BORNEO JOURNAL OF SCIENCES AND TECHNOLOGY (BJoST)
VOL. : 6, ISSUE: 1 , 39-49
DOI: http://doi.org/10.35370/bjost.2024.6.1-05
e-ISSN: 2672-7439 © 2018, UTS Publisher.

University of Technology Sarawak

ORIGINAL ARTICLE

A Bibliometric Analysis of NMC Type Lithium-Ion Battery Using VOSviewer Application

*[1]Marvin Horale Pasaribu, [1]Rokiy Alfanaar, [1]Mokhamat Ariefin, [1]Tety Wahyuningsih Manurung and [1,2,3]Rendy Muhamad Iqbal

[1]Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Palangka Raya, Kampus UPR Tunjung Nyaho, Palangkaraya 73111, Indonesia
[2]Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia
[3]Advanced Membrane Technology Research Center (AMTEC), Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Skudai 81310, Johor, Malaysia

ABSTRACT - The Nickel-manganese-cobalt (NMC) lithium-ion battery (LIB) landscape has witnessed robust expansion in recent years, fueled by the exponential demand for LIBs in electric vehicles (EVs), consumer electronics, and energy storage applications. NMC LIBs exhibit advantageous characteristics compared to their counterparts, boasting superior energy capacity, density, cycle life, and affordability. This surging need for batteries has underscored the imperative for continuous research aimed at optimizing their performance and efficiency. This study employs a bibliometric framework to comprehensively delve into the NMC LIB domain. A meticulous mapping analysis was conducted leveraging VOSviewer software for visualization and Publish or Perish for data acquisition. Titles, abstracts, and keywords containing "NMC-type Lithium Battery" served as the primary search criteria, yielding a corpus of 999 pertinent articles published between 2018 and 2023. The analysis identified a pronounced, progressive increase in NMC LIB-related publications, highlighting its burgeoning scientific interest. Key research clusters encompassed advancements in battery technology and manufacturing processes, future prospects and challenges, potential environmental ramifications, and the application of computational methodologies for in-depth analysis. This study demonstrates the effectiveness of bibliometric analysis in gleaning valuable, domain-specific insights into the NMC LIB field, thereby establishing itself as a vital resource and roadmap for future researchers. NMC technology carries substantial potential to shape the future of energy storage by enhancing LIB performance and cost-effectiveness, ultimately propelling their widespread adoption across diverse applications.

ARTICLE HISTORY
Received: 8 Nov 2023
Revised: 22 Dec 2023
Accepted: 11 Jan 2024

KEYWORDS
Bibilometric Analysis, NMC type lithium-ion battery (LIB), VOSviewer, Data analysis.

INTRODUCTION

Fossil fuels currently remain the dominant source of energy for human needs, encompassing electricity generation, industrial processes, and transportation. However, their utilization presents a multitude of severe environmental challenges, including ozone depletion, global warming, and air pollution [1]. A primary contributor to global warming is carbon dioxide gas emitted through fossil fuel combustion, particularly from motor vehicles. The U.S. Energy Information Administration (EIA) reports that the transportation sector accounted for nearly 25.6% of global carbon dioxide emissions in 2021 [2]. In an effort to mitigate fossil fuel dependence, automobile manufacturers are increasingly turning to electric energy sources, such as batteries and ultra-capacitors, to power their vehicles [3].

Since their inception in the early 1990s, lithium-ion (Li-ion) batteries have evolved into a crucial energy storage technology for diverse applications, encompassing electronic devices and stationary storage systems [4]. Their high energy density, minimal maintenance requirements, extended lifespan,

*Corresponding Author: Marvin Horale Pasaribu. Universitas Palangka Raya (UPR),
email: marvin.pasaribu@mipa.upr.ac.id

superior performance, and inherent versatility [5], coupled with their promising potential for electric vehicles (EVs), have solidified their position as a leading energy solution [6]. Notably, commercial batteries are classified based on the lithium-ion donor at the cathode, which plays a pivotal role in determining the overall cell characteristics. Consequently, utilizing diverse cathode materials results in a spectrum of battery properties [7].

Nickel-manganese-cobalt (NMC) oxide lithium-ion (Li-ion) batteries (LIBs) offer exceptional power and energy density characteristics. The inherent tunability of NMC materials allows for tailoring to achieve a wide range of charge capacities, rendering them suitable for diverse battery types and powering nearly all electric vehicles [8]. A recent report confirmed that NMC LIBs now claim a dominant 50% share of the global LIB market [9]. The global electric vehicle (EV) market is poised for significant growth, with projections forecasting a value of USD 951.9 billion by 2030 [10]. This growth is expected to be driven by the increasing adoption of battery electric vehicles (BEVs), with the global market predicted to surge from 5,318,850 units in 2019 to a staggering 39,996,720 units by 2030 [11]. Additionally, the development of urban micromobility as a viable alternative to traditional transportation systems further contributes to this growth trajectory [12].

Bibliometric analysis represents a quantitative methodology for analyzing bibliographic information within articles and journals. Its applications encompass investigating references to cited scientific works, mapping the scientific domains covered within a journal, and classifying scientific articles according to their respective research fields [13; 14]. In the pursuit of comprehensive knowledge acquisition, bibliometric analysis emerges as a complementary tool to qualitative literature reviews. By leveraging quantitative metrics and statistical procedures, it provides an objective lens for uncovering dominant research trends and evaluating the scientific performance of specific fields or individual researchers [15]. Notably, bibliometric analysis excels at illuminating under-researched areas and unveiling potential avenues for future investigation [16]. Therefore, researchers grappling with nascent topics often prioritize this approach to identify knowledge gaps and formulate novel research questions.

The Publish or Perish (PoP) software is a widely used bibliometric analysis tool that provides a range of features for conducting bibliometric analyses. These analyses involve searching for scientific publications based on various criteria, such as keywords, titles, authors, or journals [17]. This feature can facilitate the identification of publications that are relevant to a researcher's work. The Publish or Perish software can also be used to analyze research trends in a specific field and identify areas that require further research [18]. VOSviewer, a software tool, facilitates the conversion of bibliometric networks into diverse visual formats [19; 20]. This functionality is achieved by exploring and mapping various types of network data [21], ultimately generating sophisticated visualizations with visual labeling techniques such as layout and clustering [22].

Many previous studies about NMC type lithium-ion battery have been conducted, including research about Oxygen Release and Its Effect on the Cycling Stability of LiNixMnyCozO2 (NMC) Cathode Materials for Li-Ion Batteries by Jung et al. [23]. Another study by Investigation on the thermal behavior of Ni-rich NMC lithium-ion battery for energy storage by Lyu et al. [24]. Gupta et al. are examining the Improved High Voltage Performance of Li-ion Conducting Coated Ni-rich NMC Cathode Materials for Rechargeable Li Battery [25]. However, there are still relatively few studies on bibliometric analysis in the NMC type lithium-ion battery sector. This bibliometric analysis might be beneficial for estimating the amount and current status of a study field, furthermore, allows us to quantitatively explore the intellectual structure of NMC type lithium-ion batteries, identify important areas of research that have been done, and understand the patterns of published research topics, authorship, and citation networks.

The objective of this study is to perform a bibliometric mapping analysis of research on NMC-type lithium-ion batteries using VOSviewer software. The resulting analysis aims to provide valuable assistance and serve as a reference for future researchers in research development. It also aims to facilitate decision-making in the selection of potential research topics related to materials, methods, processes, and impacts of the NMC type lithium-ion battery technology, which is increasingly growing in use.

MATERIALS AND METHODOLOGY

This study employed Google Scholar as its primary data source, leveraging Publish or Perish reference management software for efficient data collection and analysis. The focus was on retrieving and analyzing academic citations from research and study articles specifically indexed by Google Scholar and classified as journal articles. Data collection was meticulously restricted to articles relevant to NMC type lithium-ion batteries. On November 30, 2023, Publish or Perish was utilized to search for relevant publications using the keyword "NMC type lithium-ion battery" within the title, abstract, and keyword fields, with the timeframe encompassing the years 2018-2023. This rigorous search yielded 999 articles, which were meticulously assessed for their adherence to the chosen research topic. The collected articles were subsequently saved in a *.ris format, facilitating their visualization and analysis through the creation of bibliometric maps using VOSviewer software. Data processing involved filtering specific terms for inclusion in the visualizations, which were then constructed using three distinct types: network visualization, density visualization, and overlay visualization. This study further investigated the year-on-year variations in publication volume and identified the 10 articles with the highest number of citations within each publisher among the 999 collected articles.

RESULTS AND DISCUSSION

Research Developments in NMC type lithium-ion battery Field

Among prominent Li-ion battery chemistries, including Lithium Iron Phosphate (LFP), Lithium Manganese Oxide (LMO), and Lithium Nickel Cobalt Aluminum Oxide (NCA), Lithium Nickel Manganese Cobalt Oxide (NMC) stands out due to its balanced composition for high performance. The optimal synergy between nickel, manganese, and cobalt endows NMC batteries with several advantages: impressive energy capacity exceeding 200 Wh/kg, remarkable energy density surpassing 600 Wh/L, extended cycle life surpassing 4,000 cycles, and competitive cost advantages [26; 27]. These advantageous characteristics propel NMC batteries into diverse applications, serving as the energy heart of electric vehicles (e.g., Tesla and Volkswagen), powering consumer electronics, and contributing to grid-scale energy storage systems [28]. Driven by these versatile applications, NMC battery production steadily increases, necessitating sustained research and development efforts to further optimize battery efficiency and performance. The ongoing research progress in NMC batteries is graphically depicted in the provided figure, highlighting the continuous advancements in this critical technology.

This study examines the development trajectory of NMC type lithium-ion battery research conducted between 2018 and 2023. As depicted in Figure 1, the volume of research and studies focusing on NMC type lithium-ion batteries witnessed a continuous increase over the past six years, from 2018 to 2022. This upward trend is demonstrably evident in the publication numbers, with 100 articles published in 2018, rising to 113 articles in 2019, 169 articles in 2020, 195 articles in 2021, and culminating in 229 articles in 2022. However, the year 2023 displays a decline in publication volume to 193 articles due to the analysis timeframe ending in November, leaving a possibility for additional publications to be released before the year's end. The observed growth in NMC type lithium-ion battery research aligns with the increasing adoption of this technology, particularly for electronic devices and vehicles [9].

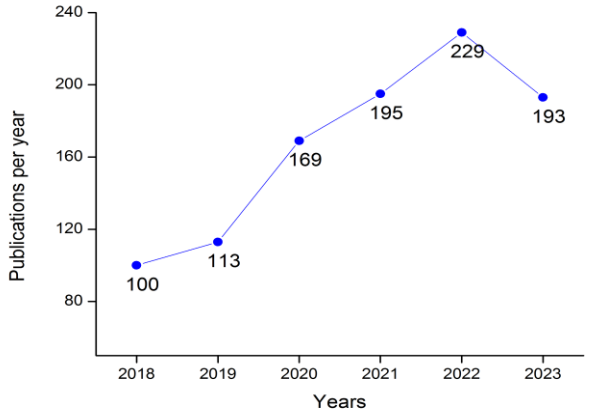

Figure 1. Level of development of research on NMC type lithium-ion battery

Table 1. Common light levels published by IESNA [14]

No	Citation Number	Document Title	Journal Title	Year	Author
1	1299	Lithium-ion batteries: outlook on present, future, and hybridized technologies	Journal of Materials Chemistry A	2019	[29]
2	769	A review of lithium-ion battery safety concerns: The issues, strategies, and testing standards	Journal of Energy Chemistry	2021	[31]
3	620	Li plating as unwanted side reaction in commercial Li-ion cells–A review	Journal of Power Sources	2018	[32]
4	470	Lithium-ion batteries–Current state of the art and anticipated developments	Journal of Power Sources	2020	[33]
5	465	All-solid-state lithium-ion and lithium metal batteries–paving the way to large-scale production	Journal of Power Sources	2018	[34]
6	411	A quick on-line state of health estimation method for Li-ion battery with incremental capacity curves processed by Gaussian filter	Journal of Power Sources	2018	[35]
7	384	A wide range of testing results on an excellent lithium-ion cell chemistry to be used as benchmarks for new battery technologies	Journal of The Electrochemical Society	2019	[36]
8	382	Application of electrochemical impedance spectroscopy to commercial Li-ion cells: A review	Journal of Power Sources	2020	[37]
9	375	Pyrometallurgical options for recycling spent lithium-ion batteries: A comprehensive review	Journal of Power Sources	2021	[38]
10	355	A review of the state of health for lithium-ion batteries: Research status and suggestions	Journal of Cleaner Production	2020	[30]

An analysis of the collected article data from 2018 to 2023 reveals the most highly cited articles related to NMC type lithium-ion batteries, as presented in Table 1. Notably, the most referenced article, authored by Kim et al. with 1,299 citations [29], focuses primarily on the technology and future prospects of lithium batteries based on working electrodes. This article discusses the evolution from conventional to advanced lithium-ion batteries (LIBs) to meet the growing demand for high charge capacity and electrode stability.

The last 10th highest article, written by Tian et al. with 355 citations [30], writing a review of technology and manufacture of commercial lithium-ion batteries. The rest articles within the top 10 most cited works explore various critical aspects of NMC type lithium-ion batteries: articles No. 2 and No. 9 explore the remaining challenges and potential environmental impacts associated with batteries, articles No. 3-5 and No. 7-8 focus on the current state and advancements in battery technology, including manufacturing processes, article No. 6 utilizes computational methods to analyze and optimize the performance of batteries.

Visualization of NMC type lithium-ion battery area using VOSviewer

Network visualization depicts the interconnected relationships between terms [20], represented by lines connecting them. Upon analysis with VOSviewer, the research landscape of NMC type lithium-ion batteries is categorized into five distinct clusters, each represented by a colored circle. The size of each circle corresponds to the number of keywords associated with the cluster, derived from the titles and abstracts of the analyzed articles [39]. Furthermore, the size of the text and circles is proportional to the frequency of each term's appearance, with more frequent terms exhibiting larger font sizes and circles [40]. Figure 2 visualizes these clusters, categorized by research topic. Notably, the central node "nickel manganese cobalt oxide" occupies cluster 1, while "state" forms the core of cluster 2. Cluster 3 is centered around "cathode material", cluster 4 focuses on "electrolyte", and cluster 5 revolves around "cycling". The prominence of these main nodes within the network signifies their frequent occurrence and interconnectedness with other keywords across the analyzed 999 articles [41; 42].

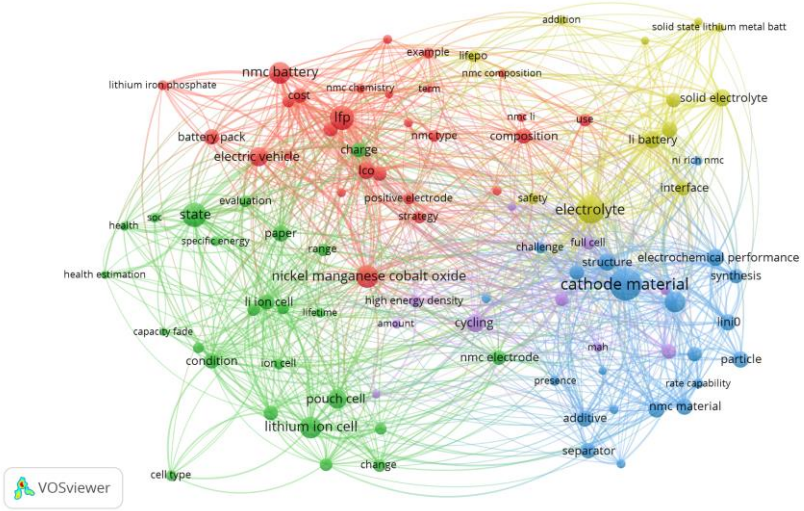

Figure 2. Network visualization of NMC type lithium-ion battery keywords

The data obtained on the area of NMC type lithium-ion battery was divided into five clusters, namely: cluster 1 has 25 items, such as battery pack, battery type, nickel manganese cobalt oxide, nmc battery, lithium ferrophosphate, composition, comprehensive review, cost, electric vehicle, example, lithium cobalt oxide, lithium ferrophosphate battery, lithium manganese cobalt oxide, lithium iron phosphate, lithium manganese oxide, nmc battery, nmc composition, nmc lithium, nmc type, part, positive electrode, recycling, strategy, term, and use. Figure 3 shows a network visualization of cluster 1 with "nickel manganese cobalt oxide" as the main node.

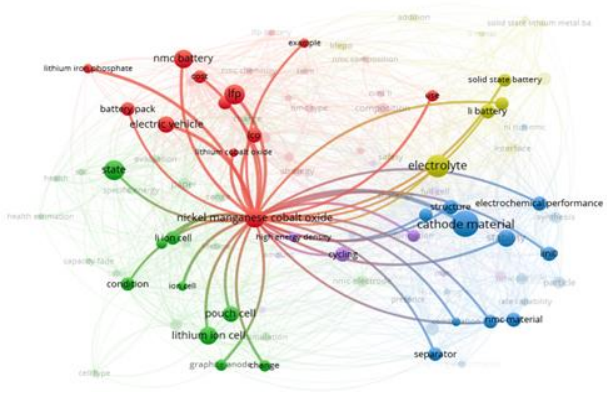

Figure 3. Network visualization of cluster 1

Cluster 2 has 24 items, namely capacity fade, case, cell type, change, charge, condition, evaluation, experiment, graphite anoda, health, health estimation, ion cell, lithium ion cell, lifetime, modelling, nmc electrode, paper, pouch cell, range, simulation, state of charge, specific energy, state, and table. As shown in Figure 4, the main node in cluster 2 is "state".

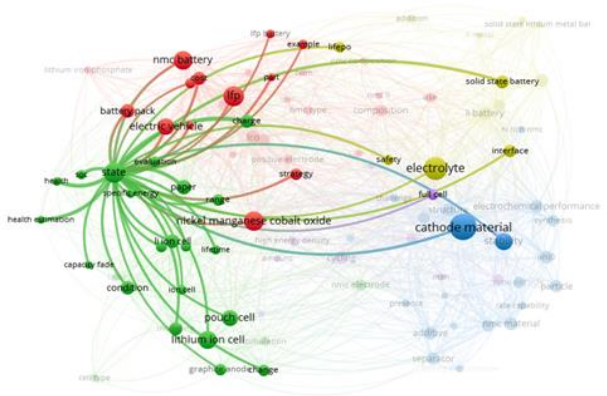

Figure 4. Network visualization of cluster 2

Cluster 3 has 21 items consisting of additive, cathode material, challenge, combination, cycling performance, electrochemical performance, lithium nickel, lithium ion batteries, nickel rich nmc, nmc material, nmc particle, particle, presence, rate capability, recent progress, rechargeable lithium battery, separator, stability, structure, surface, synthesis. Figure 5 shows a network visualization of cluster 3 with "cathode material" as the main node. Cluster 4 has 11 items, which are addition, electrolyte, high performance, interface, lithium battery, lithium metal, safety, solid electrolyte, solid state battery, solid state lithium battery, solid state lithium metal battery. As shown in Figure 6, the main node in cluster 4 is "electrolyte".

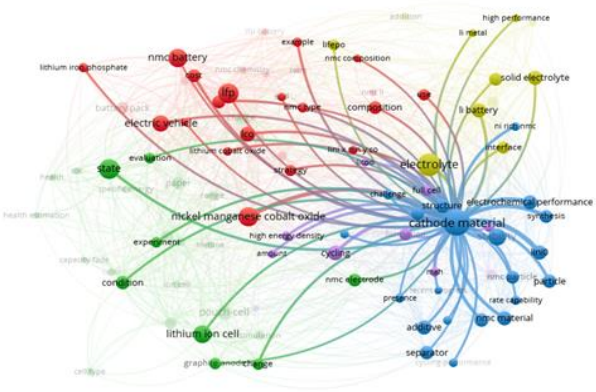

Figure 5. Network visualization of cluster 3

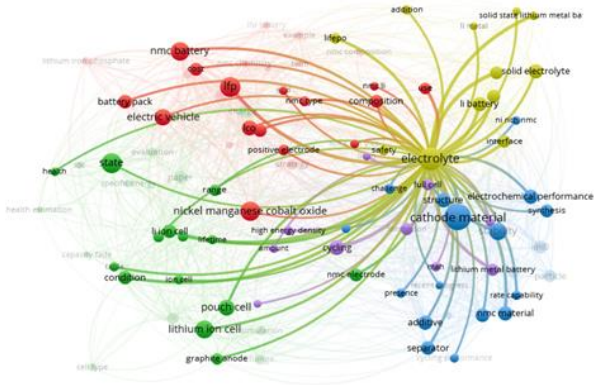

Figure 6. Network visualization of cluster 4

Cluster 5 has 9 items. There are amount, cycling, formation, full cell, high energy density, high voltage, lithium metal battery, lithium plating, milliampere-hour. As shown in Figure 7, "cycling" is the main node in Cluster 5.

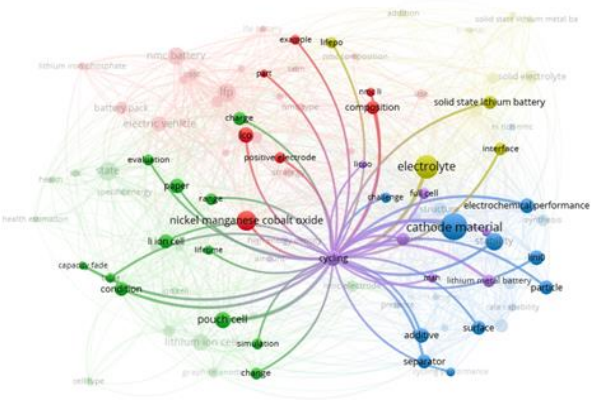

Figure 7. Network visualization of cluster 5

Overlay Visualization of NMC type lithium-ion battery keyword

Overlay visualization concurrently depicts the year-on-year research trend for NMC type lithium-ion batteries and the interconnected relationships between relevant terms. Figure 8 illustrates this dynamic visualization covering the research period from 2018 to 2023. Notably, the color gradient, transitioning from blue to yellow, represents the relative freshness of each article, with yellow signifying more recent publications [43].

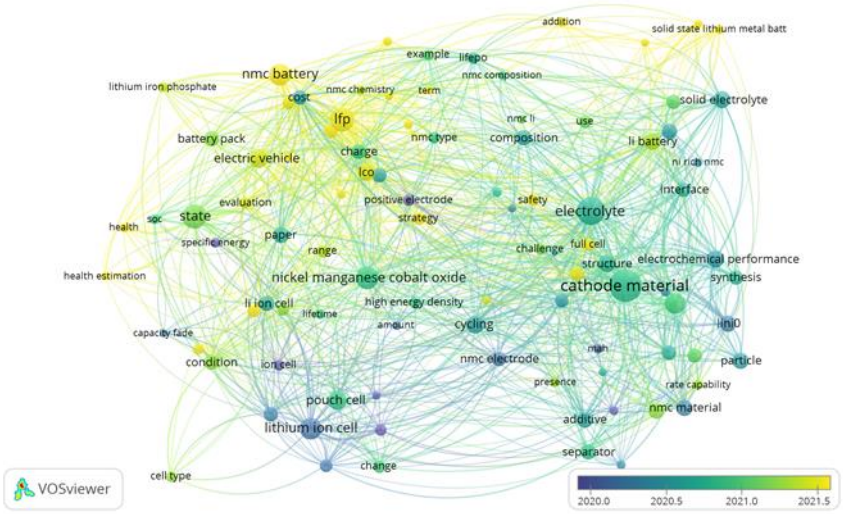

Figure 8. Overlay Visualization of NMC type lithium-ion battery keyword

Density Visualization of NMC type lithium-ion battery keyword

Density visualization provides insights into the research depth, where an increasing volume of conducted research translates into a more concentrated color, a larger circle diameter, and a denser cluster of keywords. Conversely, a sparser distribution of keywords and a diminishing color intensity represent a lower research output [44].

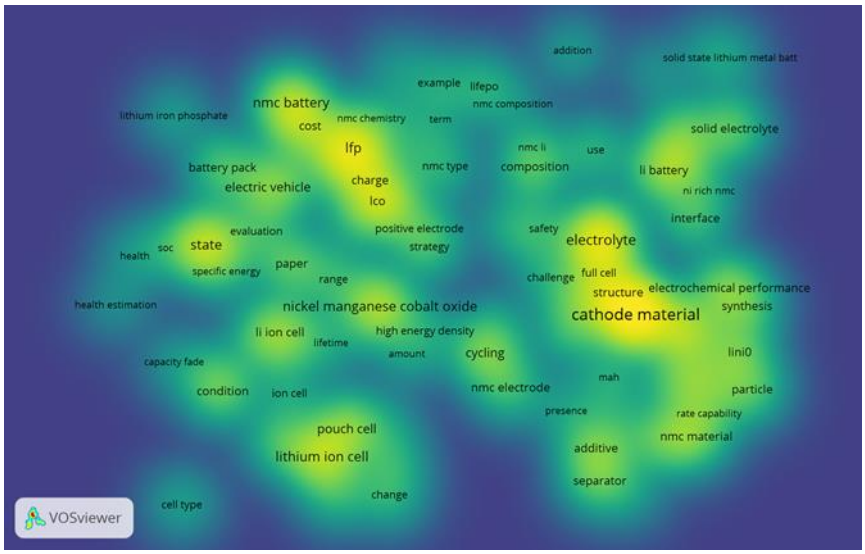

Figure 9. Density Visualization of NMC type lithium-ion battery keyword

Figure 9 highlights the terms associated with the most intensive research activity within the domain of NMC type lithium-ion batteries. Notably, keywords such as "cathode material", "electrolyte", "NMC battery", "nickel manganese cobalt oxide", "lithium-ion cell", "lithium ferrophosphate", and "state" exhibit significantly higher frequencies within the analyzed data. This bibliometric analysis provides valuable reference information for researchers in the field of NMC type lithium-ion batteries, facilitating the identification of promising research avenues and potential breakthroughs in advancing the field.

CONCLUSION

This study employed a combined approach of bibliometric mapping and reference management software to investigate the field of NMC type lithium-ion batteries. VOSviewer software was utilized for the bibliometric analysis, while Publish or Perish facilitated efficient data collection. The research focused on articles within the topic area of NMC type lithium-ion batteries, specifically targeting titles, abstracts, and keywords containing the specified keyword phrase. This rigorous search yielded 999 relevant articles published between 2018 and 2023. Further analysis was conducted using VOSviewer, which generated three distinct visualizations: network visualization, overlay visualization, and density visualization. The analysis revealed a consistent upward trend in publications related to NMC type lithium-ion batteries from 2018 to 2022. This research is expected to serve as a valuable reference point for researchers, aiding them in conducting future studies and selecting promising research topics within the NMC type lithium-ion battery field.

ACKNOWLEDGEMENT

The authors acknowledge the Universitas Palangka Raya, especially the Department of Chemistry, for the support and assistance.

REFERENCES

[1] D. Kumar, R. K. Nema, and S. Gupta, “A comparative review on power conversion topologies and energy storage system for electric vehicles,” Int. J. Energy Res., vol. 44, no. 10, pp. 7863–7885, 2020.

[2] I. E. Agency, “Global Energy Review : CO2 Emissions in 2021 Global emissions rebound sharply to highest ever level INTERNATIONAL ENERGY,” 2021.

[3] H. S. Das, C. W. Tan, and A. H. M. Yatim, “Fuel cell hybrid electric vehicles: A review on power conditioning units and topologies,” Renew. Sustain. Energy Rev., vol. 76, pp. 268–291, Sep. 2017.

[4] L. Zhou et al., “Recent Developments on and Prospects for Electrode Materials with Hierarchical Structures for Lithium-Ion Batteries,” Adv. Energy Mater., vol. 8, no. 6, pp. 1–23, 2018.

[5] H. Weiss, T. Winkler, and H. Ziegerhofer, “Large Lithium-Ion Battery-Powered Electric Vehicles - From Idea to Reality,” Proc. 2018 ELEKTRO, Mikulov, Czech Repub., pp. 1–5, 2018.

[6] A. von Wald Cresce and K. Xu, “Aqueous lithium-ion batteries,” Carbon Energy, vol. 3, no. 5, pp. 721–751, 2021.

[7] G. Zubi, R. Dufo-López, M. Carvalho, and G. Pasaoglu, “The lithium-ion battery: State of the art and future perspectives,” Renew. Sustain. Energy Rev., vol. 89, no. March, pp. 292–308, 2018.

[8] J. Peng et al., “A Review of Lithium-Ion Battery Capacity Estimation Methods for Onboard Battery Management Systems: Recent Progress and Perspectives,” Batteries, vol. 8, no. 11, p. 229, 2022.

[9] C. Pillot, “The Rechargeable Battery Market and Main Trends 2018-2030,” Avicenne Energy-Market Rep., 2019.

[10] Q. Zhang, X. Ou, X. Yan, and X. Zhang, “Electric Vehicle Market Penetration and Impacts on Energy Consumption and CO2 Emission in the Future: Beijing Case,” Energies, vol. 10, no. 2, p. 228, Feb. 2017.

[11] T. Dhakal and K.-S. Min, “Macro Study of Global Electric Vehicle Expansion,” Foresight STI Gov., vol. 15, no. 1, pp. 67–73, Mar. 2021.

[12] S. V. Ratner and V. V. Iosifov, “Analyzing the global electric vehicle market development in 2020: COVID-19 pandemic challenges and new electrification initiatives,” Econ. Anal. Theory Pract., vol. 20, no. 8, pp. 1415–

1437, Aug. 2021.

[13] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," J. Bus. Res., vol. 133, no. April, pp. 285–296, 2021.

[14] N. J. van Eck and L. Waltman, "Software survey: VOSviewer, a computer program for bibliometric mapping," Scientometrics, vol. 84, no. 2, pp. 523–538, 2010.

[15] O. José de Oliveira, F. Francisco da Silva, F. Juliani, L. César Ferreira Motta Barbosa, and T. Vieira Nunhes, "Bibliometric Method for Mapping the State-of-the-Art and Identifying Research Gaps and Trends in Literature: An Essential Instrument to Support the Development of Scientific Projects," in Scientometrics Recent Advances, IntechOpen, 2019.

[16] K. Cosh, S. Ramingwong, and L. Ramingwong, "A bibliometric analysis of Library Review trends," Glob. Knowledge, Mem. Commun., Oct. 2022.

[17] D. M. Chiu and T. Z. J. Fu, "'Publish or Perish' in the Internet Age," ACM SIGCOMM Comput. Commun. Rev., vol. 40, no. 1, pp. 34–43, Jan. 2010.

[18] R. Bergquist, L. Rinaldi, and G. Cringoli, "Publish or perish: Need for bibliometric and access reform," Geospat. Health, vol. 13, no. 2, Nov. 2018.

[19] P. S. Kurniati, H. Saputra, and T. A. Fauzan, "A Bibliometric Analysis of Chemistry Industry Research Using Vosviewer Application with Publish or Perish," Moroccan J. Chem., vol. 10, no. 3, pp. 428–441, 2022.

[20] A. S. Nugraha, "Bibliometric Analysis of Magnetite Nanoparticle Production Research During 2017-2021 Using Vosviewer," Indones. J. Multidiciplinary Res., vol. 2, no. 2, pp. 327–332, 2022.

[21] N. J. van Eck and L. Waltman, "Citation-based clustering of publications using CitNetExplorer and VOSviewer," Scientometrics, vol. 111, no. 2, pp. 1053–1070, 2017.

[22] A. Kuzior and M. Sira, "A Bibliometric Analysis of Blockchain Technology Research Using VOSviewer," Sustainability, vol. 14, no. 13, p. 8206, Jul. 2022.

[23] R. Jung, M. Metzger, F. Maglia, C. Stinner, and H. A. Gasteiger, "Oxygen Release and Its Effect on the Cycling Stability of LiNi x Mn y Co z O 2 (NMC) Cathode Materials for Li-Ion Batteries," J. Electrochem. Soc., vol. 164, no. 7, pp. A1361–A1377, May 2017.

[24] P. Lyu, Y. Huo, Z. Qu, and Z. Rao, "Investigation on the thermal behavior of Ni-rich NMC lithium ion battery for energy storage," Appl. Therm. Eng., vol. 166, no. November 2019, p. 114749, 2020.

[25] H. Gupta et al., "Improved High Voltage Performance of Li-ion Conducting Coated Ni-rich NMC Cathode Materials for Rechargeable Li Battery," ACS Appl. Energy Mater., vol. 4, no. 12, pp. 13878–13889, Dec. 2021.

[26] K. H. Choi, X. Liu, X. Ding, and Q. Li, "Design strategies for development of nickel-rich ternary lithium-ion battery," Ionics (Kiel)., vol. 26, pp. 1063–1080, 2020.

[27] J. W. Choi and D. Aurbach, "Promise and reality of post-lithium-ion batteries with high energy densities," Nat. Rev. Mater., vol. 1, no. 4, p. 16013, Mar. 2016.

[28] M.-K. Tran, A. DaCosta, A. Mevawalla, S. Panchal, and M. Fowler, "Comparative Study of Equivalent Circuit Models Performance in Four Common Lithium-Ion Batteries: LFP, NMC, LMO, NCA," Batteries, vol. 7, no. 3, p. 51, Jul. 2021.

[29] T. Kim, W. Song, D.-Y. Son, L. K. Ono, and Y. Qi, "Lithium-ion batteries: outlook on present, future, and hybridized technologies," J. Mater. Chem. A, vol. 7, no. 7, pp. 2942–2964, 2019.

[30] H. Tian, P. Qin, K. Li, and Z. Zhao, "A review of the state of health for lithium-ion batteries: Research status and suggestions," J. Clean. Prod., vol. 261, p. 120813, Jul. 2020.

[31] Y. Chen et al., "A review of lithium-ion battery safety concerns: The issues, strategies, and testing standards," J. Energy Chem., vol. 59, pp. 83–99, Aug. 2021.

[32] T. Waldmann, B.-I. Hogg, and M. Wohlfahrt-Mehrens, "Li plating as unwanted side reaction in commercial Li-ion cells – A review," J. Power Sources, vol. 384, pp. 107–124, Apr. 2018.

[33] M. Armand et al., "Lithium-ion batteries – Current state of the art and anticipated developments," J. Power Sources, vol. 479, p. 228708, Dec. 2020.

[34] J. Schnell et al., "All-solid-state lithium-ion and lithium metal batteries – paving the way to large-scale production," J. Power Sources, vol. 382, pp. 160–175, Apr. 2018.

[35] Y. Li et al., "A quick on-line state of health estimation method for Li-ion battery with incremental capacity

curves processed by Gaussian filter," J. Power Sources, vol. 373, pp. 40–53, Jan. 2018.

[36] J. E. Harlow et al., "A Wide Range of Testing Results on an Excellent Lithium-Ion Cell Chemistry to be used as Benchmarks for New Battery Technologies," J. Electrochem. Soc., vol. 166, no. 13, pp. A3031–A3044, Sep. 2019.

[37] N. Meddings et al., "Application of electrochemical impedance spectroscopy to commercial Li-ion cells: A review," J. Power Sources, vol. 480, p. 228742, Dec. 2020.

[38] B. Makuza, Q. Tian, X. Guo, K. Chattopadhyay, and D. Yu, "Pyrometallurgical options for recycling spent lithium-ion batteries: A comprehensive review," J. Power Sources, vol. 491, p. 229622, Apr. 2021.

[39] N. Huang, Y. Wu, and R.-F. Chao, "Visualization and Bibliometric Analysis of Research Trends on Hyperbaric Oxygen Therapy," Int. J. Environ. Res. Public Health, vol. 19, no. 13, p. 7866, Jun. 2022.

[40] I. Hamidah, S. Sriyono, and M. N. Hudha, "A Bibliometric Analysis of Covid-19 Research using VOSviewer," Indones. J. Sci. Technol., vol. 5, no. 2, pp. 209–216, Sep. 2020.

[41] X. Zhang, L. Song, and M. Huang, "The state-of-the-art of green building research (2010-2019): A bibliometric review," IOP Conf. Ser. Earth Environ. Sci., vol. 376, no. 1, 2019.

[42] J. A. Cano, A. Londoño-Pineda, M. F. Castro, H. B. Paz, C. Rodas, and T. Arias, "A Bibliometric Analysis and Systematic Review on E-Marketplaces, Open Innovation, and Sustainability," Sustain., vol. 14, no. 9, 2022.

[43] Y.-M. Guo, Z. Huang, J. Guo, H. Li, X. Guo, and M. J. Nkeli, "Bibliometric Analysis on Smart Cities Research," Sustainability, vol. 11, no. 13, p. 3606, Jun. 2019.

[44] X. Mao, L. Guo, P. Fu, and C. Xiang, "The status and trends of coronavirus research," Medicine (Baltimore)., vol. 99, no. 22, p. e20137, May 2020.