researchers.

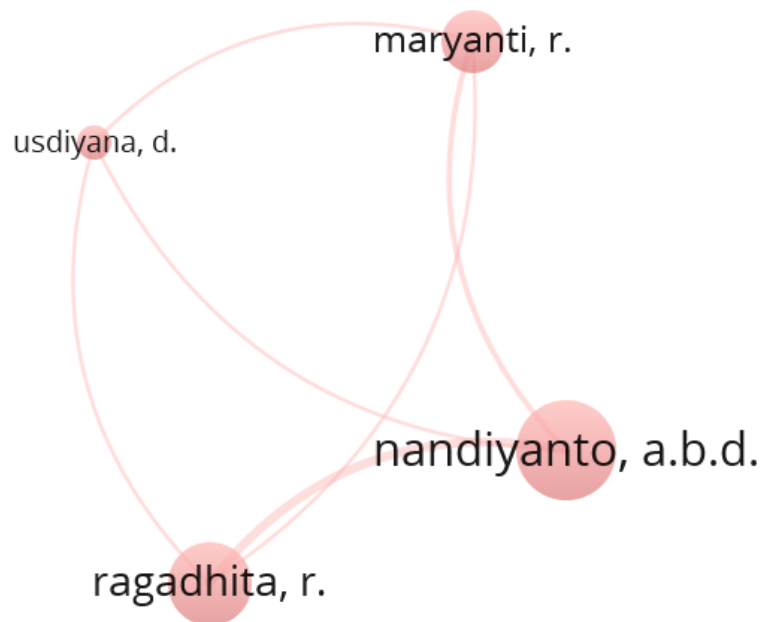


Figure 4. Author-based network visualization: Cluster 1.

3.5. Article Data Visualization

Network visualization in bibliometric analysis is an important tool for identifying and analyzing relationships between scientific articles, authors, journals, or certain keywords in a research field (Liao *et al.*, 2018; Donthu *et al.*, 2021). The results of network visualization are usually in the form of graphics showing nodes and edges that represent entities and the relationships between them. For example, in a co-authorship visualization, nodes can represent authors, and edges represent collaboration between those authors. This helps researchers to identify collaboration patterns, centers of interest, and research trends that are developing in a scientific field.

Figure 5 shows the shape of the visualization network. Based on Figure 5, the visualization network in this research produces 2 cluster groups, namely Cluster 1 which is marked in red, and Cluster 2 which is marked in green. Further explanation of the resulting clusters is as follows:

1. Cluster 1: Activity, adsorbent, adsorption, adsorption isotherm, adsorption process, analysis, application, approach, aqueous solution, article, case, change, characterization,

chemistry, China, concertation, concept, country, data, development, education, effect, efficiency, end, engineering, environment, experience, experiment, experimental result, field, impact, importance, influence, issue, knowledge, Langmuir, mechanism, ministry, model, order, paper, preparation, presence, problem, process, removal, research, review, science, student, study, surface, synthesis, system, technology, temperature, time, type, university, utilization, water, way, work, and year.

- Cluster 2: 2nd joint international conference, awareness, biochar, carbon nanotube saturable absorber, combination, computing technology, demographic variable, determination, equilibrium isotherm, erbium doped fiber laser, fuzzy risk, HDI, higher education, human development index, ICT usage, implementation, Indonesia, initial study, learning, machine, MDI, Medan, methylene, MHz fundamental repetition rate, mode, motion graphic, motor development, motor development indexing, multimodal transportation, new perspective, number, observational study, parent, parkia speciosa pod, perception, preschool child, proceeding, quality, SDI, small scale reverse osmosis water industry, social medium, software engineering theory, sport development index, sports, stress, success parameter, systems quality engineering, topic, Universiti Malaysia perlis, use, web, and weight coefficient.

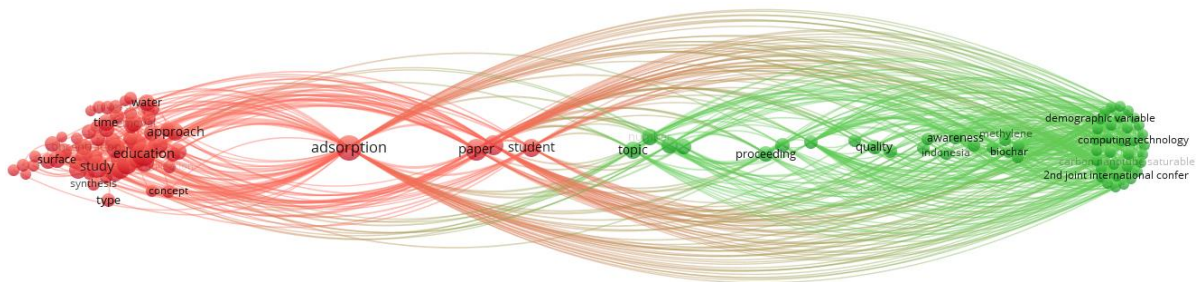


Figure 5. Network visualization based on keywords.

4. CONCLUSION

This research explores trends and developments in the literature on adsorption in education through bibliometric analysis using data from the Scopus database. The analysis shows fluctuations in the number of publications over the last five-year period (2019-2024), with the highest peak occurring in 2020 with 23 documents published. Meanwhile, in 2024, the number of publications regarding adsorption in education will be 12 documents. Other results from this research also show that international collaboration is considered crucial in this research, both in the form of collaboration between authors, countries, and collaboration between affiliated institutions.

This research highlights the importance of adsorption in educational contexts and how this topic continues to evolve over time. Collaboration across institutional and national boundaries enriches research perspectives, enables the exchange of ideas and methods, and increases the global impact of research.

Overall, this bibliometric analysis provides an in-depth understanding of the dynamics of scientific publications on adsorption in education, indicating potential future development directions for further research and practical application in educational contexts.

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6. 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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