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Review Article

Trends of Filtration and Adsorption Technology Using Biomaterials from Agricultural Wastes: A Bibliometric Analysis

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ABSTRACT

This study aims to bibliometrically review the trends of literature related to agricultural wastes in the filtration and adsorption technology, published from 2016 to 2020 while providing future research directions. It includes removing suspended solids, chemical contaminants, and toxic gases from water, wastewater, and other industrial applications. A total of 206 published documents from the Scopus database, authored by 160 scholars across 63 countries, have been analyzed using Harzing's POP (for analyzing the citations) and VOSviewer (for constructing and visualizing bibliometric networks) program. The findings show that countries from Asia, mainly China, India, and Malaysia, dominate the publication in this field, with the Desalination and Water Treatment topping the journal list, followed by the Journal of Environmental Chemical Engineering and Science of the Total Environment. In terms of co-occurrence, the top author keywords are "agricultural wastes," "water and wastewater treatment," and "adsorption." In addition, five research streams were identified, namely "biomass characterization and optimization," "adsorbent for water and wastewater quality improvement," "filtration by activated carbon," "heat treatment for biochar," and "bio-adsorbents kinetics, isotherms and thermodynamic." Finally, the authors suggest potential research directions on filtration modeling for optimization, utilizing agricultural-based media for water and wastewater treatment.

Keywords: Agricultural wastes, bibliometric analysis, biomaterials, purification, trends

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INTRODUCTION

Agricultural activity is one of the critical sectors with a multi-level impact on the socio-economic and environmental ecosystems. Moreover, this sector increased considerably in the past decades due to the rise in population, which affects demand and consumption habits. Therefore, it is to be expected that the agricultural sector will have continuous growth, remarkably, when the demand for food and raw material production increases, thus strengthening trade relations between countries (Grace et al., 2016).

The massive by-products from the agricultural sector may lead to global consequences when not appropriately managed and become a nuisance to the surroundings. However, with the current advancement in research and design (R&D), it has been demonstrated that agricultural wastes are potential renewable sources, inexpensive, readily available, environmental-friendly, and have become one of the income sources for the agricultural sector (Yahya et al., 2018). Nonetheless, it would be a wastage should these biomaterials not be fully utilized. Furthermore, they consist of characteristics that may be useful in various applications, such as water and wastewater treatment (Bolong et al., 2016), bioenergy production (Suzuki et al., 2017), biopolymer reinforcement (Alsubari et al., 2018), and food technology (Bhardwaj et al., 2019). Since then, the study related to agricultural wastes has been receiving greater attention.

Bibliometric analysis is a scientific study that can determine the recorded discourse quantitatively. It also can effectively describe the features and trends for a specific discipline. Table 1 shows the previous articles on bibliometric analysis in a similar field. The number

Table 1
Previous bibliometric analysis article on agricultural wastes

Domain	TDE	Source	BAE	By
agricultural waste, straw, livestock and poultry manure, energy, biogas, and fuel	4,062	CNKI (China National Knowledge Infrastructure)	• Literature quantity • Top institutions, journals, authors, & keywords • Research streams	J. Wei et al. (2020)
agricultur*waste, agricultur*residue, crop*residue*	3,148	Scopus	• Document & authorship • Co-citation of documents & authors • Co-occurrence of keywords & terms • Impact factor of journals • Networking maps of main authors, institutions & countries	Duque-Acevedo et al. (2020)
pineapple*, waste*, residue*, bagasse*, skin*, crown*, peel* core*	364	Scopus	• Publication trends • Subject areas • Top journals, countries & collaborations, authors, institutions & keywords with mapping • Research themes • Citation analysis	Lima et al. (2018)

Notes. TDE=total documents examined; BAE=bibliometric attributes examined.

of documents extracted from the database will largely depend on the used domain, and the scope area desired to be studied. Thus, it is essential to have a searching strategy for bibliometric analysis.

The bibliometrics of this scope of the study has not been systematically analyzed. Hence, this study aims to determine and analyze bibliometrically the agricultural literature, which focuses on removing suspended solids, chemical contaminants, and toxic gases from water, wastewater, and other industrial applications for filtration purposes. The goal is to: 1) Identify the literature characteristics, including the number of articles, research subject, and journals; 2) Determine the top powerhouse of this research area, such as countries and authors; 3) Classify the significant research streams and trends over time; and 4) Point out potential opportunities for future research. The analysis includes the current publication trends between 2016–2020, including the popular themes, top authors, and influential articles among scholars. Also, to show the development and future research directions related to the utilization of agricultural wastes in water purification.

MATERIALS AND METHODOLOGY

The methodology in this study was divided into three sub-sections: searching strategy from database resources, search strings, screening, and data abstraction analysis, with the primary focus on applying agricultural wastes in the filtration and adsorption technology. The research questions (RQs) were:

RQ1: What are the document, source type, and research subject area?
RQ2: What are the citation patterns of publication on agricultural wastes and purification technology?
RQ3: What are the significant research streams and trends over time?
RQ4: What are the potential opportunities for future research?

Searching Strategy from Database Resources

A systematic search strategy from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), modified from Ali et al. (2021), was used to assess the collected data to produce quality and significant analysis. Published PRISMA guidelines allow the authors to use appropriate search strings with objective screening before examining the abstracted literature data. It is worth mentioning that there are no perfect databases available at present as they may have classification schemes and full coverage limitations (Pranckutė, 2021). Using more than a single database may offer better data collection, but due to constraints, this study used only one primary database, namely Scopus, which covers varying environment fields. Nonetheless, systematic reporting from recognized sources such as Scopus, or others, would benefit scholars as they contain massive databases of quality research literature. Furthermore, Scopus enables the export

of the list of articles in both CSV and RIS format, which aids in sorting data, albeit there is a limit of 2,000 documents per transfer for exporting the documents.

Search Strings and Screening

The topic and research questions (RQs) need to be narrowed before developing the search strings. Once done, relevant keywords for the search strings were identified based on the selected research area. The preliminary searching efforts include five keywords of "agriculture wastes," "filtration," "adsorption," "purification," and "treatment." Table 2 shows the search strings with the Boolean and Truncation Operator used. A total of 493 documents were retrieved on 6th August 2021.

Table 2
The search strings with Boolean and Truncation Operator

Database Source	Scopus
Search Strings	TITLE (agr*-waste* AND filt* OR adsor* OR purif* OR treat*)

Usually, should the methodology involve more than one database, duplicate articles between the databases need to be removed. Surprisingly, one duplicate was found from the same database when data was imported, sharing a similar author name with a different ID but with different/additional publications. Thus, it was combined instead of excluded (later using Harzing's POP for analysis). Then another 284 documents were removed (total n=285), according to the inclusion and exclusion criteria. The first criteria is the period year where only published literature between 2016 to 2020 was selected. Next is the publication stage, where only those documents in the final form were considered. In contrast, documents known as Articles in Press, accepted to be published but unassigned to any publication's volume/issue, were excluded. Usually, these documents are in the stage of pre-proofs, uncorrected proofs, corrected proofs, and withdrawal of articles. As for the type of source, all were included. These comprise the review paper, conference proceedings, book, book series, trade journal, and others. Lastly, English was selected, excluding other languages from the selected articles. Table 3 summarizes the criteria used in this study.

After that, the exported data of the remaining documents were screened thoroughly to ensure that the selected articles were reliable as primary data. Two non-related documents

Table 3
The inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Period Year	2016-2020	<2016; 2021
Publication Stage	Final	Article in Press
Source Type	All	None
Language	English	Others

were excluded due to erratum (n=2). Hence, a final of 206 documents remains to be analyzed in the next stage. Figure 1 shows the overall systematic searching processes in this study.

Data Abstraction Analysis

Identifying major research streams was done by compiling and scrutinizing information where authors analyzed all the 206 documents to abstract data that fulfill the RQs' needs. First, the citations analysis was done using Harzing's POP, and the VOSviewer was used to map the bibliometric networks. Then, the directive groups were created according to the data connections and presented as tables and figures.

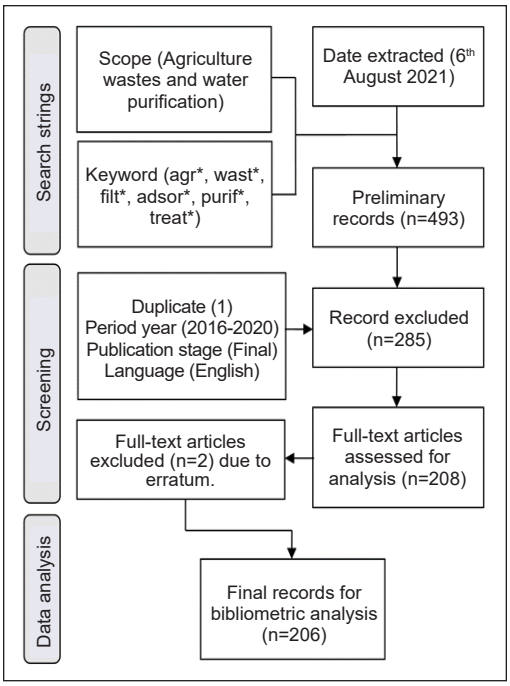

Figure 1. Overall systematic searching processes

RESULTS AND DISCUSSION

This section elaborates the literature characteristics, top contributors, research streams, and future directions. These aspects were analyzed: document types, source types, subject area, citation metrics, yearly publication by country and institution, source title, top articles, and productive authors. Findings are presented as frequency and percentage, and some are extended to the number of cited publications (NCP), total citations (TC), average citations per publication (C/P), average citations per cited publication (C/CP), h-index, and g-index.

Literature Characteristics

RQ1: What are the document, source type, and research subject area?

Document and Source Type. The current state of the publication related to agricultural wastes and purification technology is presented. Table 4 summarizes the four documents obtained from the Scopus database on 6th August 2021. They are articles, conference papers, reviews, and book chapters. Most of the publications are in the form of an article (80.58%), followed by a conference paper (11.65%), a review (6.31%), and a book chapter (1.46%). Book chapters may have a high acceptance rate for publication but are less prestigious and less rigorous in review (Woodrow, 2014). Vice versa, review papers usually include quantitative, narrative, and qualitative components. Commonly the review papers are

disproportionate to other research articles as it takes a considerable effort to prepare them (Suter, 2013), albeit these reviews tend to be highly cited (Palmatier et al., 2018). The ratio of citations per paper (C/P) can be seen from Table 4.

Table 4
Document type from Scopus database

Document Type	TP	(%)	TC	C/P
Article	166	80.58%	2064	12.43
Conference Paper	24	11.65%	48	2
Review	13	6.31%	380	29.23
Book Chapter	3	1.46%	10	3.33
Total	206	100.00		

Notes. TP=total publications; TC=total citations; and C/P=citations per paper

The source type refers to the documents based on the category of source title. For instance, a review paper document can be published in conferences and journals. Table 5 shows the summary of four source types obtained. As expected, the journals are the highest source type (87.86%), followed by conference proceedings (9.71%). Book and book series contribute with 1.46% and 0.97%, respectively. These results suggest that most authors prefer preparing article forms for publications in selected journals when reporting their scholarly works. Factors such as comprehensiveness, citations, publication speed (González-Albo & Bordons, 2011), publication frequency, citation impact, and subject fields (Zhang & Glänzel, 2012) may have a role.

Table 5
Source type during 2016-2020

Source Type	TP	Percentage (%)
Journal	181	87.86%
Conference Proceeding	20	9.71%
Book	3	1.46%
Book Series	2	0.97%
Total	206	100.00

Notes. TP=total publications

Subject Areas. The subject areas for most of the publications are currently under environmental science (24.9%), followed by chemical engineering (13.2%), engineering (11.1%), and chemistry (10.2%). This evidence shows how popular this subject is in those fields. The increase in studies related to agricultural wastes and purification technology would involve experimental methods and theories, which explains their dominance in science and engineering subject research. The summary of the subject areas is shown in Table 6. As for others, studies such as cost analysis and economic feasibility (Sharma & Ayub, 2019) is included, all of which are less than 1.6%. Thus, it indicates a multidisciplinary interest in the water applications subject of concern.

Table 6
Subject area in agricultural wastes and purification technology

Subject Area	TP	Percentage (%)
Environmental Science	110	24.9%
Chemical Engineering	58	13.2%
Engineering	49	11.1%
Chemistry	45	10.2%
Materials Science	27	6.1%
Agricultural and Biological Sciences	26	5.9%
Biochemistry, Genetics, and Molecular Biology	25	5.7%
Energy	24	5.4%
Physics and Astronomy	22	5.0%
Earth and Planetary Sciences	12	2.7%
Others	43	9.8% (≤1.6%)

Notes. TP=total publications

Top Contributors

RQ2: What are the citation patterns of publication on agricultural wastes and purification technology?

Citation Metrics. The citation metrics are presented in Table 7. For the retrieved 206 documents, there is an average of 498.4 citations per year from 2,492 citations reported within the recent five-year period. However, out of the 206 documents, only 172 were cited when this data was analyzed. Whereas the remaining 34 have yet to be cited. With an average of 12.1 citations per paper, this would be a benchmark indicator, particularly for new researchers interested in majoring in this study field. Other bibliometric studies in a similar field of wastewater and activated sludge have reported average citations per paper in the range of 9.13-35.81 (Zyoud et al., 2016; Durán-Sánchez et al., 2020; Ahnert & Krebs, 2021).

Table 7
Citation metrics from Harzing's POP

Metrics	Data
Papers	206
Citations	2,492
Years	5
Cites/Year (C/Y)	498.4
Cites/Paper (C/P)	12.1

Yearly Publications. Table 8 shows the extended analysis for yearly publication. There has been a steady trend in publications from 2016 to 2019 (28 to 38 documents). However, a remarkable publication contribution can be identified in 2020 (67 documents), almost double the figure from the previous year (increase by 44.8%). The year 2020 also has the highest number of cited publications (32.52%), with total citations of 48, even though they are considered new publications. These results suggest that research productivity in this

subject area has increased and attracted more interest from researchers and is aligned with the needs and nature of scientific publishing (Niles et al., 2020).

Table 8
Yearly publication for agricultural wastes with filtration and adsorption technology

Year	TP	NCP	TC
2020	67	32.52%	48
2019	37	17.96%	33
2018	38	18.45%	31
2017	28	13.59%	26
2016	36	17.48%	33

Notes. TP=total publications; NCP=number of cited publications; and TC=total citations

Top Contributing Countries and Institutions. Overall, 160 authors are affiliated with various institutions from 63 countries recorded in the publications, and the top ten of the most productive countries are listed in Table 9. It is no surprise that the first three are from the Asia continent, namely China (TP=34), India (TP=32), and Malaysia (TP=17). Asia is well known for its biodiversity and agricultural activity, leading to massive agricultural waste (Neh, 2020). This observation can also be related to Table 10, by which two of the top three most active institutions are depicted to be from the same countries (Ministry of Education China and Universiti Kebangsaan Malaysia). In contrast, Aligarh Muslim University (India) is seventh from the top eight list. Hence, it can be inferred that these countries have considerable awareness and effort from their government supported by their respective educational advancement. When institutions are ranked according to the h-index, the Ministry of Education China and the University of Santa Maria are the top institutions with leading publications. The visualization map on the geographical distribution of these publications worldwide is shown in Figure 2.

Table 9
Top contributing countries in publications

Country	TP	NCP	TC	C/P	C/CP	h	g
China	34	16.50%	30	673	19.79	22.43	15
India	32	15.53%	28	398	12.44	14.21	12
Malaysia	17	8.25%	15	145	8.53	9.67	6
Egypt	12	5.83%	11	116	9.67	10.55	5
Iran	11	5.34%	10	137	12.45	13.70	7
U.S.	11	5.34%	8	98	8.91	12.25	5
Brazil	8	3.88%	8	133	16.63	16.63	6
Nigeria	7	3.40%	4	44	6.29	11.00	3
Thailand	6	2.91%	5	25	4.17	5.00	3
Turkey	6	2.91%	3	125	20.83	41.67	2

Notes. TP=total publications; NCP=number of cited publications; TC=total citations; C/P=citations per paper; C/CP=average citations per cited publication; h=h-index; and g=g-index

Table 10
Top contributing institutions with a minimum of three publications

Affiliation	TP	NCP	TC	C/P	C/CP	h	g
Ministry of Education China (China)	6	6	130	21.67	21.67	6	6
Universiti Kebangsaan Malaysia (Malaysia)	4	4	45	11.25	11.25	3	4
National Research Centre (Egypt)	4	4	21	5.25	5.25	3	4
University of Santa Maria (Brazil)	4	4	100	25.00	25.00	4	4
Silpakorn University (Thailand)	3	2	14	4.67	7.00	1	3
Czech Academy of Sciences (Czech Republic)	3	2	8	2.67	4.00	2	2
Aligarh Muslim University (India)	3	3	30	10.00	10.00	2	3
Qatar University (Qatar)	3	3	55	18.33	18.33	3	3

Notes. TP=total publications; NCP=number of cited publications; TC=total citations; C/P=citations per paper; C/CP=average citations per cited publication; h=h-index; and g=g-index

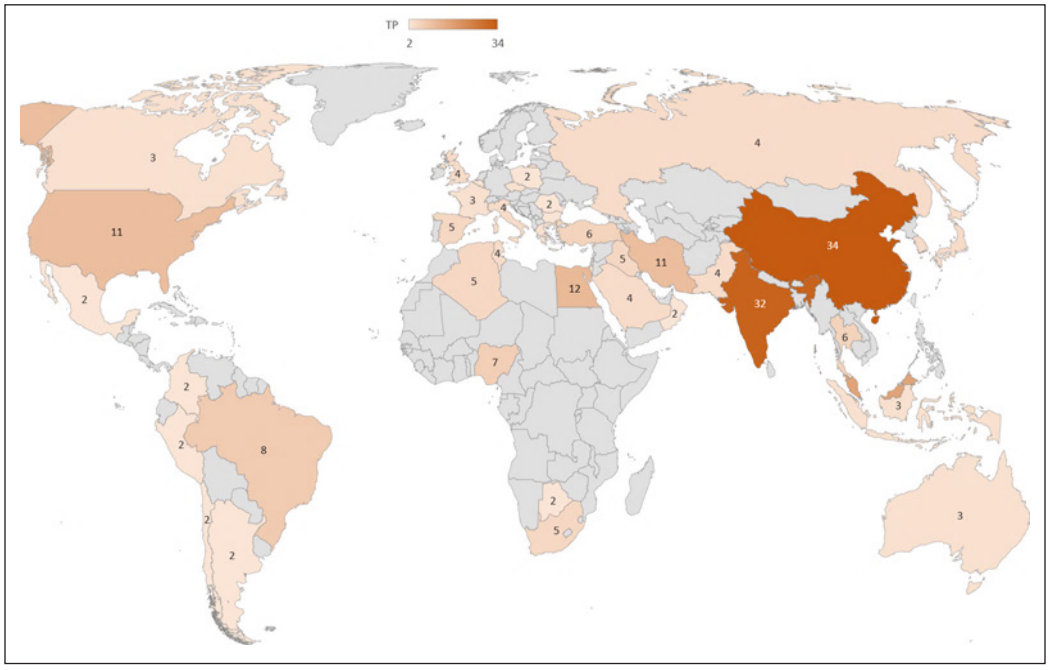

Figure 2. Geographical distribution of publications

Most Active Source and Top Cited Publications. Table 11 shows that the most active source title within the past five years is Desalination and Water Treatment, with 18 publications compared to others. It is followed by the Journal of Environmental Chemical Engineering (TP=7) and Science of the Total Environment (TP=6). It can also be seen that Elsevier dominated as a publisher, with 5 out of 8 in the list being journals published by them. The Cite Score, SCImago Journal Rank (SJR) 2020, and Source Normalized Impact per Paper (SNIP) 2020 are also shown. SJR measures weighted citations received by the

source title, while SNIP measures actual citations received relative to citations expected for the source title's subject field. Nonetheless, the factors in selecting a journal, such as reliability of reviewing, the usefulness of reviewers' feedback, the journal's reputation, and confidence that their article is in scope for the journal, may contribute to these results (Rowley et al., 2020).

Next, Table 12 shows the top ten highly cited documents with average citations per year. The document entitled "Utilizations of agricultural waste as adsorbent for the removal of contaminants: A review" by Dai et al. (2018) has the highest total of citations (141 citations or an average of 47 citations per year). Another interesting finding is that half of the top articles are published in the most active source, as mentioned previously. Hence, it would play a role in increasing the high citations.

Table 11
Most active source title in publications

Source Title (Publisher)	TP	TC	Cite Score	SJR 2020	SNIP 2020
Desalination and Water Treatment (Desalination Publications)	18	8.74%	1.6	0.251	0.351
Journal of Environmental Chemical Engineering (Elsevier)	7	3.40%	7.5	0.965	1.354
Science of the Total Environment (Elsevier)	6	2.91%	10.5	1.795	2.015
Journal of Molecular Liquids (Elsevier)	5	2.43%	8.4	0.929	1.420
Bioresource Technology (Elsevier)	4	1.94%	14.8	2.489	2.073
Chemosphere (Elsevier)	4	1.94%	10.1	1.632	1.708
IOP Conference Series Materials Science and Engineering (Conference Proceeding)	4	1.94%	0.7	0.198	0.484
Water Switzerland (Multidisciplinary Digital Publishing Institute)	4	1.94%	3.7	0.718	1.179

Notes. TP=total publications; and TC=total citations

Table 12
Top 10 highly cited documents (Retrieves as of 6th August 2021)

Title	Cites	Cites/Year	By
Utilizations of agricultural waste as adsorbent for the removal of contaminants: A review (Chemosphere)	141	47	Dai et al. (2018)
Tetracycline adsorption onto rice husk ash, an agricultural waste: Its kinetic and thermodynamic studies (Journal of Molecular Liquids)	92	18.4	Chen et al. (2016)
Valorization of agricultural waste with an adsorption/ nanofiltration hybrid process: From materials to sustainable process design (Green Chemistry)	89	22.25	Didaskalou et al. (2017)
Adsorptive potential of agricultural wastes for removal of dyes from aqueous solutions (Journal of Environmental Chemical Engineering)	81	20.25	Singh et al. (2017)

Table 12 *(continue)*

Title	Cites	Cites/Year	By
Insight into the adsorption mechanism of cationic dye onto biosorbents derived from agricultural wastes (Chemical Engineering Communications)	60	15	Tran et al. (2017)
Management of agricultural waste for removal of heavy metals from aqueous solution: adsorption behaviors, adsorption mechanisms, environmental protection, and techno-economic analysis (Environmental Science and Pollution Research International)	57	14.25	Elhafez et al. (2017)
Biochar-based functional materials in the purification of agricultural wastewater: Fabrication, application and future research needs (Chemosphere)	54	18	Wei et al. (2018)
Exploring the adsorption mechanisms of cationic and anionic dyes onto agricultural waste peels of banana, cucumber, and potato: Adsorption kinetics and equilibrium isotherms as a tool (Journal of Environmental Chemical Engineering)	50	16.67	Stavrinou et al. (2018)
Adsorption of methylene blue on agro-industrial wastes: Experimental investigation and phenomenological modeling (Progress in Biophysics and Molecular Biology)	44	22	Meili et al. (2019)
Adsorptive behavior of methylene blue onto sawdust of sour lemon, date palm, and eucalyptus as agricultural wastes (Journal of Dispersion Science and Technology)	43	21.5	Esmaeili & Foroutan (2019)

Productive Authors. No distinctive authors were identified as most active since most authors have similar publications (TP=2) except for the two (TP=3) shown in Table 13. Between their six authored and co-authored publications, wrapped a total of 147 citations. They are part of the contributors in top contributing institutions too.

Table 13
Most productive authors

Author (Affiliation)	TP	NCP	TC	C/P	C/CP	h	g
Almomani, F. (Qatar University, Qatar)	3	3	55	18.33	18.33	3	3
Dotto, G.L. (University of Santa Maria, Brazil)	3	3	92	30.67	30.67	3	3

Notes. TP=total publications; NCP=number of cited publications; TC=total citations; C/P=citations per paper; C/CP=average citations per cited publication; h=h-index; and g=g-index

Research Streams

RQ3: What are the significant research streams and trends over time?

Top Keywords. The authors' keywords are vital to review trends while assessing research areas (Babaii & Taase, 2013). Therefore, the authors' top keywords and co-occurrence are analyzed to determine the research streams and trends over time. Since the keywords

contain duplicated terms in singular, plural, or synonyms, they were merged manually using Microsoft Excel. Table 14 summarizes the top keywords found from the Scopus. The top favorite keyword is "agricultural wastes" (11.5%), followed by "water and wastewater treatment" (8.7%) and "adsorption" (7.8%). Thus, it can be concluded that these are the expected trends that have become a frequent target of current research.

Table 14
Top keywords

Author Keywords	Total Publications (TP)	Percentage (%)
Agricultural Wastes	159	11.5%
Water and Wastewater Treatment	121	8.7%
Adsorption	108	7.8%
Kinetics	76	5.5%
Agriculture	63	4.6%
Metals Removal	62	4.5%
Water Quality	50	3.6%
Article	48	3.5%
Water and Wastewater Management	48	3.5%
Isotherms	42	3.0%
Dye Removal	34	2.5%
pH	32	2.3%
Activated Carbon	30	2.2%
Waste Treatment	28	2.0%
Characterization	27	2.0%
Biochar	26	1.9%
Agricultural Robots	23	1.7%
Aqueous Solution	19	1.4%
Scanning Electron Microscopy	19	1.4%
Others	369	26.7% (≤1.3%)

Co-Occurrence Analysis. Having more than one keyword in a single document shows a relationship between the concepts, known as co-occurrence (Baker et al., 2020). In this study, the minimum of co-occurrences of each keyword is set at six. Based on this threshold, 28 keywords emerged for selection in the VOSviewer program Figure 3 shows the network overlay visualization map generated based on keywords by authors. The color, font, and circle size indicate the keywords' relationship strength.

Five major clusters or research streams were formed based on the color grouping from the map. The first and second cluster consists of 8 items, themed as biomass characterization and optimization, and adsorbent for water and wastewater quality improvement. Then the remaining clusters, all consisting of 4 items, are themed as filtration by activated carbon, heat treatment for biochar, and bio-adsorbents kinetics, isotherms, and thermodynamic. Hence, based on the analysis, these themes are suggested as the primary research streams.

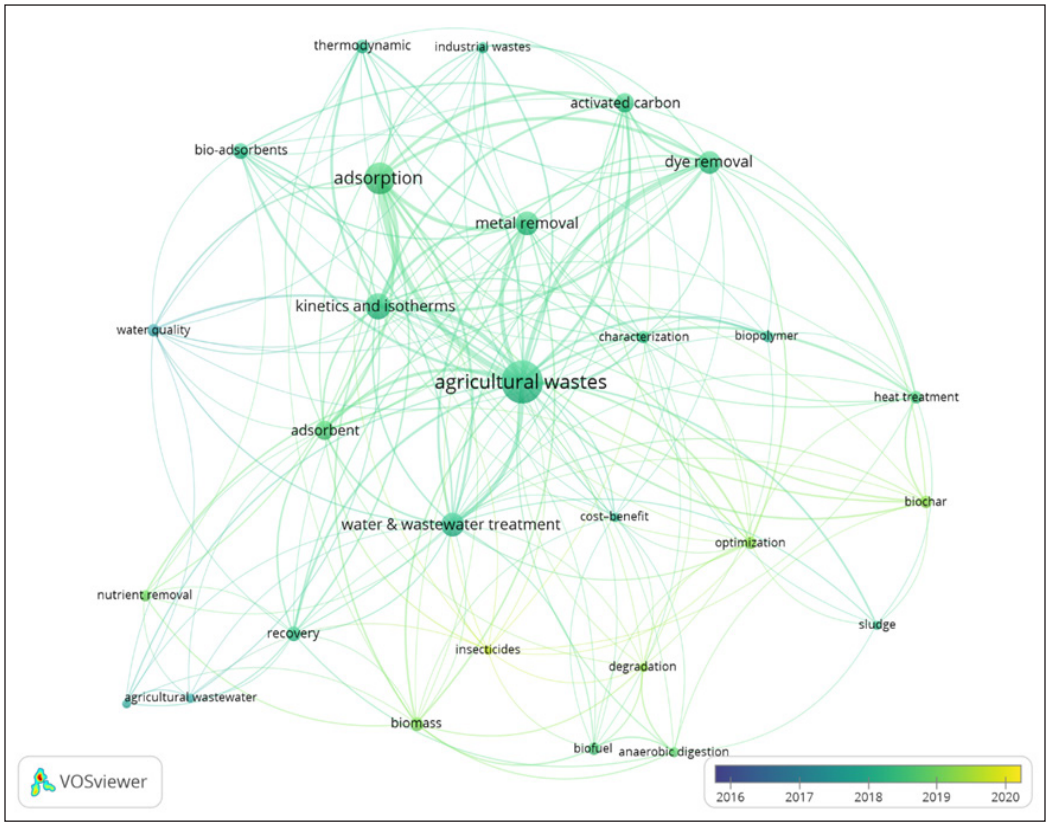

Figure 3. Network overlay visualization map of the author keywords

Future Directions

RQ4: What are the potential opportunities for future research?

Based on Figure 3, specific keywords labeled in yellow/light green can be observed leaning towards the year 2020. These keywords are "insecticides," "biochar," "biomass," and "optimization." It should be noted that these are not new terms or keywords used in this research field. Instead, they may be applied differently from the conventional way. Thus, the keyword trend will mostly rely on the authors' research interests (Lu et al., 2021). The authors suggest that future research emphasizes filtration modeling for optimization, utilizing agricultural-based media for water and wastewater treatment.

Previous works of literature have demonstrated that agricultural-based media can be utilized for water and wastewater treatment (Kristianto et al., 2017; Farjana et al., 2018). They can be used either as raw or carbonized, with and without activation. In addition, some other studies successfully modified biochar from these wastes and improved adsorption capacity (Seixas et al., 2017; Bispo et al., 2018; Shakya & Agarwal, 2019). Nonetheless, more works are needed to study this alternative material (Hoslett et al., 2018).

Laboratory experiments are usually performed to analyze one factor, but it is time-consuming, costly, and tedious as it involves replications. Thus, computer modeling would offer flexibility to simulate and optimize the filter design. It can even determine the response prediction and show the relationship or interactions between several independent factors or variables (Dashti et al., 2018). It complements the conventional method, which requires changing variables one at a time while the others remain constant (Bashir et al., 2015).

CONCLUSION

Agricultural wastes as filtration media have attracted global interest due to their abundance and potential to be transformed from waste to wealth. This study has bibliometrically analyzed the agricultural waste literature related to their filtration and adsorption technology application. Here are some of the conclusions drawn based on the findings:

- There is noticeable growth (increase 44.8% in 2020) of interest in this field based on publications from 2016–2020 (as of 6th August 2021).
- Most authors prefer article form (80.58%) in journal publications (87.86%) for sharing their scientific findings.
- The agricultural waste and purification technology studies dominate science and engineering subject research.
- The top publication contributors for institutions and countries mainly come from Asia (China, India, and Malaysia).
- Half of the top-cited articles (50%) are published in the most active source title.
- The top keywords identified are “agricultural wastes” (11.5%), “water and wastewater treatment” (8.7%), and “adsorption” (7.8%).
- Five themes developed from co-occurrence analysis are 1) biomass characterization and optimization; 2) adsorbent for water and wastewater quality improvement; 3) filtration by activated carbon; 4) heat treatment for biochar; and 5. bio-adsorbents kinetics, isotherms, and thermodynamic.

On the bibliometric analysis, combining more than one database can be suggested. However, the duplicates need to be removed, and the database must be fully accessible for thorough data analysis. In terms of using Scopus export, the data downloaded needs to be checked to ensure no error in the file, such as non-related documents (proceeding/journal content information). Also, the study experienced the author’s name with split IDs. At the moment, Scopus users can only combine, run, edit, change the name, set up an alert for, and delete a saved search. Since the documents from the search result are based on the search criteria, they cannot be manually removed or combined from the results list. So, the study used Harzing’s POP to combine the author’s information (ID and publications record) to remove duplicates as the data is not added up.

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