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ARTICLE

Trends Of Deep Eutectic Solvent for Silver Nanoparticle Recovery Based on Bibliometric Computational Analysis Using VOSViewer

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ABSTRAK

Pemulihan logam perak (Ag) menggunakan *Deep Eutectic Solvent (DESs)* adalah salah satu topik hangat untuk diteliti. Pemulihan logam ini bertujuan untuk mensintesis logam perak dari limbah elektronik, film radiografi atau lainnya menjadi logam perak murni sehingga dapat memiliki nilai guna kembali. Topik mengenai penelitian ini menjadi trend dan meningkat dari tahun ketahun jika ditinjau dari data bibliometric dan memiliki cakupan data yang sangat luas. Data hasil pencarian menunjukan ada sebanyak 534 data artikel yang memenuhi kriteria penelitian pada rentang waktu 10 tahun terakhir dari 2013 hingga 2022. Hasil penelitian menunjukkan bahwa penelitian di bidang pemulihan nanopartikel perak menggunakan DESs dapat dipisahkan menjadi 3 istilah yaitu DESs, perak, dan nanopartikel. Istilah "DESs untuk pemulihan nanopartikel perak" menghasilkan 102 item yang berhubungan dari 534 artikel yang didapat dan dipisahkan kedalam 8 cluster yang berbeda dan disesuaikan dengan keidentikan dengan topik penelitian yang diangkat. Secara keseluruhan trend penelitian untuk topik ini meningkat dari tahun ketahun seperti yang ditunjukan pada tahun 2020 yang hanya memiliki 76 artikel publikasi menjadi 157 artikel pada tahun 2021 dan 188 artikel pada tahun 2022. Data data tersebut diambil dari *application reference manager* kemudian dihubungkan dengan *VOSViewer*. Tinjauan ini dapat menjadi titik awal untuk penelitian-penelitian selanjutnya yang terkait.

Kata Kunci: Pemulihan Nanopartikel Perak; EDSs; Bibliometri; Analisis pemetaan komputasi; VOSviewer.

ABSTRACT

The recovery of metallic silver (Ag) using Deep Eutectic Solvent (DESs) is one of the hot topics for research. This metal recovery aims to synthesize silver metal from e-waste, Radiographic Films or else into pure silver metal so that it can have reuse value. The topic of this research is becoming a trend and increasing from year to year when viewed from bibliometric data and has a very broad scope. The search data showed that there were 534 data articles that met the research criteria in the last 10 years from 2013 to 2022. The results show that research in DESs for recovery of silver nanoparticles can be separated into 3 terms, namely DESs, silver and nanoparticles. The term "DESs for recovery of silver nanoparticles" resulted in 102 related items from 534 articles which were obtained and separated into 8 different clusters that were matched to the identification of the research topic raised. Overall, the research trend for this topic is increasing from year to year as shown in 2020 which only had 76 published articles to 157 articles in 2021 and 188 articles in 2022. The data were taken from the application reference manager and then connected to the VOSViewer. This review can be a starting point for further related research.

Keywords: *Silver Nanoparticles recovery;DESs, Bibliometric; Computational mapping analysis; VOSviewer Sertakan*

1. INTRODUCTION

DESs are formed by a hydrogen-bond acceptor (HBA, quaternary salt etc.), and hydrogen-bond donor (HBD, amines, carboxylic acids, carbohydrates, etc.). As a green solvent, DESs reported as a highly efficient and eco-friendly method to recycle metal (such as silver) from waste material [1]. Silver metal is one of the metals that is widely used in various fields, one of which is in the electronics field. In the electronics field, silver metal is found in waste printed circuit boards (WPCBs). This waste is one of the main components in various electrical and electronic equipment which is rich in several valuable metal contents [2]. Generally, WPCBs contain precious metals such as Cu, Zn, Ni, Al and Fe from 1% to 40% (w/w) by weight [3-4].

This study aims to show the trend of the topic of research on "DESs for Silver Nanoparticle Recovery" which is based on the results of a bibliometric application reference manager based on Google Scholar and then connected to VOSViewer so as to produce valid statistical data.

The bibliometric analysis technique is a form of meta-analysis of research data that can assist researchers in studying bibliographic content, research topic trends and citation analysis from various articles published in journals and other scientific works.

There have been many studies on bibliometric-based analysis, including bibliometric analysis in chemical research [5] and chemical engineering [5-7], bibliometric analysis in materials research [8], Scientific Publications [9], Datasets describing the decline in the number of scientific publications [10], Magnetite Nanoparticles [11], and Nano Metal-Organic Synthesis Framework [12].

2. METHODS

The article data used in this study is based on research from publications that have been published in Google Scholar indexed journals. The author chose Google Scholar as the main database because Google Scholar is an open source. The Publish or Perish reference manager application is used to obtain research data to conduct a literature review on the selected topic. Detailed information on how to use and install the software and a step-by-step process for obtaining data are described in the previous study [13]. The search for article data from Publish or Perish is used to filter publications using the keyword "Silver nanoparticles recovery" so that article data is obtained that is relevant to the research conducted.

2.1 Software

The articles taken are in the last ten years from 2012 to 2022. All data were obtained in September 2022. VOSviewer displays three variations of mapping publication visualizations, namely network visualization, density visualization, and network-based overlay visualization (co-citation) between existing items.

2.2 Procedure

The research was conducted through several stages:

1. Collection of publication data using the publish or perish application,
2. Processing of bibliometric data for articles that have been obtained using Microsoft Excel applications,
3. Computational mapping analysis of bibliometric published data using the VOSviewer application, and Analysis of computational mapping analysis results.

3. RESULT AND DISCUSSION

3.1 Publication data search results

Based on data searching through the publish or perish application reference manager from the Google Scholar database, 534 article data were obtained that met the research criteria. The data obtained in the form of article metadata consist of the author's name, title, year, journal name, publisher, number of citations, article links, and related URLs. Figure 1 shows the details of the published data that will be used in the VOSviewer analysis of this study.

Table 1 shows the sample data taken by the 18 relevant articles that have the highest number of citations. The number of citations from all articles used in this study is 12788, the number of citations per year is 1278.80, the number of citations per article is 4.08, the average author in the articles used is 2.90, all articles have an average h-index is 29, and the g-index is 98.

Citation metrics	Help
Publication years:	2012-2022
Citation years:	10 (2012-2022)
Papers:	534
Citations:	12788
Cites/year:	1278.80
Cites/paper:	23.95
Authors/paper:	4.08
h-index:	53
g-index:	98
hI,norm:	29
hI,annual:	2.90
hA-index:	34
Papers with ACC >= 1,2,5,10,20:	423,374,270,161,80

Figure 1. Citation metrics of DESs for silver nanoparticles recovery research

3.2 Research development in the field of metal silver nanoparticles recovery

Table 2 shows the development of research in the field of nanoparticles recovery published in the Google Scholar indexed journal. Based on Table 2, the data can be seen that the number of articles in nanoparticle recovery is 534 from 2013-2022. In 2013 there were 4 articles, in 2014 there were 3 articles, in 2015 there were 6 articles, in 2016 there were 7 articles, in 2017 there were 16 articles, in 2018 there were 21 articles, in 2019 there were 55 articles, in 2020 there were 76 articles, in 2021 there were 157 articles and in 2022 there were 188 articles.

Table 1 The sample data taken by the 18 relevant articles

No.	Authors	Title	Year	Cites	Ref
1	J Sudagar, J Lian, W Sha	Electroless nickel, alloy, composite and nano coatings–A critical review	2013	806	[14]
2	SK Singh, AW Savoy	Ionic liquids synthesis and applications: An overview	2020	434	[15]
3	A Abo-Hamad, M Hayyan, MAH AlSaadi…	Potential applications of deep eutectic solvents in nanotechnology	2015	397	[16]
4	DA Alonso, A Baeza, R Chinchilla…	Deep eutectic solvents: the organic reaction medium of the century	2016	384	[17]
5	K Vikrant, KH Kim	Nanomaterials for the adsorptive treatment of Hg (II) ions from water	2019	218	[18]
6	RK Thines, NM Mubarak, S Nizamuddin…	Application potential of carbon nanomaterials in water and wastewater treatment: a review	2017	178	[19]
7	KS Egorova, VP Ananikov	Fundamental importance of ionic interactions in the liquid phase: A review of recent studies of ionic liquids in biomedical and pharmaceutical applications	2018	118	[20]
8	I Wazeer, M Hayyan…	Deep eutectic solvents: designer fluids for chemical processes	2018	86	[21]
9	MK AlOmar, MA Alsaadi, TM Jassam, S Akib…	Novel deep eutectic solvent-functionalized carbon nanotubes adsorbent for mercury removal from water	2017	66	[22]
10	M Periyasamy, A Kar	Modulating the properties of SnO 2 nanocrystals: morphological effects on structural, photoluminescence, photocatalytic, electrochemical and gas sensing properties	2020	59	[23]
11	N Altunay, A Elik, R Gürkan	Monitoring of some trace metals in honeys by flame atomic absorption spectrometry after ultrasound assisted-dispersive liquid liquid microextraction using natural deep eutectic solvent	2019	56	[24]
12	LC Tomé, D Mecerreyes	Emerging ionic soft materials based on deep eutectic solvents	2020	49	[25]
13	RK Ibrahim, A El-Shafie, LS Hin, NSB Mohd…	A clean approach for functionalized carbon nanotubes by deep eutectic solvents and their performance in the adsorption of methyl orange from aqueous solution	2019	44	[26]
14	AM Abdel-Mohsen, D Pavliňák, M Čileková…	Electrospinning of hyaluronan/polyvinyl alcohol in presence of in-situ silver nanoparticles: Preparation and characterization	2019	34	[27]
15	VT Elakkiya, P SureshKumar, NS Alharbi…	Swift production of rhamnolipid biosurfactant, biopolymer and synthesis of biosurfactant-wrapped silver nanoparticles and its enhanced oil recovery	2020	19	[28]
16	J Wang, Y Zhang, L Yu, K Cui, T Fu, H Mao	Effective separation and recovery of valuable metals from waste Ni-based batteries: A comprehensive review	2022	12	[29]
17	SJ Bryant, AJ Christofferson, TL Greaves…	Bulk and interfacial nanostructure and properties in deep eutectic solvents: Current perspectives and future directions	2022	8	[30]

Table 2 shows the development of research in the field of nanoparticles recovery published in the Google Scholar indexed journal

Year of Publications	Number of Publications
2012	1.0
2013	4.0
2014	3.0
2015	6.0
2016	7.0
2017	16.0
2018	21.0
2019	55.0
2020	76.0
2021	157.0
2022	188.0
Average	**53.3**

Figure 2 shows the development of research for silver recovery nanoparticles in the last 11 years, ranging from 2012 to 2022. Based on Fig. 2, it is known that the development of research related to silver recovery nanoparticles has increased every year especially in 2017-2022. This result shows that the topic is very interesting and valuable. The data shows that the popularity of research on silver recovery nanoparticles tends to be stable and recently, interest in silver recovery nanoparticles research has increased.

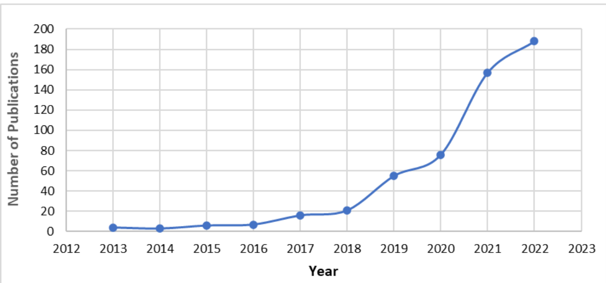

Figure 2. Level of development in silver recovery nanoparticles research.

3.3 Visualization metal silver recovery topic area using VOSviewer

The data generated from VOSViewer shows various different clusters. In this study, there were a total of eight different clusters which were separated according to their identity with the material being raised. Below are explained the eight clusters along with the keywords and visualization colors shown in Figure 3.

1. Cluster 1 has 10 items and is marked in red, the 10 items are addition, adsorbent, adsorption, carlon nanotube, composite, derivative, gold nanoparticle, graphene, heavy metal, immobilization, magnetic nanoparticle, metal nanobaride, metal oxide nanoparticle, nanomaterial, poly, polymer, property, removal, and wastewater treatment.
2. Cluster 2 has 18 items and is marked in green, the 18 items are aqueous solution, biological sample, detection, determination, dispersive liquid liquid, effect, electrode, electrodeposition, extraction recovery, Ion, liquid phase microextraction, metal jon, nickel, nitrofurantoin, sample, Sensor, type and zinc.
3. Cluster 3 has 18 items and is marked in blue, the 18 items are, analyte, carbon dot, extraction, fiber, graphene oxide, high recovery, hydrophobic deep eutectic solvent, lead, mechanism, microextraction, organic solvent, parameters, polycyclic aromatic hydrocarbon, recovery, silica nanoparticle, surface, utilization, and water sample
4. Cluster 4 has 16 items and is marked in yellow, the 16 items are catalyst, choline chloride, copper, deep eutectic solvent, des, efficient catalyst, eutectic solvent, formation, gold, green chemistry, hydrogen, metal, mixture, process, reaction, and silver.
5. Cluster 5 has 14 items and is marked with purple color, the 14 items are, application, comparison, fabrication, ionic liquid, metallic nanoparticle, natural deep eutectic solvent, overview, performance, praCessine, recent advance, silver nanoparticle, solvent, treatment, and ZnO nanoparticles.
6. Cluster 6 has 11 items and is marked with sky blue color, the 11 items are analysis, atomic spectrometry, atomic spectrometry update, chemical, deep eutectic, environmental analysis, nanoparticle, preparation, review, silver ion, and silver np.
7. Cluster 7 has 3 items and is marked in orange, the 3 items are comprehensive review, efficiency, and separation.
8. Cluster 8 has 3 items and is marked with brown color, the 3 items are characterization, green synthesis, and synthesis.

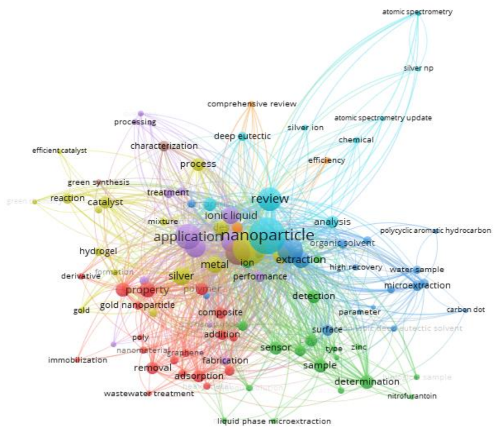

Figure 3. Co-word map Network visualization of silver nanoparticle recovery keyword.

The relationship between one term and another is shown in Figure 3. Each cluster is given with colored circles. The frequency of each term distinguishes the circle size of each related keyword. The size of the label circle shows a positive correlation with the occurrence of the term in the title and abstract [13].

The more the term is used, the larger the label size [13]. The mapping visualization analysed in this study consists of 3 parts namely network visualization (see Fig. 3), density visualization (see Fig. 4), and overlay visualization (see Fig. 5).

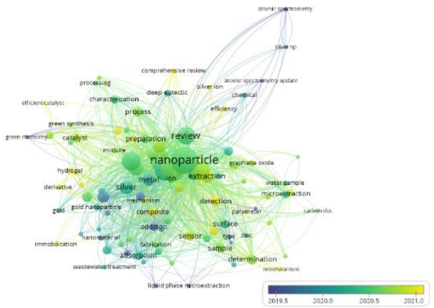

Figure 4. Overlay visualization of silver nanoparticle recovery keyword.

Figure 3 showing about Co-Word keyword maps Network visualization of silver nanoparticle recovery that are useful for obtaining an overview of the general structure of bibliometric maps by showing important items for analysis.

The cluster density view are items that marked on the same as the visible item. The item point has a color depending on the density of the item at the time. Figure 23 shows a density map result of an analysis using all articles on nanoparticle. The density map means that the yellower the color is with the diameter of the largest circle, the tighter the keyword means that it appears more often and if the color fades, it blends with the green background less often (Tupan, 2019). The brightness of the density color explains that a lot of research on related terms has been done. On the other hand, if the color of the term fades closes to the background color, this indicates that the number of studies on the term is small.

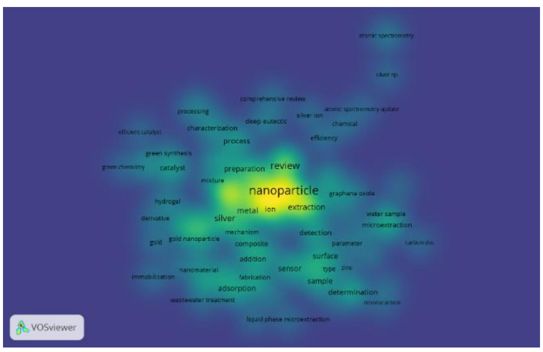

Figure 5. Density visualization of silver nanoparticle recovery keyword.

Figure 6 shows a visualization of the distribution of data on the keyword " deep eutectic solvent" which explains how this keyword is related to various other keywords. Also, this keyword shows that deep eutectic has many relation to another terms specially with silver and ionic liquid.

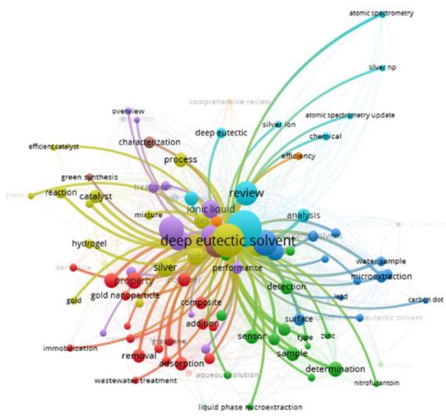

Figure 6. Network visualization of deep eutectic solvent terms.

Figure 7 shows the visualization of the distribution of data on the keyword "silver". Each keyword shows the relationship to each other which is connected by a line span for each circle, especially nanoparticles, ionic liquid, deep eutectic, catalyst, reaction, and properties.

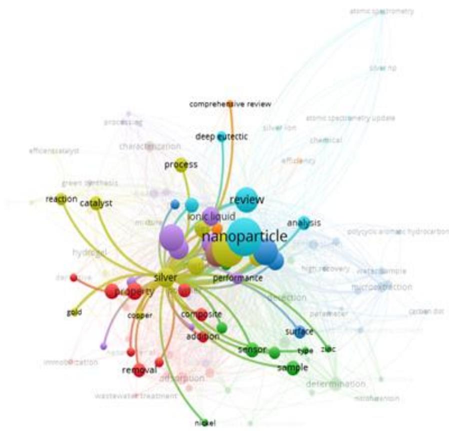

Figure 7. Network visualization of deep eutectic solvent terms.

Figure 8 shows the visualization of the distribution of data on the keyword "nanoparticles". Each keyword shows the relationship to each other which is connected by a line span for each circle. The keyword of nanoparticle shows the relation with another term especially with, silver, nanoparticle, review, deep eutectic, ionic liquid, chemical, and silver ion.

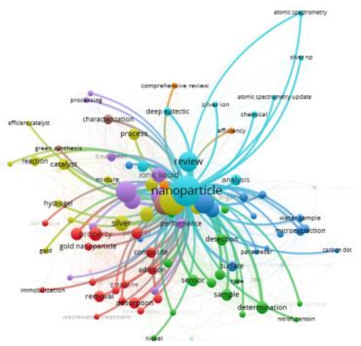

Figure 7. Network visualization of nanoparticle term.

Based on the results of data mapping analysis of the collected article data, it can be seen that the keywords " DESs for Silver Nanoparticle Recovery" has been widely used and become trends in research.

4. CONCLUSION

Based on the search results data, there are 534 data articles that meet the research criteria in the period 2013 to 2022. The highest research data is shown in 2021 as many as 157 published articles and 2022 as many as 188 published articles. These bibliometric data show that the research topic on recovery of silver nanoparticles using deep eutectic solvents from waste materials is developing every year and become a trend in various research fields.

5. AUTHOR CONTRIBUTION

HANR and ABDN all contributed to the data analysis and the writing. Authors have read the manuscript and agreed on the final version.

6. ACKNOWLEDGEMENT

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