

Bibliometric Analysis of Hydrogels from Graphene Oxide Nanoparticles Using the VOSviewer Application

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INFO ARTIKEL

Diterima 28 September 2022

Disetujui 29 Oktober 2022

Key word:

Bibliometric

Computational Analysis

Hydrogel Graphene Oxide

Nanoparticles

VOSviewer

ABSTRACT

This study aims to examine the development of research on hydrogels from graphene oxide nanoparticles published in Google Scholar from 2013 to 2022 (September) through a bibliometric computational analysis approach using the Publish or Perish and VOSviewer applications. The title, publication type, abstract, keywords, and range of years are the parameters used to select the data taken in the Publish or Perish application. Two hundred twenty-seven articles that are relevant to the desired theme. From year to year, there is an increase in the number of scientific publications related to hydrogels from graphene oxide nanoparticles to a peak in 2021, with as many as 46 articles; the following year, it decreased slightly to 31 articles. Topics of discussion widely raised in nanoparticle hydrogel research include synthesis, characterization, doping, application, and industrial-scale production. From this data, it appears that there is still an opportunity to continue to do more research related to hydrogels from graphene oxide nanoparticles, assisted by the VOSviewer application, which can also help to find problem topics that can be used as research innovation materials on hydrogels from graph oxide nanoparticles in the future.

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Introduction

Graphene is a monolayer carbon atom with a hexagonal crystal structure, has sp² hybridization bonds, and is a supercapacitor material with high electrical (thermal) conductivity. Graphene is also relatively new in the carbon family and has unique physical and chemical properties, so research continues to develop with extraordinary results now [1]. Graphene has been widely used in various applications, both macro-micro (electronic) scales. Modifications were made in various aspects, such as structure, polymers, synthesis, doping, and sensors. The application of graphene is also carried out not only in the industrial world but in the medical world, water treatment, energy, coatings, Etc. [2]. Chemically reduced graphene oxide (rGO) is very similar to graphene. In manufacturing supercapacitor materials, rGO is more advantageous than graphene sheets.

Hydrogel is a polymer that can absorb and release water depending on the external stimulant received by the application medium

(pH, temperature, and humidity) [3]. Currently, the research limitations in Indonesia on super absorbent hydrogels are in the synthesis (graft copolymerization and gamma-ray irradiation). Hydrogels are widely used in agriculture because of their three-dimensional tissue structure and excellent hydrophilicity, which can be used for tissue regeneration (cell culture scaffolds). Publications related to graphene oxide (GO) hydrogels are still minimal and attract much attention for further research [4].

Bibliometric is an analysis using a massive data mining method on a quantitatively selected database related to the number of citations in a certain period according to the desired analysis theme and then processed with mathematical statistics. Bibliometric data can be visualized using graphs or clusters, making it easier to interpret the problem's general description and broad topic [5]. This bibliometric analysis is used to see how the selected research trends are hydrogels from graphene oxide nanoparticles and what

research potential can be used as material for further research[6].

In this study, an analysis was carried out to see the hydrogel trend of graphene oxide nanoparticles in the period 2013 to 2022 (September). The purpose of this study was to analyze bibliometrically the trend of hydrogel research on graphene oxide nanoparticles with restrictions on the type of publication, title, keywords, abstract, and year range. Data mining on Google Scholar is done using the Publish or Perish application, and VOSviewer visually assists the bibliometric analysis process. The purpose of this research can be a consideration to determine the research theme to be taken with graphene oxide nanoparticle hydrogel objects. This research theme in Indonesia is very rare, so the benefits cannot be felt.

Methods

Data Acquisition

The application used to obtain the required data is Publish or Perish. This application facilitates the acquisition of literature review data based on the selected topic. The VOSviewer application is used to make it easier to map data visually. This application provides three visual data results: network visualization, density visualization, and overlay visualization. When making a bibliometric map using the VOSviewer application, the frequency of keywords that enter the map at least three times are mentioned in one article. If there are words that are not relevant, they are removed from the map. The desired data can be obtained with the following steps:

1. The process of searching and sorting data using the Publish or Perish application with the Google Scholar database,
2. The process of processing bibliometric data can be done with Microsoft Excel,
3. The process of mapping bibliometric data can be done with the VOSviewer application,
4. Computational analysis.

The data presented in this article were obtained from journal publications indexed in Google Scholar. The data on Google Scholar is open source, so it is necessary to have parameters to select the desired data results.

Sorting of publication data was carried out using the publication type parameter "Journal OR Science OR Nature OR Sciences OR Scientific OR Materials OR Environmental OR Nano OR Chemistry OR MDPI"; title "Graphene Oxide Hydrogel"; keyword "Nanoparticle"; and the range from 2013 to 2022. Data collection was carried out on September 14, 2022. Two types of data files are taken, namely (.ris) and (*.csv) formats. File format (.ris) is used for visual processing of data using the VOSviewer application with mind map results, and file format (*.csv) is used for statistical data processing using the Microsoft Excel application with statistical graph results.

Data analysis

The data analysis processes are performance analysis and bibliometric analysis. Performance analysis was performed using Publish or Perish and Microsoft Excel, while bibliometric analysis used the VOSviewer application. Both sections were conducted on the same day and time to reduce the error factor in data acquisition and analysis.

The work analysis was carried out by processing files (*.cvs) in Microsoft Excel, including data on the number of citations, author's name, article title, year of publication, journal name, publisher name, h-index value, and the number of articles relevant to the theme during the range of years. Use of Microsoft Excel application to create graphs and tables based on data presented by Publish or Perish (number of publications per year). Bibliometric analysis is assisted by the VOSviewer application processing data from files (.ris); this application synthesizes the data and then makes a bibliometric network work that can describe keywords from various relevant articles.

Result and Discussion

Bibliometric Analysis

This research combines two problems, namely bibliometric and hydrogel graphene oxide nanoparticles. All data processed in the bibliometric analysis are taken from Google Scholar metadata. The Publish or Perish application obtained 114 data articles relevant to the desired theme: Hydrogel from Graphene Oxide Nanoparticle. The results from Publish or

Perish application period from 2013 to 2022 (September) provide information on how much the article was cited, the author's name, title, publication's year, journal's name, and publisher's name. The selection process is also carried out by understanding the contents of the article's abstract if the title does not interpret the desired theme. The journals with the most

relevant titles and the highest citation numbers are designated in **table 1**. Based on the number of relevant journals obtained, 227 have 7447 citations; citations per year 827.44; citations per article 32.81; citations per author 4.83; the total h-index and g-index for all articles are 48 and 76.

Table 1. Hydrogel from Graphene Oxide nanoparticle publication data

No.	Autors	Title	Year	Cites	ref.
1	A Paul <i>et al.</i>	Injectable graphene oxide/hydrogel-based angiogenic gene delivery system for vasculogenesis and cardiac repair	2014	411	[7]
2	R Sahraei <i>et al.</i>	Novel magnetic bio-sorbent hydrogel beads based on modified gum tragacanth/graphene oxide: Removal of heavy metals and dyes from water	2017	213	[8]
3	D Ghosh <i>et al.</i>	Hydrothermal Growth of Hierarchical Ni ₃ S ₂ and Co ₃ S ₄ on a Reduced Graphene Oxide Hydrogel@Ni Foam: A High-Energy-Density Aqueous Asymmetric Supercapacitor	2015	204	[9]
4	T Jiao <i>et al.</i>	Reduced graphene oxide-based silver nanoparticle-containing composite hydrogel as highly efficient dye catalysts for wastewater treatment	2015	203	[10]
5	C Dong <i>et al.</i>	Developing stretchable and graphene-oxide-based hydrogel for the removal of organic pollutants and metal ions	2018	196	[11]
6	X Zeng <i>et al.</i>	Silver/reduced graphene oxide hydrogel as novel bactericidal filter for point-of-use water disinfection	2015	171	[12]
7	T Jiao <i>et al.</i>	Self-Assembly Reduced Graphene Oxide Nanosheet Hydrogel Fabrication by Anchorage of Chitosan/Silver and Its Potential Efficient Application toward Dye Degradation for Wastewater Treatments	2015	169	[13]
8	A Konwar <i>et al.</i>	Chitosan–iron oxide coated graphene oxide nanocomposite hydrogel: a robust and soft antimicrobial biofilm	2016	157	[14]
9	Y Chen <i>et al.</i>	Ti ₃ C ₂ Tx-Based Three-Dimensional Hydrogel by a Graphene Oxide-Assisted Self-Convergence Process for Enhanced Photoredox Catalysis	2018	156	[15]
10	F Wang <i>et al.</i>	A graphene oxide/amidoxime hydrogel for enhanced uranium capture	2016	139	[16]
11	J Wu <i>et al.</i>	Improved selectivity and sensitivity of gas sensing using a 3D reduced graphene oxide hydrogel with an integrated microheater	2015	126	[17]

12	H Qian <i>et al.</i>	Synthesis of lignin-poly (N-methylaniline)-reduced graphene oxide hydrogel for organic dye and lead ions removal	2020	113	[18]
13	Y Huang <i>et al.</i>	High-water-content graphene oxide/polyvinyl alcohol hydrogel with excellent mechanical properties	2014	109	[19]
14	X Yi <i>et al.</i>	Graphene oxide encapsulated polyvinyl alcohol/sodium alginate hydrogel microspheres for Cu (II) and U (VI) removal	2018	106	[20]
15	H Hosseinzadeh <i>et al.</i>	Fabrication of starch-graft-poly (acrylamide)/graphene oxide/hydroxyapatite nanocomposite hydrogel adsorbent for removal of malachite green dye from aqueous ...	2018	106	[21]
16	K Soleimani <i>et al.</i>	Bioconjugated graphene oxide hydrogel as an effective adsorbent for cationic dyes removal	2018	103	[22]
17	J Li <i>et al.</i>	Au nanoparticles–3D graphene hydrogel nanocomposite to boost synergistically in situ detection sensitivity toward cell-released nitric oxide	2015	93	[23]
18	H Jiang <i>et al.</i>	Preparation of a novel bio-adsorbent of sodium alginate grafted polyacrylamide/graphene oxide hydrogel for the adsorption of heavy metal ion	2020	91	[24]
19	W Liu <i>et al.</i>	Reduced graphene oxide (rGO) hybridized hydrogel as a near-infrared (NIR)/pH dual-responsive platform for combined chemophotothermal therapy	2019	88	[25]
20	E Makhado <i>et al.</i>	Microwave assisted synthesis of xanthan gum-cl-poly (acrylic acid) based-reduced graphene oxide hydrogel composite for adsorption of methylene blue and methyl violet from aqueous solution	2018	85	[26]

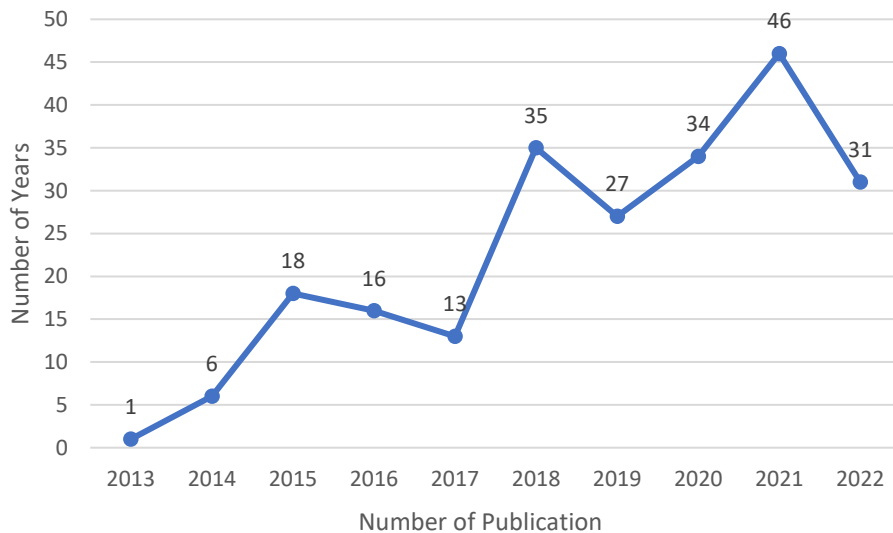
From 2013 to 2022, the number of articles relevant to the title was 227, with an average number of publications per year of 22 articles. Number of articles published annually: 1 article (2013); 6 articles (2014); 18 articles (2015); 16 articles (2016); 13 articles (2017); 35 articles (2018); 27 articles (2019); 34 articles (2020); 46 articles (2021); and 21 articles (September 2022) can be seen in **table 2**. The number of publications fluctuates from year to year, with

the highest publication peak in 2021. It can be seen that 2013 was the year that had the least number of publications related to hydrogels from graphene oxide nanoparticles.

Figure 1. describes that there has been a reasonably visible decrease in changes in 2019 and 2022. A significant increase is most visible in 2018 and 2022, which can be assumed to be a decrease and increase in interest in this research topic.

Table 2. Hydrogel Graphene Oxide Nanoparticle research development

Number of Years	Number of Publication
2013	1
2014	6
2015	18
2016	16
2017	13
2018	35
2019	27
2020	34
2021	46
2022	31
Total	227
Mean	22,7

**Figure 1.** Level of Hydrogel Graphene Oxide Nanoparticle research development.

Visualization Analysis using VOSviewer

Data computational mapping is done using the VOSviewer application. This mapping obtained 83 items divided into 8 clusters characterized by different colors. Among them:

1. cluster 1 (red): acrylamide, acrylic acid, adsorbent, adsorption, aqueous solution, gold, graphene oxide nanocomposite, hydrogel bead, isotherm, microwave, network, poly, removal, and water.
2. Cluster 2 (green): carbon nanotube, chitosan hydrogel, cyclodextrin, drug, graphene oxide, group, hybrid hydrogel, magnetic graphene oxide, n-isopropylacrylamide, nanocomposite hydrogel, nanoparticle, performance, and polymerization.
3. Cluster 3 (blue): application, composite, effect, crosslinker, incorporation, polymer, PVA, release, surface, synthesis, and vitro
4. Cluster 4 (yellow): composite hydrogel, cross, graphene, graphene oxide nanosheet, large surface area, mechanical strength, polyacrylamide, polypyrrole, property, and vinyl alcohol.

5. Cluster 5 (purple): addition, development, efficient adsorption, filter, GO nanoparticle, hydrogel nanocomposites, magnetic nanoparticle, metal ion, nanocomposite, and presence.
6. Cluster 6 (cyan): antibacterial activity, dispersion, GO nanosheet, graphene hydrogel, graphene oxide nanoparticle, mechanical property, oxide, process, rGOH, and work.
7. Cluster 7 (orange): GO hydrogel, fabrication, graphene oxide hydrogel, hydrogel, reduce graphene oxide, rGO, self-assembly, and silver nanoparticle.
8. Cluster 8 (pink): characterization, chemo photothermal therapy, chitosan, preparation, present study, and sensitive hydrogel.

Size, colour, and cluster give special meaning in bibliometric computational mapping using this VOSviewer. The more prominent the circle label, the closer the correlation of the word to the title and abstract of the article; this measure also shows the more often the word appears in each article. **Figure 2, 7, and 8.** Is visualization mapping analysis.

Figure 2. It shows a network visualization that describes the relationship between terms that are related to each other. In this drawing, there are also colour differences that indicate clusters. Clusters group topics that are often discussed in each article. Cluster 1 shows the topics often appearing in each article and vice versa. Each word in a cluster is a word that is often discussed in the topic. In this bibliometric theme, four main terms are the research focus: Hydrogel, Graphene Oxide, graphene oxide hydrogel, and nanoparticles. Hydrogels are included in cluster 7 (orange); 81 words related to hydrogels, occurrences with the theme are 138, and a total link strength of 590, as shown in **figure 3**. Graphene Oxide are included in cluster 2 (green); 82 words related to hydrogels, occurrences with the theme are 172, and a total link strength of 744, as shown in **figure 4**. Graphene Oxide Hydrogel are included in cluster 7 (orange); 52 words related to hydrogels, occurrences with the theme are 36, and a total link strength of 159, as shown in **figure 5**. Nanoparticle are included in cluster 2 (green); 75 words related to hydrogels, occurrences with the theme are 82, and a total link strength of 355, as shown in **figure 6**.

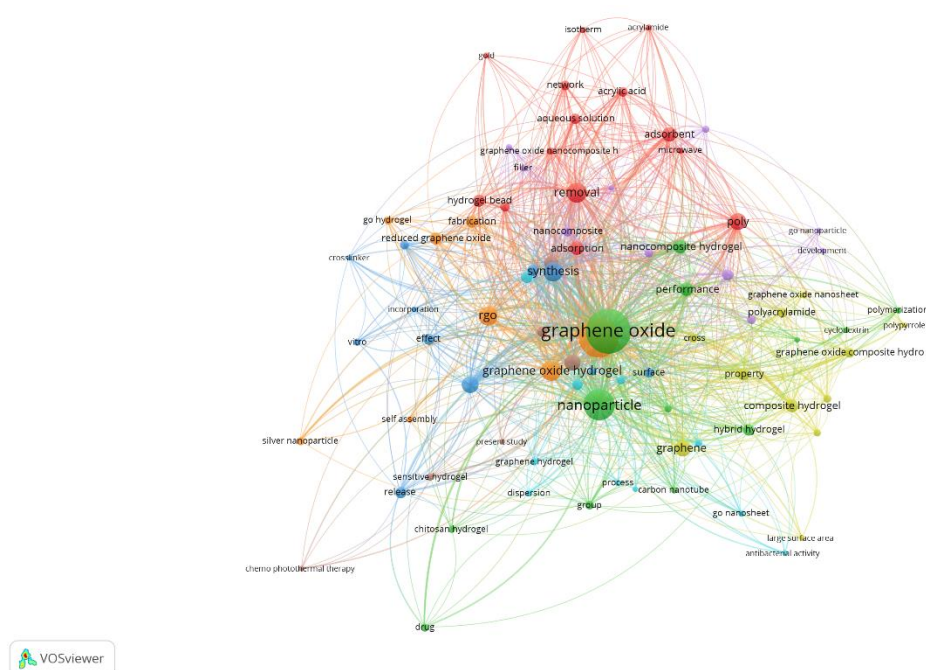


Figure 2. Network visualization of Hydrogel from Graphene Oxide Nanoparticle.

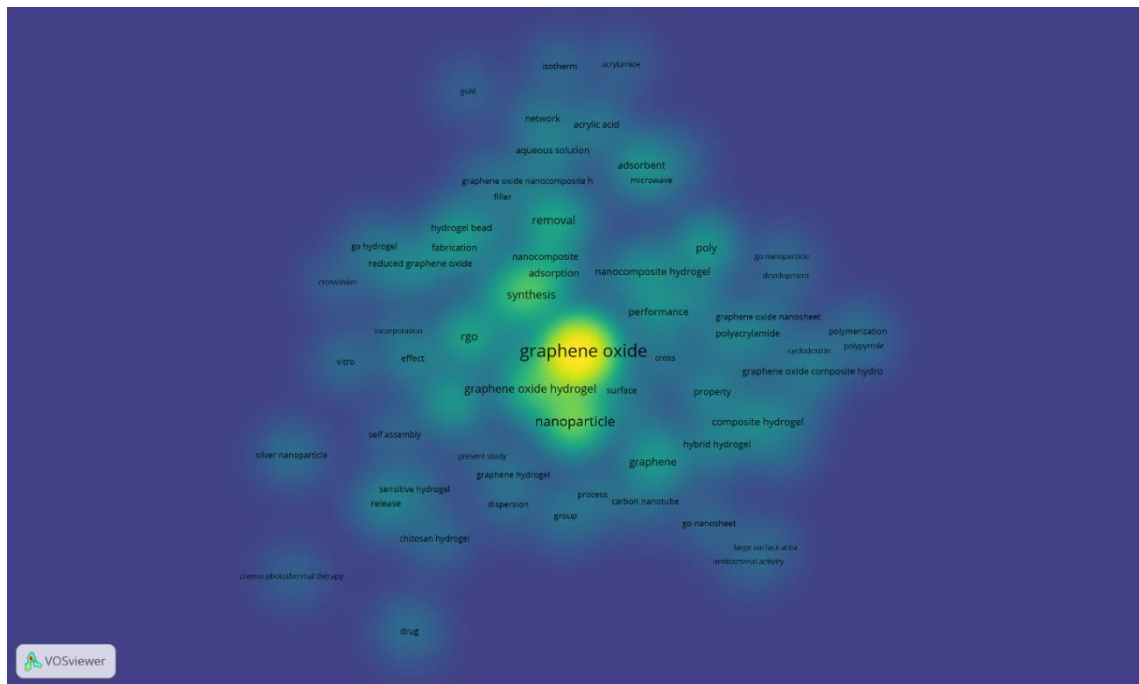


Figure 8. Density visualization of Hydrogel from Graphene Oxide Nanoparticle.

Conclusion

The results of the bibliometric analysis of research trends on hydrogels from graphene oxide nanoparticles have increased in 2013-2014, 2017-2018, and 2019-2021. The decline occurred in 2015-2017 and 2018-2019. In 2022, it appears that there is still the possibility of an increase in the number of publications related to the themes raised in September; there have been 31 articles have been published and indexed by Google Scholar. Research on this topic is very much needed, considering the many applications that can facilitate the resolution of environmental and agro-industry problems, especially in Indonesia.

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