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A Bibliometric Analysis of Sustainable Solid Waste Management Technologies using Scopus Database

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ABSTRACT

A bibliometric analysis of sustainable solid waste management (SSWM) technologies was conducted to establish the hotpots and research shifts based on literature from Science Citation Index (SCI) database from 2010 to 2023 that was retrieved from Scopus database. The research trends and statistics are presented first and then a comprehensive bibilometric analysis using VOSviewer software is performed. The research establishes that, publication output increased between 2020 and 2022 and the Journal of Cleaner Production had the highest number of publications. Between 2017 and 2019 the focus of research on SSWM technologies was towards waste management and sustainable development. The technologies considered during this period were recycling, waste incineration, gasification, anaerobic digestion, and waste to energy, bioenergy and composting. Between 2020 and 2023 the focus was on environmental sustainability and circular economy. The SSWM technologies between 2020 and 2023 focused on resource recovery and pyrolysis.

Keywords-- Bibilometric, Sustainability, VOSviewer, Management, Technology, Solid Waste

I. INTRODUCTION

Sustainable solid waste management (SSWM) is a serious challenge in both developed and developing economies. According to [1] solid waste management (SWM) has become a global challenge. Urbanization, improvement in material science and economic growth have contributed to increased solid waste generation rates [2; 3]. It is anticipated that; universal waste will increase by 70% to 3.40 billion metric tons by 2050 [1] posing a serious environmental dilapidation threat [4]. Improper SWM is a proven cause of environmental degradation and dangerous air pollution causing acute health related problems [5]. Therefore, this is a call for more studies to be conducted in the SWM arena.

Globally, different SWM practices are implemented to address the challenges of wastes. Nevertheless, based on the country or city, the characteristics and complexities of the SWM practices differ. In developing economies, the practices have the presence of the informal sector [6] and are less technologically advanced while in developed economies, the practices are technologically advanced [7]. Despite the differences in the implementation of the SWM practices, different technologies have been developed to manage the different types of solid wastes. Among the technologies are incineration, composting, fermentation, thermochemical, pyrolysis, etc. [8, 9]. In addition, many studies have been conducted in different countries across the globe on SWM technologies [10, 11, 12, 13]. Further, many scientometrics investigations have been conducted to analyze the patterns in SWM [14, 15, 16]. These studies have not focused on reviewing and comparing SWM technologies from a global perspective.

Intellectuals utilize bibliometric analysis for many reasons for example, to discover emerging trends in journal and article performance, research constituents, collaboration or to investigate the intellectual formation of a particular realm in the present literature [17,18,19]. Several works related to solid waste have been conducted using bibilometric analysis. [16] analyzed solid waste reuse and recycling using Science Citation Index (SCI) database from 1992 to 2016. [20] conducted a bibliometric analysis of solid waste research between 1993 and 2008 to investigate the current trends. These studies did not focus on establishing and comparing the SSWM technologies as [20] focused on Solid waste research while [16] focused on reuse and recycling.

This research aims at plotting the shifts of global SSWM technologies from 2010 to 2023 and comparing the leading research realizations by utilizing the bibilometric approach. This includes the audit of the volume and distribution by time and geographic source; and intellectual structure of SSWM technologies by considering author, journal and institution keywords, words in the topic and Keywords Plus. To this regard a diverse bibilometric analysis accenting on all pertinent peer-reviewed journal articles on SSWM is conducted. The research questions to be addressed in this paper are;

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RQ1: *what is the volume and distribution by time of SSWM technologies across the globe?*
RQ2: *what authors, countries and journal articles from the globe have had prominent influence on SSWM technologies over the last 13 years?*
RQ3: *what topics in SSWM technologies literature have been studied with considerable frequency and are attracting significant attention in the last 13 years?*
RQ4: *what are the existing SSWM technologies by frequency from the global perspective?*

We analyze and compare the studies from 2010 to 2023 to investigate (1) leading collaborations and countries in both domestic and international and (2) the intellectual structure and development shifts in the area of SSWM technologies. An updated review of this area is provided from 2010 to 2023 and an analysis of studies using bibliometric approaches and literature analysis instruments is performed. The co-occurrence of author keywords and co-authorship network analysis is conducted to further understand the global research standing and development shifts. In addition, dominant classes, leading countries and most dominant journals are analyzed.

The rest of the paper is organized as follows: the methodology that was applied is discussed in the next section. In section 3, the bibliometric analysis is outlined, demonstrating the major shifts before observing and discussing the collaborative networks. Lastly the discussion of results is presented in section 4 while the conclusions and future areas is presented in section 5.

II. METHODOLOGY

Data Source and Search Approach

Scopus is one of the largest citation and abstract database that was launched by [21]. It is a peer- reviewed literature database that features smart tools for visualizing, tracking and analyzing research. It has over 25,000 titles accounting for more than 7000 international publishers and covers publications from 1788 to date [22]. It is among the biggest curated bibliographic citation and abstract databases today with roughly 3 million latest items been uploaded every day. Further, it distributes diverse reviews of the earth's research output in the areas of social sciences, medicine, humanities, science, technology and arts. Scopus indexes several disparate constituents of scientific publications such as keywords, references, author names, abstracts, drug terms and linked affiliations [23].

Data mining was performed between January and February 2023 using the Scopus database. The main theme of this research was articles consisting of the words "technology*solid*management*waste*sustainable" in their abstract and titles. The initial query string utilized in search was TITLE-ABS-KEY (sustainable AND solid AND waste AND management AND technology) and it resulted in 1698 documents. Further, additional filters were included such as year of publication, subject area, document types, and language and publication stage. The search query was: TITLE-ABS-KEY (sustainable AND solid AND waste AND management AND technology) AND PUBYEAR > 2009 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "CENG")) AND (LIMIT-TO (DOCTYPE , "ar")). The query string brought about 741 documents. In this search string, only articles published in English language between 2010 and 2023 were included. Further, the subject area only consisted of engineering, energy, chemical engineering and environmental science. With an aggregate of 741 documents, a title analysis methodology adopted from [24] was performed and an aggregate of 514 documents were excluded. Further, a total of 37 duplicate articles and 1 book were removed and the remaining 189 articles were subjected to an abstract analysis. A total of 67 articles were excluded as they did not correspond to the aim of the study. After performing the inclusion and exclusion criteria, a sample size of 115 articles were considered after 7 articles were excluded. The final register (consisted of author names, abstracts, titles, sources) and references which were downloaded in CSV (comma delimited) format for network and mapping analysis. Author ID is the most suitable approach for obtaining accurate data of an author's output. A Scopus author identity (ID) is assigned mechanically to every author that has published a paper in a Scopus indexed journals. It is a unique identifier that permits authors to differentiate themselves from other authors as well as link themselves to their work. In reality, an author profile consists of a group of the entire name variations positioned in single profile. For example, the exported data consisted of the author last name and abbreviated initials. Figure 1 depicts the research design that was applied to search, obtain and treat the data.

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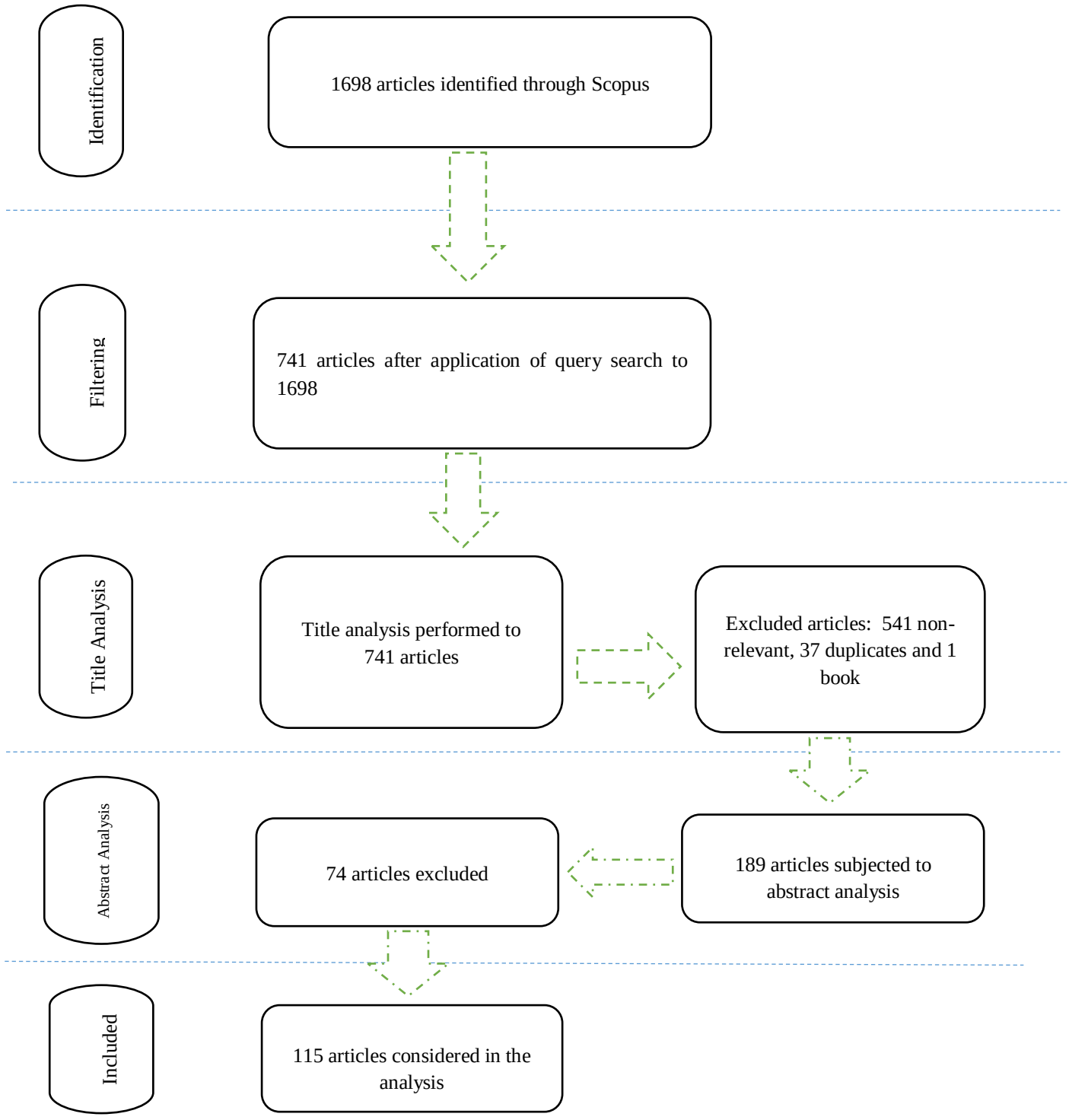

Figure 1: Research Design Flow Chart

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Bibliometric Maps

Author keywords, citation and bibliographical information of 115 articles were exported to VOSviewer, a software aid for visualizing and constructing bibliometric maps. In this study, the items of interest analyzed in the VOSviewer maps included author keywords or countries. Links exist between any set of items- an association or connection between two items. A positive numerical value portrays the strength of each link. The strength is in the highest value of the link. For co-authorship evaluation, the link strength among countries specifies publication numbers co-authored by two associated countries whereas the total strength of the co-authorship links of a specified country with other countries is indicated by the total link strength. Likewise, for the co-occurrence evaluation, the quantity of publications where two keywords exist together indicates the link strength between author keywords. VOSviewer user manual provides more details on its features [25].

III. RESULTS

This section interprets visual maps that emanated from the bibliometric analysis of 115 articles.

Publication Output

Figure 2 depicts the number of research articles that focused on SSWM technologies as well as their distribution by year. The period of publication considered was between 2010 and 2023. The figure reveals that, 2022 had the highest publication rate compared to the other years. 2010, 2012, 2013 and 2017 had the lowest number of publications but it is also observed that the publication increased from 2020 to 2022. It is also observed that, only articles published in English language were considered for analysis in this study.

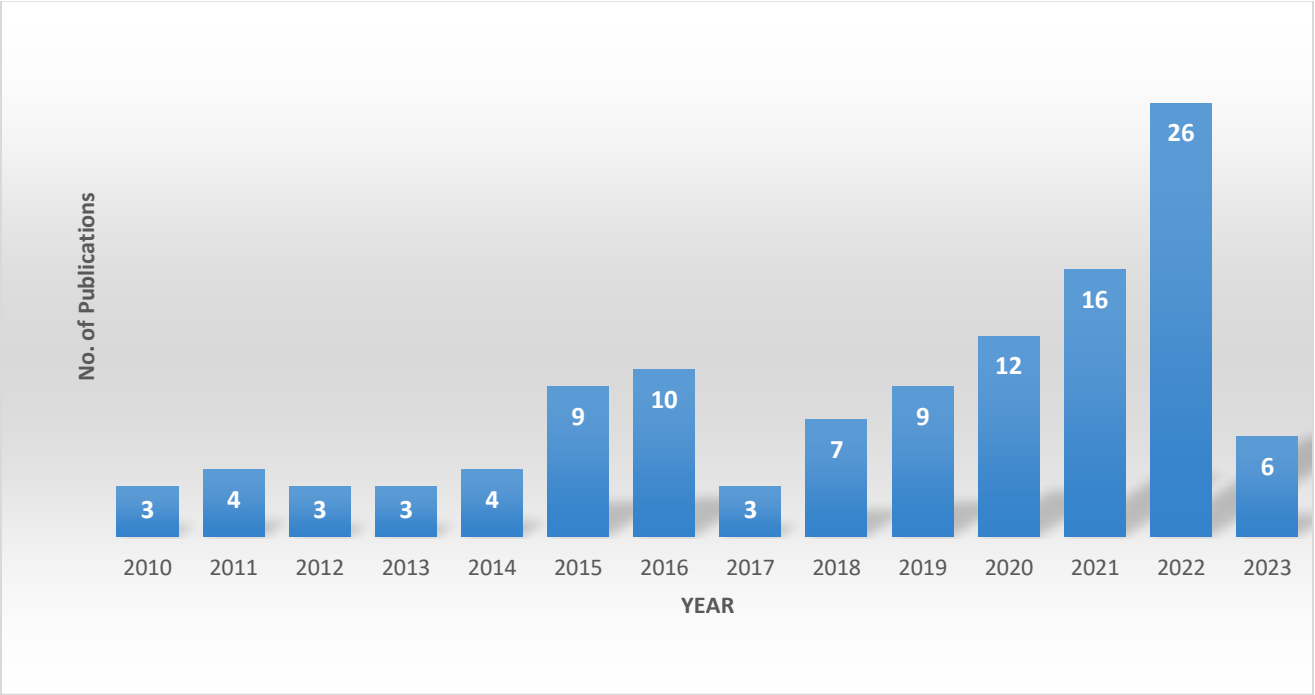

Figure 2: Publication count per year

Author Keywords Distribution

The key content of this study is represented using the keywords [26]. An aggregate of 1523 author keywords were utilized in the research articles considered in the analysis. A therasuras analysis was conducted in which words such as solid wastes were replaced by solid waste; bio-refineries were replaced by bio-refinery etc. After a replacement process, 75 keywords satisfied a threshold of at least 5 occurrences to be mapped in VOSviewer. Figure 3 depicts the associated keywords and their clusters.

Figure 3 depicts the keywords distribution for the research articles considered in this research. The frequency of the word in the articles is represented by the dimension of the nodes. WASTE MANAGEMENT had the highest frequency with an appearance of 80 times. SUSTAINABLE DEVELOPMENT had the second highest frequency with an appearance of 61 times and it was followed by RECYCLING OR ANAEROBIC DIGESTION with appearances of 34 times and WASTE INCINERATION had the fourth highest ranking with an appearance of 32 times.

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A total of 3 clusters were created from 75 keywords and each cluster is depicted in a different color. All the terms in a cluster are represented in the same color and have a strong relationship. Terms that have a short distance between each other tend to be in the same article titles and abstracts. Additionally, terms in the middle of the network chart have a broader span of terms compared to the ones around the chart [27].

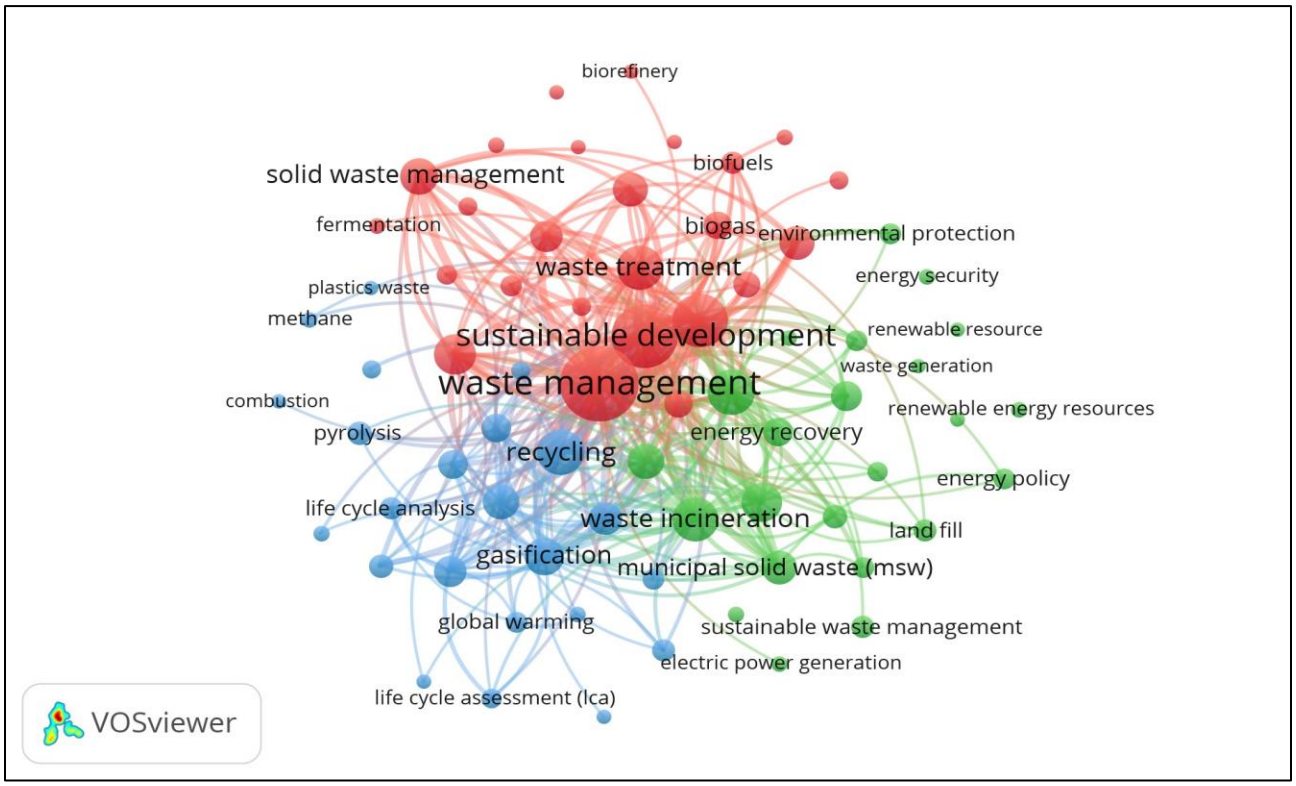

Figure 3: Keywords Analysis

Publication by Country

Table 1 depicts the publication by country. A total of 48 countries were identified from the publications that were examined in this study. For a finer interpretation of the results, it was specified that at least three (3) publications be considered. A total of 26 countries had at least three publications among the 48 examined. In ascending order of publications by country, India had 32, followed by China with 21, Malaysia with 10 and the United Kingdom with 9.

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Table 2: Publication per Country

No.	Country	Number of Publications	Citations
1	India	32	738
2	China	21	806
3	Malaysia	10	526
4	United Kingdom	9	252
5	United States	7	188
6	Germany	6	88
7	South Korea	6	230
8	Iran	5	137
9	Portugal	5	166
10	Saudi Arabia	5	187
11	United Arab Emirates	5	218
12	Bangladesh	4	18
13	France	4	311
14	Italy	4	66
15	Pakistan	4	167
16	Thailand	4	44
17	Australia	3	77
18	Belgium	3	335
19	Brazil	3	40
20	Canada	3	116
21	Denmark	3	200
22	Finland	3	73
23	Hong Kong	3	149
24	Nigeria	3	151
25	Taiwan	3	75
26	Viet Nam	3	199

Co-Authorship Analysis

The center of co-authorship analysis is the scientific collaboration and literature's interrelationships [278. Within the span of examination, it was observed that, there were a total of 476 authors. The condition for this analysis was that authors should have at least one citation and publication. A total of 420 authors met the threshold. The biggest set of joined items comprised of 39 items. Figure 4 depicts the major co-authorship on SSCM.

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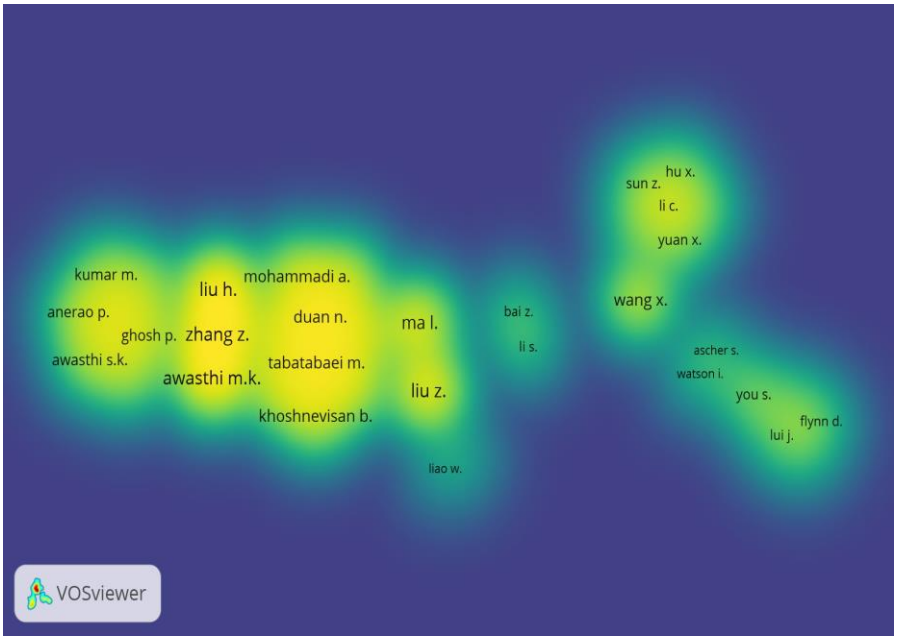

Figure 4: Authors with Most Co-authorization

The density visualization graph (figure 4) shows how the color of the field containing the author's names differ depending on the unit of co-authorships. Author names with the acute blue color shows a small unit of co-authorships. It was clearly observed that Awashi, Zhang and Liu are the authors with the highest co-authorship. The total link strength of 22 has demonstrated the co-authorship distribution. Despite, Varjani having the highest unit of publications (4), he has a total link strength of 14 compared to the above authors that have at least 2 publications with the total link strength of 22.

Top Publishing Authors Analysis

For this analysis, only authors with at least three (3) articles were considered. Only 9 authors were considered in this analysis. Table 2 depicts the number of authors' citations and publications. Despite Varjani having the most publications (4); Chi, Dong, Nzihou and Tang were the most cited authors with 274 citations. It is also interesting to note that, most of Varjani's publications were in 2021 and for the authors with the most citations, their publications were between 2018 and 2019.

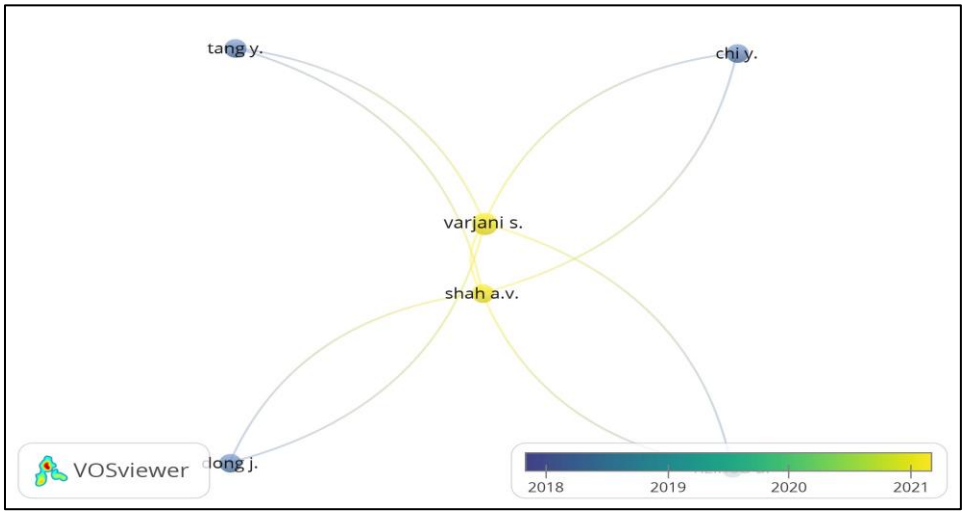

Figure 5: Top Publishing Authors

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Table 2: Number of Publications per Author

Author	No. of Publications	Citations	Total Link Strength
Varjani s.	4	225	5
Chi y.	3	274	2
Dong j.	3	274	2
Liu z.	3	147	0
Monteiro e.	3	107	0
Nzihou a.	3	274	2
Shah a.v.	3	168	5
Tang y.	3	274	2
Wang x.	3	82	0

Countries & Publications with most Citations

Out of the 48 countries, 26 had at least three publications and citations. These were considered countries with the most citations. Figure 6 depicts that China had the highest citations (806) followed by India (738), Malaysia (526), Belgium (335), France (311) and United Kingdom (252). Clusters and links also exist among the countries, and it was observed that, Iran, Finland, Germany and China are in a similar cluster. Existence of countries in the same cluster is an indication that, these countries jointly broadcast among each other. It was further observed that, despite China having the highest number of citations compared to India, it had 21 publications while India had 32 publications.

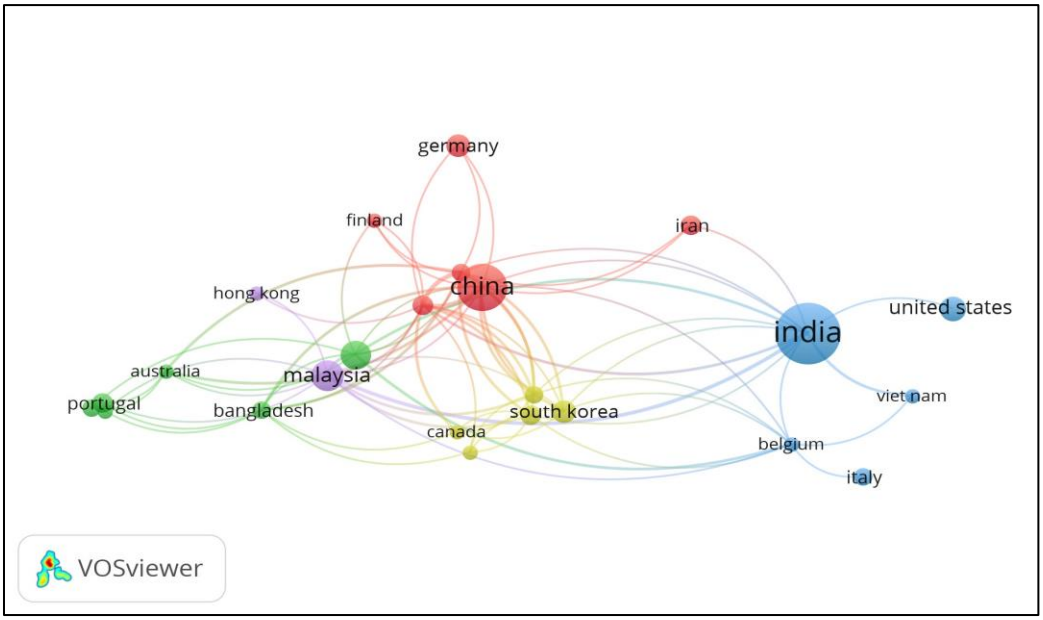

Figure 6: Countries with Most Citations

Figure 7 depicts the most cited publication because of being referenced by other published articles. At least 71 publications had at least ten citations out of 115 publications. The node's size is critical as it shows the rate the author's name is cited in the publications. For this research, [29] publication has the highest citations at 316. The study by [29] contributed to SSWM technologies by focusing on the critical function of waste to energy technologies in intensified landfill mining: a technology review. There is a line between the author, and it indicates the relationship of the authors to each other. The thicker the line, the more the authors work together.

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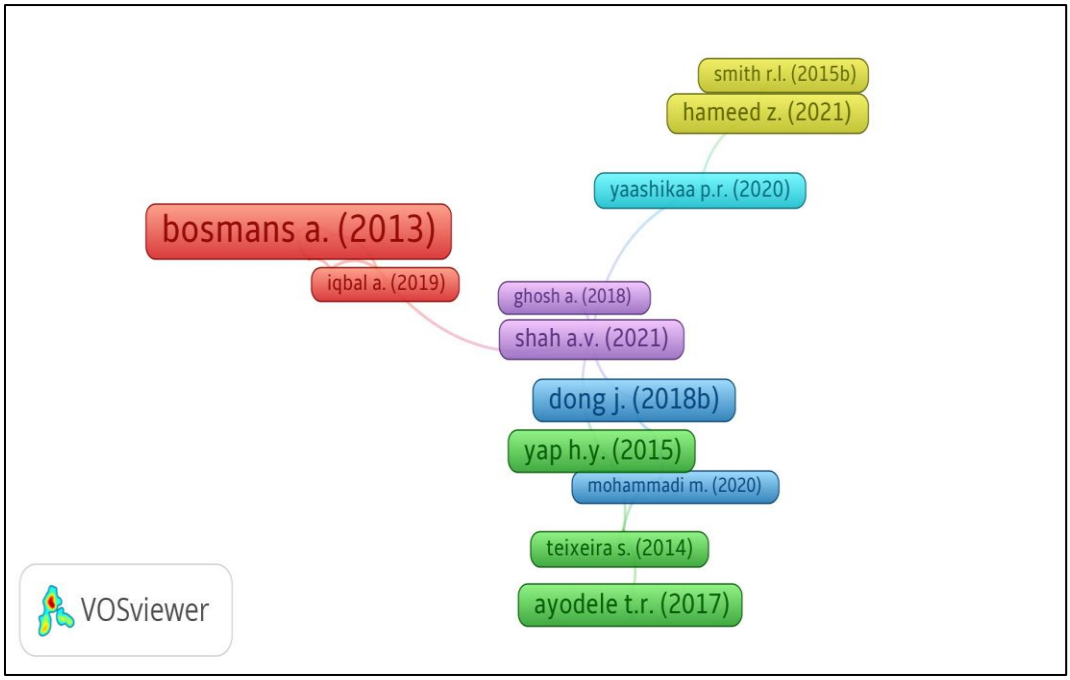

Most Published Journals

The impact of a publication in a particular field is measured by the number of articles and citations published in the journal [30]. Using the bibilometric analysis, the journals with the highest number of publications on SSWM technologies are depicted in Table 2. Out of the 68 journals considered, at least 15 met the threshold of having at least 2 documents and at least 15 citations. The journals are presented in ascending order of publications and the journal of cleaner production had the highest number of publications (12).

Table 3: Journals with most publications

Journal	Number of Publications	Citations
Journal of cleaner Production	12	972
Waste Management	7	362
Science of the Total Environment	6	312
Renewable and Sustainable Energy Reviews	4	235
Energy Policy	4	101
Journal of Environmental Chemical Engineering	4	93
Resources, Conservation and Recycling	3	91
Chemosphere	3	71
Bio-resource Technology	2	67
Renewable Energy	2	62
Journal of Environmental Management	2	60
Sustainability (Switzerland)	2	53
Biofuels	2	44
Energy Conversion and Management	2	38
Environmental Pollution	2	15

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IV. DISCUSSION OF RESULTS

SSWM technologies contribute to the utilization of organic resources, preservation of human health and the environment, and economic contribution. From a sustainability perspective, SSWM technologies look out for the future generations. The fact that SWM is a global problem and almost every nation has an agenda to resolve this problem, the approach to SSWM technologies has become relevant and investigations in this arena is strong. In this study, 116 articles on SSWM technologies accessed from Scopus between 2010 and 2023 were envisaged and explained through VOSviewer mapping method. The findings from the application of a bibilometric analysis to answer the research questions through VOSviewer maps provides important information on the current position and development procedure of worldwide literature on SSWM technologies. The study shows that, majority of the studies were published in 2021 with 139 articles. The number of publications on SSWM has increased since 2017. The increase in the number of publications is due to the need to utilize sustainable technologies to manage solid wastes. The agenda to develop and utilize technologies that protect the environment and human health as well as improve the application of the circular economy concepts has contributed to more research on SSWM technologies. The prediction of the increase in solid waste generation by 2050 by the World Bank has also driven the agenda of applying SSWM technologies to the treatment of solid wastes.

The keywords analysis shows that waste management was the most used with 112 appearances, sustainable development had 86 appearances and was in second place. The frequency of times waste management is used in the papers indicates that, the purpose to develop and utilize the SSWM technologies is to manage the solid wastes while sustainable development can only be achieved through the utilization of these SSWM technologies and therefore it appeared in second place. Further the development of sustainable development goals in 2015 has contributed to the development and utilization of SSWM technologies in the waste management arena.

The study assessed the countries, authors and journal articles with the greatest influence across the globe on SSWM technologies over the past 13 years. Per country analysis, India was seen to have the highest number of publications (32) and it is followed by the China with 21. Malaysia is in third place with 10. In addition, the most cited country is China with 806, followed by India with 738 and Malaysia has 526. Solid waste management is an intense problem in China because there is a huge production and consumption of products that later result in solid wastes. As a result of this waste related problem, many studies are conducted within the scope of SSWM as a strategy to address its problem. The study by [29] has shown how solid wastes can be managed by using SSWM technologies. This study is also supposed by [30, 31, 32]. According to the figure 6, most studies on SSWM are concentrated in China. In terms of author analysis, it was established that Varjani had the highest number of publications (4) while the publication by Broman had the highest citation of 316. Lastly, the journal with the highest influence on SSWM technologies was the Journal of Cleaner Production with 12 publications.

Among the main problems facing modernization is generation and utilization of waste. One of the strategies to resolve this issue is through the achievement of sustainable development goals and this cannot be achieved without understanding scientific data and indicators. Resolving the problem of SSWM cannot be possible without measurements and evaluation to adherence to social, economic and environmental requirements. Therefore, this study has theoretically contributed to scientific literature on SSWM and provides information that can be used to develop SSWM technologies framework for providing competitive waste management services. Establishing dominating articles, indicating the most leading journal in this discipline and outlining dormant international collaborators is useful information to journal editors, waste management stakeholders and the scientific community. In this study, literature on SSWM technologies has been reviewed and the trends in the discipline pointed out. This means that, a basis for professionals and academicians has been laid for future research.

The findings in this study are projected to provide a diversity of favorable relevance to institutional and scientific activity. Through this study, waste managers and researchers are enabled to review the literature with an organized collection of bibliographic references of dissimilar sizes obtained using the VOSviewer tool. The graphic findings from this study can be envisaged to acquire the most cardinal information for application in companies. In addition, conducting a literature review demands a significant amount of time, therefore, other researchers will render this literature useful. To policy makers, new outlooks concerning the existing development in SSWM has been presented.

The study has advanced knowledge on SSWM technologies and provided direction to researchers. In addition, an idea on the type of literature to focus on has been presented to authors that will have the desire to research on SSWM technologies. Nevertheless, the study presents some limitations. The major limitation is the assessment of articles with ESCI, SSCI and SCI indexes and only accessed via Scopus database. It is suggested that other indices as well as these indices be included in future studies. The application of VOSviewer as a visual mapping tool can also be applied to other databases as WoS, JSTOR databases. Thus, comparisons and analysis for future studies

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can be performed using dissimilar visual mapping tools such as Rstudio, Citespace and Pajek.

V. CONCLUSION

This study has answered the research questions by providing an overview of SSWM technologies research shifts based on 115 publications recovered from the Scopus database. In the last 13 years, the publication growth has been rapid, and it is projected to continue to increase. The countries with (China and India) the highest number of publications and powerful international collaborations have been discovered. These establishments are an opportunity for researchers across the globe to expand research collaborations. Several areas that are well examined such waste to energy are presented and those newly investigated such as biorefinery are presented for potential topics in future studies.

CONFLICTS OF INTEREST

There is no conflict of interest to be declared for this paper.

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