Bibliometric Analysis of Biochar's Use in Surface Water Treatment

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Received: *18 August 2023;* ***Accepted:*** *30 August 2023;* ***Published:*** *1 December 2023*

Abstract: The utilization of biochar holds promise as a viable method for the preservation of water resources and the remediation of wastewater. The objective of this study is to evaluate the advancements achieved in the field of biochar research pertaining to the remediation of surface water. The review was conducted by systematically collecting data from Scopus and doing bibliometric analysis. This study utilized the Scopus database to retrieve data pertaining to countries, institutions, highly cited articles, keywords, emerging subjects, and prospective research directions. Furthermore, the VOSviewer bibliometric software was utilized to assess the scholarly citations in this research paper. The results indicate that significant advancements have been achieved in this area of study during the year 2015. A total of 48 works has been indexed by Scopus, a renowned academic database, across 28 distinct international journals. A significant proportion of researchers primarily operate within the United States, often engaging in collaborative efforts with their counterparts from China. This article attempts to study the bibliography on the biochar for surface water treatment, identify popular topics, and discern the fields of future studies in this discussion. Furthermore, it investigates future research in the field of biochar will primarily concentrate on optimizing the synthesis of biochar and exploring its potential use in the treatment of heavy metals and organic chemicals.

Keywords: Bibliometric, Biochar; Surface water treatment

1. Introduction

Surface water serves as a primary water supply for human sustenance (Prayogo et al., 2023). Like the hydrological systems seen in rivers, lakes, and wetlands, water is sourced from these natural bodies. The quality of surface water worldwide is diminishing because of pollution stemming from anthropogenic activity (Mulyana et al., 2023). The primary contributors to environmental pollution arise from agricultural practices involving the utilization of pesticides, animal husbandry practices that involve the administration of antibiotics to livestock, and the discharge of chemicals originating from pharmaceutical or other industrial activities. According to Mateo-Sagasta, Zadeh, and Turral (2017), agriculture emerges as the primary source of pollutants in rivers across several regions, including the United States, China, and developing countries such as Indonesia. The existence of chemical compounds inside surface water poses a significant threat to the survival and well-being of aquatic organisms. Even at low doses, it has the potential to disrupt metabolic processes. The presence of contaminant chemicals in water is influenced by various factors, including land utilization, pesticide application practices, meteorological conditions, soil composition, terrain, and characteristics of water pathways (Moschet et al., 2014; Schuwirth, 2020).

The resolution of this issue necessitates the implementation of effective surface water treatment methods. The technology should possess qualities of effectiveness, cost-efficiency, and user-friendliness. It is imperative to implement measures aimed at mitigating the ingress of contaminants into aquatic ecosystems, as well as safeguarding the community against the utilization of contaminated water resources. One potential technological solution that aligns with the criterion is the implementation of a filtration process utilizing biochar. The utilization of biochar holds promise as a viable technological solution for the conservation of water resources and the treatment of wastewater. Biochar exhibits considerable potential as an alternative adsorbent due to its ability to be derived from widely accessible biomass waste sources. According to Bentley and Summers (2020), biochar possesses the ability to retain material properties and perform adsorption in a manner akin to activated carbon, albeit at a reduced expense and energy demand.

Multiple studies have demonstrated the efficacy of biochar as a sorbent for various pollutants. For instance, Mohan et al. (2011) found that biochar effectively adsorbs chromium metal. Furthermore, biochar has been shown to significantly reduce the concentration of total suspended solids (TSS) by 86%, nitrate by 86%, phosphorus by 47%, heavy metals by 18-24%, and polycyclic aromatic hydrocarbons by 68% (Reddy, Xie, & Dastgheibi, 2014). According to Belmonte, Benjamin, and Tan (2017), the application of biochar in agricultural settings has the potential to enhance the water absorption capacity of the land and reduce the influx of pesticides into water bodies. In their study, Fang et al. (2020) elucidates the impact of pyrolysis on the physicochemical characteristics of biochar when exposed to aqueous environments. In their study, You et al. (2020) sought to enhance the adsorption capacity of biochar through the incorporation of nanocomposites.

The objective of this work is to conduct a comprehensive evaluation of the progress made in biochar research pertaining to the treatment of surface water. The review was undertaken by systematically gathering data in the form of global scientific articles that were indexed by Scopus. Subsequently, employ the bibliometric approach and conduct a comprehensive literature study for analysis. Bibliometric analysis is employed as a means of examining the progression of a research subject, verifying the originality of a study, and offering direction for future research endeavors. The utilization of this tool can serve to elucidate prevailing patterns in research, identify prominent research institutions, and delineate the parameters of research subjects. Furthermore, it is possible to ascertain the countries, institutions, and authors that have exerted effect on the advancement of biochar in the domain of surface water treatment.

2. Methodology

The bibliometric data utilized in this study were acquired from the Scopus database. The selection of Scopus as the preferred database was based on its comprehensive coverage of scientific article publications. Moreover, the publication quality of the entity is commendable due to its meticulous examination procedure (Baas, Schotten, Plume, Cote, & Karimi, 2020). The data for this study was obtained from Scopus, which was accessed on October 9, 2020. A comprehensive search was conducted to identify publications pertaining to the utilization of biochar for the purpose of managing surface water quality. Biochar possesses a highly porous structure characterized by a substantial surface area, rendering it a highly effective adsorbent material. The substance could adsorb a wide range of contaminants present in surface water, such as heavy metals, organic pollutants, and some microorganisms. This characteristic renders biochar an asset in the realm of water purification. The primary terms employed in this study are "biochar" or "biochars" in conjunction with "surface water." The search results are restricted to scientific publications, reviews, and scientific conference articles. The publications that have been chosen for inclusion are limited to those written in the English language, whereas publications written in Chinese have been omitted from the selection. A total of 77 documents were obtained because of the search using the specified keywords. Subsequently, a total of 48 papers were chosen for comprehensive analysis and further examination, following a meticulous process of filtering based on their titles and abstracts. The data comprising the author's name, author affiliation, subject category, journal name, publication title, year of publication, and number of citations from the 48 articles were obtained using the Scopus website. Additional research was conducted using Microsoft Office Excel to examine variables such as the year of publishing, number of citations, journal of publication, journal category, nation, and author institution. The Scimago website provides access to the SJR value of published journals. The mapping process is conducted with the open VOSviewer tool, accessible at www.vosviewer.com. The map illustrates the interconnections among the author's chosen keywords, the respective countries, the affiliated institutions, and the author affiliations.

3. Result and Discussion

3.1 The most-referenced articles and the most active journals

The publication of articles pertaining to the topic of biochar and its impact on surface water experienced a significant increase in 2011. Figure 1 illustrates the upward trend in publishing rates from the year 2011 to 2020. The objective of this study is to assess the progress made in the field of biochar for surface water treatment over a decade, with the intention of providing a comprehensive overview of the advancements in biochar materials. A total of 48 publications have been published, resulting in 1,291 citations. The journal papers that have received the highest number of citations are those that were published in the year 2011. The author presents a comprehensive analysis of the utilization of biochar as a water absorbent, focusing on its modeling and evaluation. There was a significant surge in the number of scholarly publications in 2019 that focused on the utilization of biochar for the purpose of purifying surface water. Subsequently, there was a further upward trend observed in the year 2020. The level of interest among researchers in biochar is steadily growing. Nevertheless, there is a tendency for the number of individuals who engage in quoting to decrease. According to Mohan et al. (2011), the year with the greatest number of citations is 2011, as of the time of writing. The potential reason for this phenomenon may be attributed to the temporal aspect of the publishing and the extensive scope of the research discourse.

The articles that were chosen for analysis were published in a total of 28 international journals that are indexed by Scopus. Out of the total of 28 journals that have been published, a careful selection was made to identify the top 5 journals that hold significant influence within the academic community, as evidenced by their high citation counts. Table 1 displays a compilation of the journal publishers that have exerted the most significant influence. All journals that hold significant influence in the academic publishing industry are those that possess a quartile value of Q1, indicating their inclusion within the top 25% of journals. The magazine of Hazardous Materials (JHM), originating from the Netherlands, is widely regarded as one of the most prestigious academic publications. It has published a total of three articles specifically addressing the topic of biochar in surface water treatment. Additionally, the magazine has an impressive roster of 372 publishers. The initial publication of this journal occurred in 1975, focusing on the examination and management of items that pose a risk to health and the environment. The Journal of Health Management (JHM) possesses a SCImago Journal Rank (SJR) rating of 1.96. The SJR is a bibliometric metric utilized to assess the impact of scientific journals. The calculation of the SJR value is derived from extensive bibliographic data, as outlined by González-Pereira, Guerrero-Bote, and Moya-Anegón (2010). The five periodicals encompass a range of subject matter pertaining to the environment, each falling into distinct categories.

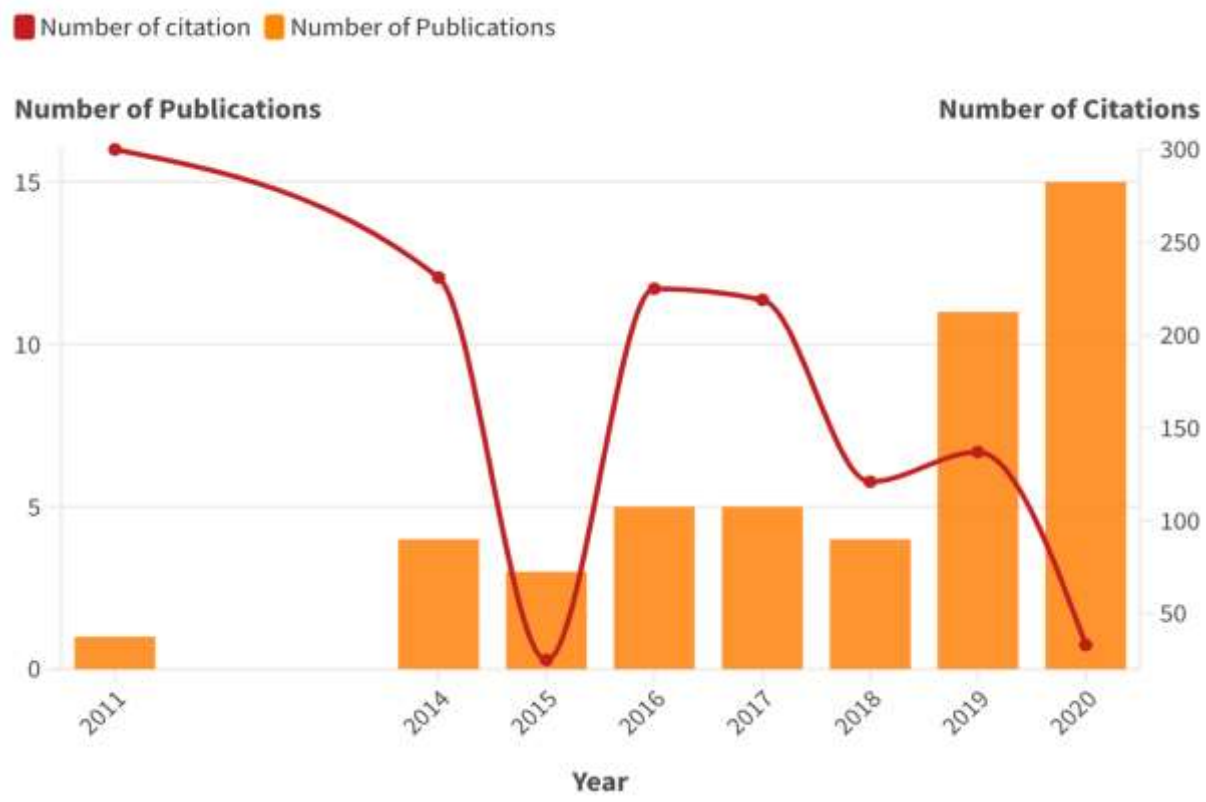

Figure 1. Development of biochar journal publication in wastewater management

Table 1. Journal of publication of articles on biochar in surface water treatment

No.	Publication Journal	Number of articles	Citation numbers	Country	Category	Journal Position
1	Journal of Hazardous Materials	3	372	Netherlands	Environmental Chemistry; Environmental Engineering; Health,	Q1, SJR 1.96

					Toxicology and Mutagenesis	
2	Science of the Total Environment	5	164	Netherlands	Environmental Chemistry; Environmental Engineering; Pollution; Waste Management and Disposal	Q1, SJR 1.54
3	Environmental Science and Technology	3	148	America	Anthropogenic Impacts; Biogeochemical Cycling; Contaminants in Aquatic and Terrestrial Environments; Ecotoxicology and Public Health	Q1, SJR 2.7
4	Water Research	2	139	Netherlands	Ecological Modeling; Pollution; Waste Management and Disposal; Water Science and Technology	Q1, SJR 2.72
5	Bioresource Technology	2	97	Netherlands	Chemical Engineering; Energy; Environmental Science; Medicine	Q1, SJR 2.43

3.2 Countries, institutions and writers who are active in writing biochar articles in surface water treatment

The selected articles include contributions from researchers hailing from 17 different nations. The three countries that exert the greatest influence are the United States of America, the People's Republic of China, and the Commonwealth of Australia. The United States of America has contributed to the academic discourse by publishing a total of 23 articles, which have garnered a substantial number of citations, amounting to 811 quotes. Similarly, China has made its mark with 17 published articles, resulting in 419 quotes. Australia, on the other hand, has a more modest publication record, with only 3 publications, but these have been referenced by 77 other scholarly works. Not only researchers from industrialized nations, but also those from emerging countries such as Bangladesh, Pakistan, Vietnam, and Thailand are actively engaged in conducting study on this subject matter. Figure 2 illustrates the intercountry collaboration and partnership among scholars. Researchers from the United States have engaged in collaborative efforts with counterparts from China, India, Canada, Switzerland, and Australia. Academic researchers from China are engaged in active collaborations with counterparts from other countries, including the United States, Canada, Bangladesh, Turkey, Pakistan, Australia, and Vietnam. The most robust collaborative partnership is observed between scholars from the United States and China. Furthermore, there exist scholars from other nations who lack interconnections, specifically Brazil, Lithuania, Thailand, Sweden, and New Zealand.

Subsequently, an examination of the affiliations of the researchers and the identities of these researchers will be conducted. Based on bibliometric research conducted using VOS Viewer, it has been determined that there are a total of 114 institutions of origin. There exist four prominent academic institutions, specifically Hunan University, Mississippi State University (representing the departments of chemistry, forestry, and environmental science), Re-inventing the Nation's Urban Water Infrastructure (Renuwit), and Jawaharlal Nehru University. The visualization is depicted in Figure 3. A total of 219 researchers have been identified from a sample of 48 selected journals. Figure 4 depicts the visual representation of the interconnections among 219 researchers. The quantification of citations often serves as a

defining characteristic for scholars who have had a significant impact in their respective fields. Summer RS emerged as the most prolific researcher in terms of published articles, having authored a total of six scholarly works. Furthermore, these articles garnered significant attention within the academic community, as evidenced by their citation count of 105. Summers RS is affiliated with the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado in the United States. The article on biochar for clean water management highlights the significant contributions made by notable researchers, namely Mohan D., Rajput S., Singh VK, Steele PH, Pittman CU, affiliated with Mississippi State University and Jawaharlal Nehru University.

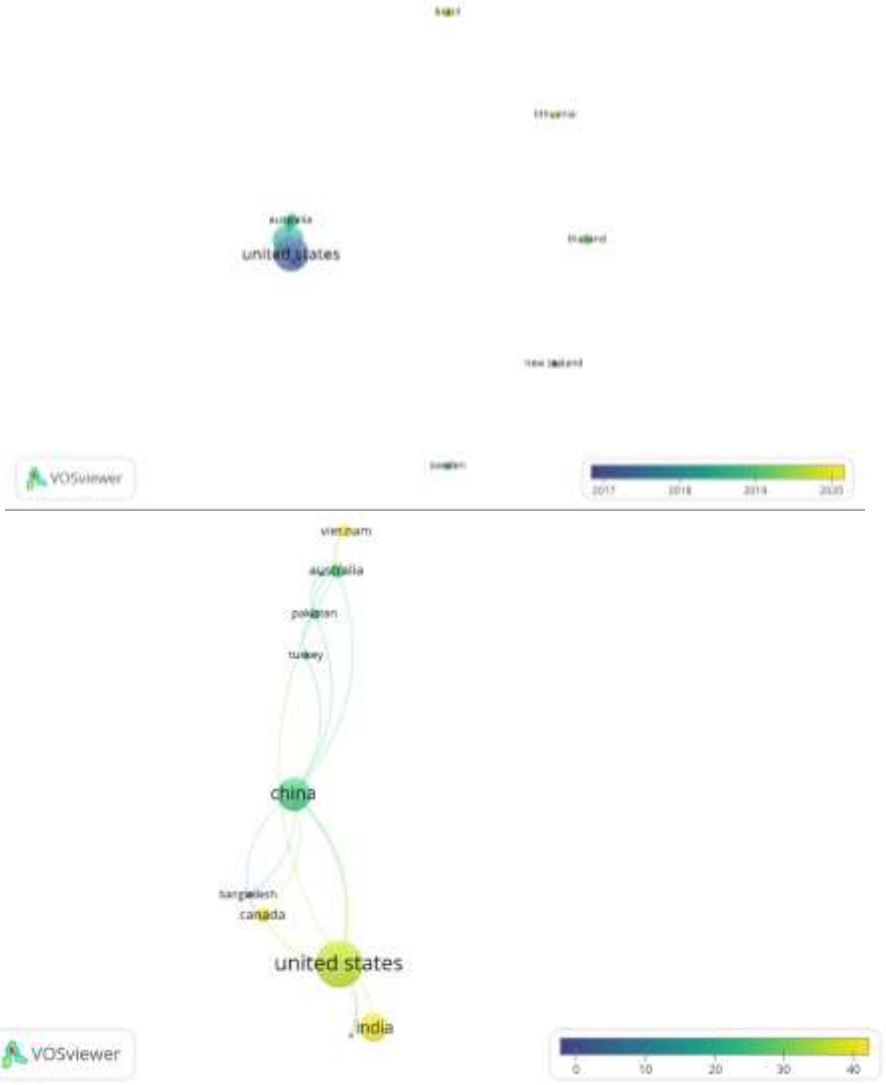

Figure 2. Visualization of researchers' relationships between countries in biochar research for surface water treatment. Note: circle size indicates a heavily cited article, while line thickness and color refer to link strength and grouping

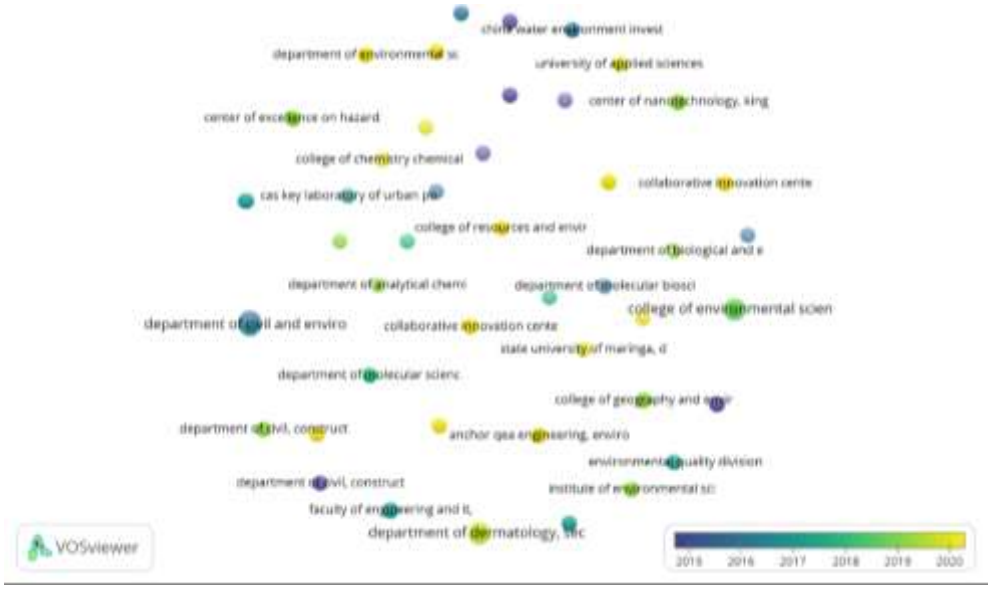

Figure 3. Visualization of researchers' relationships between institutions in biochar research for surface water treatment. Note: the circle size indicates a heavily cited article, while the line thickness and color refer to link strength and grouping

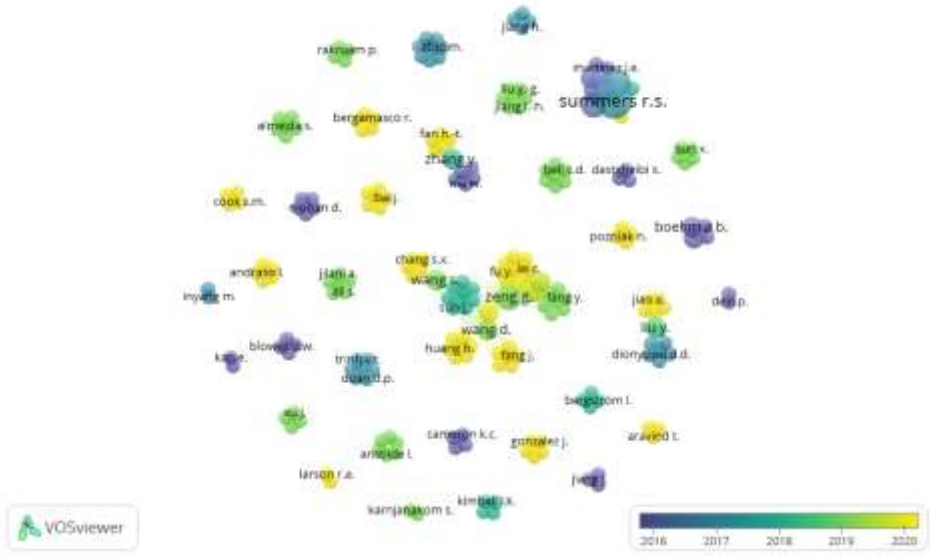

Figure 4. Visualization of collaboration between researchers in biochar research for surface water treatment. Note: circle size indicates a heavily cited article, while line thickness and color refer to link strength and grouping

3.3 Examining research focus and future trends

The selected terms in the paper serve as representative indicators of the scientific research domain. Online repositories such as Scopus and Google Scholar can assist readers from academia and researchers in locating relevant information through the utilization of keywords. The advancement of research in a specific subject will be ascertained. The ability to forecast the configuration and patterns of forthcoming scientific information can assist researchers in making informed decisions regarding the allocation of their resources, including time and financial investments (Behrouzi et al., 2020).

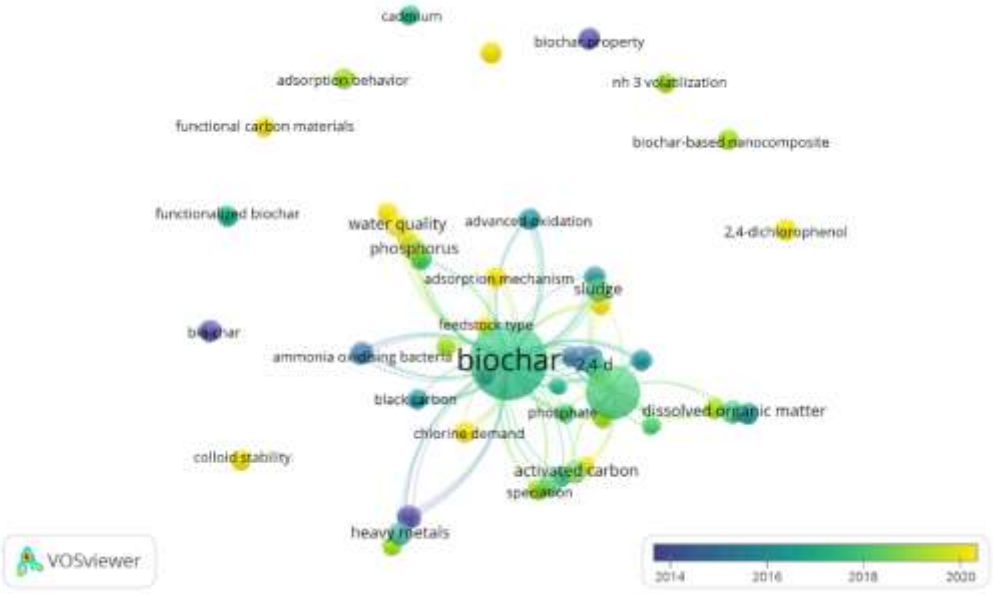

Figure 5. Visualization of the author's keyword relationships in biochar research for surface water treatment. Note: the size of the circles indicates the most widely used words, while the thickness of the lines and colors refer to the strength of the links and groupings

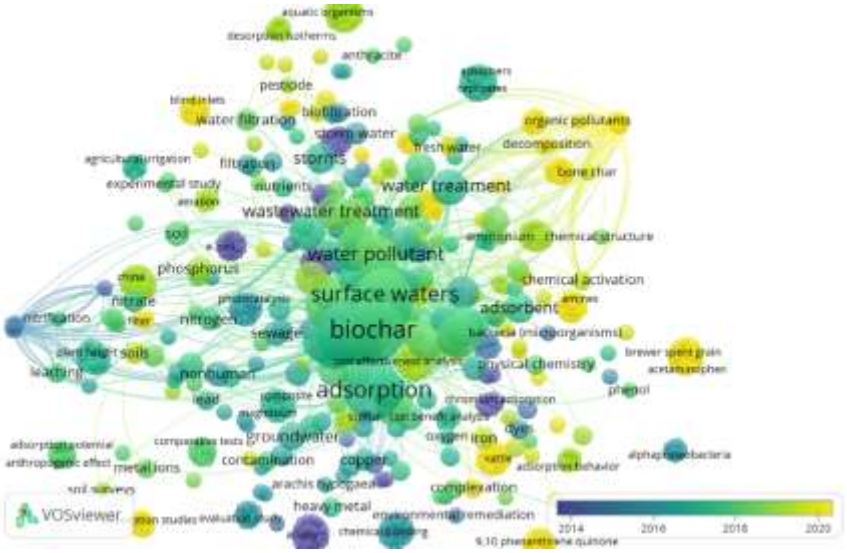

Figure 6. Visualization of index keyword relationships in biochar research for surface water treatment. Note: the size of the circles indicates the most widely used words, while the thickness of the lines and the colors refer to the strength of links and groupings

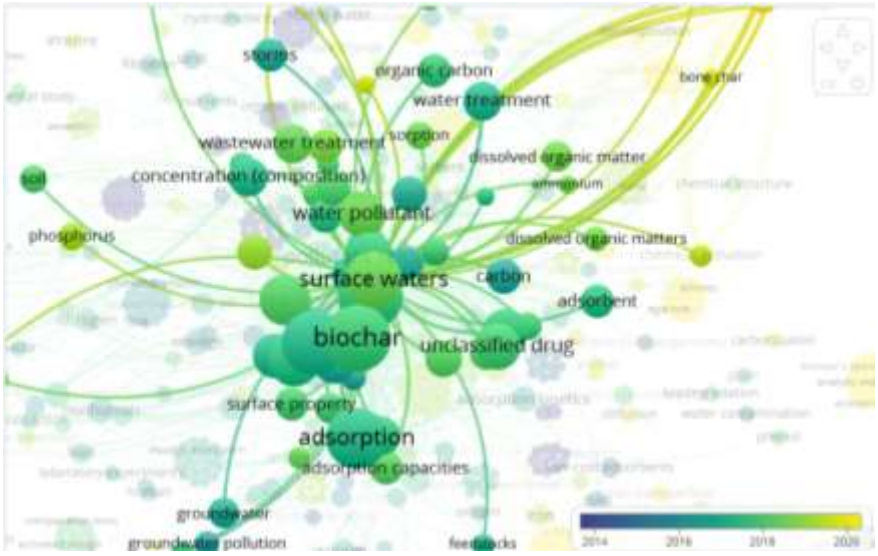

Figure 7. Specific exploration of the biochar keyword

In the realm of scientific paper composition, two distinct categories of keywords are employed to enhance the effectiveness of article retrieval: author keywords and index keywords. The determination of author keywords is the responsibility of the author, but the determination of index terms is a collaborative effort between the author and the journal publisher. The use of bibliometric analysis yielded a discovery of 164 keywords provided by the author, along with an additional 962 index keywords. The five most often occurring keywords among writers are biochar (22), adsorption (11), charcoal (2), 2,4-d (2), and heavy metals (2). The five often encountered index terms include biochar, charcoal, adsorption, surface waters, and pollutant removal. The author will categorize their keywords into three main areas: the physical and chemical features of biochar, the mechanism of adsorption, and the substances that are adsorbed, specifically heavy metals, organic compounds, and microorganisms (Reddy, Xie, & Dastgheibi, 2014; Mohan et al., 2011; Marčiulaitienė et al., 2020). Furthermore, there exist many substances, including phosphorus (Penn et al., 2020), 2,4-dichlorophenol (Kearns, Knappe, & Summers, 2015), antibiotics (Zeng et al., 2019), ammonium (Hassanpour et al., 2019), and aromatic hydrocarbons (Reddy, Xie, & Dastgheibi, 2014). The present study focuses on the immobilization of microorganisms often present in surface water, as discussed by Que et al. (2019).

The term "biochar" exhibits the highest frequency of occurrence and is strongly associated with the phrase "adsorption" (1,9). The robustness of the network demonstrates the strong correlation between biochar and the keywords. The investigation of heavy metal adsorption emerged as the primary focus in scholarly literature beginning in 2014, afterwards evolving to encompass the absorption of organic molecules. By categorizing the author's keywords into three distinct stages, the evolution of study work becomes discernible. The initial stage spanning from 2011 to 2015 marks the commencement of investigations pertaining to biochar in surface water. The utilized terms encompass biochar, cost-effective adsorbent, heavy metals, and water treatment. During the subsequent phase spanning from 2015 to 2018, the following terms were identified: adsorption, pyrolysis, advanced oxidation, ammonium, microbiological, and 2,4-d. The subsequent stage demonstrates the progression of research in the direction of optimizing biochar and its application for the adsorption of organic and microbiological components. In the period of 2018-2020, there was a noticeable emergence of terms related to organic contaminants, including antimony, acetaminophen, and arsenic, in the context of sustainable applications. Based on the present analysis, it can be asserted that the field of biochar research in surface water treatment is advancing to enhance

the removal of organic compounds, including pharmaceutical and domestic substances. The primary contributor to surface water contamination is predominantly organic chemicals originating from agricultural activities. Research on biochar in surface water treatment focuses on the utilization of this material for the removal of organic contaminants. According to Utami et al. (2020).

4. Conclusions

A bibliometric analysis was conducted to investigate the body of research pertaining to the utilization of biochar in surface water treatment, focusing on publications from the period spanning 2011 to 2020. This study evaluates biochar materials for surface water treatment over a decade to provide a thorough perspective. The findings indicate that this study has undergone advancements since 2015. A total of 48 papers have been disseminated throughout 28 international journals that are indexed by Scopus. Most researchers originate from the United States and frequently engage in collaborative efforts with scholars from China. Subsequently, several additional nations, including India, Canada, Switzerland, Australia, Turkey, Pakistan, and Vietnam, proceeded in a similar manner. Biochar research in surface water treatment primarily focuses on two primary areas: the utilization of biochar for the remediation of heavy metals and organic compounds, as well as the enhancement of biochar manufacturing processes. The exploration of these two subjects has the potential to shape the trajectory of future biochar investigations. The efficacy of biochar as an adsorbent is attributed to its porous structure and substantial surface area. The material has the capacity to adsorb heavy metals, organic contaminants, and microbes from surface water. Biochar has been found to be advantageous in the context of water treatment. This study is expected to assist researchers in tracking the progress and research trends on the use of biochar for water quality improvement and to discover more information about potential future studies. This can help researchers not only identify topic.

Acknowledgements

We are thankful to our dedicated colleagues and research assistants who worked tirelessly during the data collection and analysis phases of this project. Their commitment and expertise greatly enriched the quality of our research. This research is funded by Universitas Tanjungpura.

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