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Scientometric Analysis of Waste Management: Unveiling Global Trends, Patterns, and Impact - An Update of Last 50 Years

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ABSTRACT
This study presents a comprehensive scientometric analysis of global research in waste management over the past five decades (1974–2024). Using the Scopus database, 1,770 research and review articles were analyzed through bibliometric techniques such as citation analysis, co-authorship mapping, keyword co-occurrence, and bibliographic coupling with the support of VOSviewer and MS Excel. The analysis highlights significant growth in waste management research, particularly after 2015, in response to global sustainability initiatives. Findings reveal that the United States, India, and China are the top contributors, while key research themes center on medical waste, plastic waste, hazardous waste, recycling, and the circular economy. Highly cited works and influential authors were identified, along with collaboration patterns across 136 countries. Additionally, keyword analysis indicates emerging areas such as COVID-19-related waste management. The study underscores the role of scientometric methods in identifying research gaps, mapping global contributions, and guiding future investigations. By providing a structured overview of trends and patterns, this work contributes to advancing effective waste management practices aligned with sustainable development goals.

Keywords: *Waste Management, Bibliometric Analysis, Scientometric Study, Plastic Waste, Medical Waste, Hazardous Waste, Recycling, Circular Economy, Sustainable Development, Global Research Trends*

1. INTRODUCTION

Waste management and sustainability are essential to guaranteeing our planet's harmony in the future. The amount of waste we produce seriously threatens our ecosystems and natural resources as the world's population grows and urbanization increases [1-2]. Since waste contaminates the environment, it has become one of society's biggest worries due to its growing volume. Therefore, efficient waste management practices are essential to a state's development goals and building a more sustainable society. Waste management involves reducing excess utilization, reusing of things, and recycling of remains, which supports a circular economy. By strongly emphasizing sustainability, we understand that resources are limited and work to leave as little of an environmental impact as possible. By making these values our top priorities, we protect the environment, guarantee that resources will be available for future generations, and create a healthier and more just world. [3-4]

Ineffective waste management can cause significant harm to the environment and public health, particularly when it is located in an unsuitable area—that is, near sewage systems, water sources, or areas with significant populations. It exacerbates the consequences of global warming by increasing greenhouse gas (GHG) emissions [5-6]. Furthermore, the costs of poor waste management outweigh the initial outlay for appropriate facilities for storage and disposal [7-8]. Waste management significantly impacts global and local ecology, the economy, and public health. The types of waste that people produce significantly impact how well waste is managed. [9-10]

Air pollution, water contamination, soil contamination, and detrimental effects on the biosphere are a few examples of waste management-related issues [11]. At the international, national, regional, and municipal levels, the proper measures must be implemented to reduce the environmental impact of trash [12]. Local, grassroots initiatives hold significant importance even though there are limits to what one person can do to cut waste [13]. Every choice made regarding waste disposal affects where the waste ends up and if recycling is a viable option. For this reason, it is crucial to carry out waste management-

related operations in the locations where they are created [14]. Local waste management systems are progressively implementing intelligent, cutting-edge solutions based on IT tools. Numerous scientists have underlined their importance in implementing the smart city concept Utilizing the strategies that have been outlined will make waste management more effective [15-16].

Several researchers have done bibliometric analysis in waste management and circular economy in recent years, but they focused on specific areas or types of waste management or locations. Some of the studies are on Construction [17-18], Maritime [19], Organic solid waste [20], Smart Cities [21]. However, the analysis of toxic, plastic, hazardous, and medical waste is minimal. So, the current study is exploring these areas with the help of bibliometric analysis for five decades to provide potential research gaps for future researchers.

A bibliometric analysis identifies the connection between various research articles with the help of different assessing techniques mainly citation analysis, bibliographic coupling, co-authorship analysis and co-occurrence analysis. It is the best way to shape scientific situations nationally or internationally [22]. This study used bibliometric analysis to synthesize 1562 articles from 1974 to 2024 with the help of VOS Viewer and Microsoft excel. Using bibliometric analysis for research helps in assessing large pool of articles to identify relationship between authors, sources, organizations and keywords. It is also synthesis a large data set compared to other classical reviews that uses critical or narrative synthesis. The following research objectives frames rest of the study.

- To obtain an overview of currently available literature on waste management
- To analyze contributions based on author, source citation and geographical location
- To identify authors based on citations and their collaborations
- To identify top and least used keywords based on their occurrence.
- To find the contributions of countries based on their literature

2. METHODOLOGY

Prior to the release of Google Scholar and Scopus in 2004, the Web of Science was the best available tool for citation analysis. Research on Google Scholar's data quality and sustainability of research evaluation was given less attention when issues were raised. In this scenario, the scientific community is dominated by Scopus and Web of Science, [23-25] these two are most appropriate for bibliometric examination since they have similar traits. We have selected the Scopus database because it fulfills our goal of studying five decades, although the Web of Science only displays article results from 1988 when searching with keywords. We have used a systematic strategy in this investigation and acquired 1770 papers by refining the search terms, which are represented in **Table 1**. [26-29]

Table 1: Search Criteria and Article Selection

Criteria	Inclusion	Exclusion
Search date: 06-August-2024	3015	-
Database: Scopus		
Search terms: ("waste management" OR " garbage management" OR " trash management") AND ("plastic waste management" OR "hazardous waste management" OR "toxic waste management" OR "medical waste management")		
Year: 1974-2024	3014	1
Document type: Article and review	1997	1017
Language: English	1889	108
Source type: Journal	1796	93
Publication stage: Final	1770	26

(**Table 1** discloses the systematic process of reviewing the final 1770 articles. The search terms were derived through brainstorming among the authors.)

On the basis of United Nations sustainable development goals, the authors intended to research on "waste management" as most of the goals ultimately speak about the effective utilization of resources, proper waste disposal, and pollution reduction [29]. In this regard, authors searched the keyword “waste management” in Scopus data base and found 1,08,355 articles. After observing the quantity of research in this field, authors mainly confined to plastic waste, medical waste, and toxic waste and fixed the final search term as "waste management" OR "garbage management" OR "trash management") AND ("plastic

waste management" OR "hazardous waste management" OR "toxic waste management" OR "medical waste management".

At first, the authors inserted the identified search term in the Scopus database and found 3015 related studies. Secondly, as the authors aim to study 5 decades of waste management, they selected the years ranging from 1973 to 2024 but received the results from 1974 to 2023 along with the filtration of 1 study and finally provided 3014 articles. Thirdly, considered the research and review articles and observed 1997 articles by excluding 1017 articles i.e book chapters, conference proceedings etc. Fourthly, studies in English language were included, and 108 studies other than English were removed. Fifthly, the source was selected as a journal, which resulted in 1796 articles. And lastly, 26 articles which are in progress are excluded and considered 1770 articles for the current research analysis using network visualization of different connections.

3. RESULTS AND DISCUSSION

3.1Waste Management at World Level

Figure 1 & Table 1 depicts that only a few papers were published annually worldwide from 1974-1980. However, the number of publications published increased gradually starting in 1981 it might be because in 1980 medical waste reaches to several east cost beaches of united states which leads to the increase in the concern of medical waste in public as well as government [30]. Later, on September 2015 world leaders were agreed to reach 17 sustainable goals by 2030 [31], which leads to continuous booming in the area.

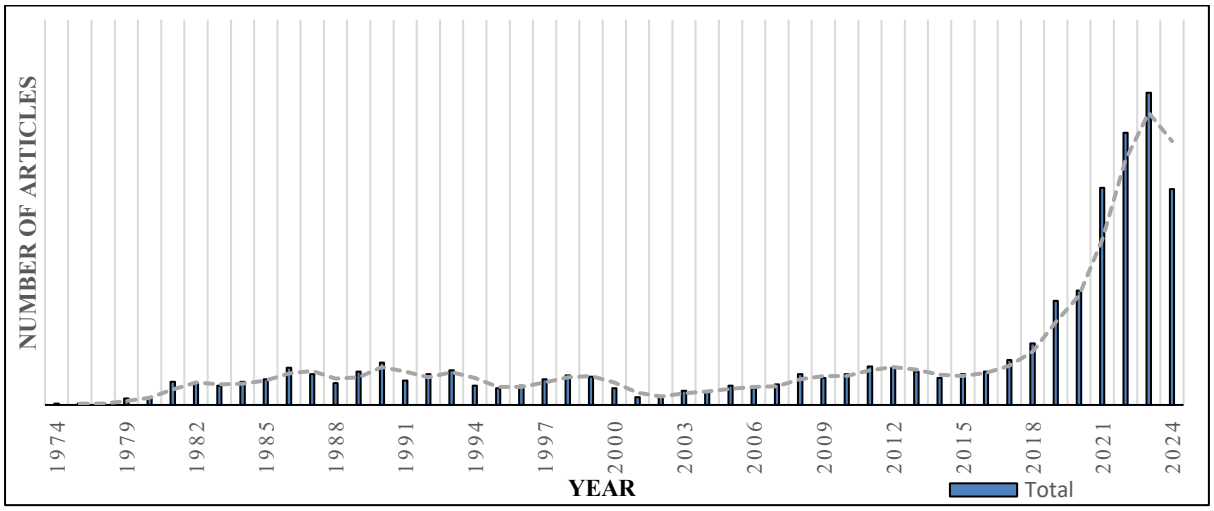

Figure 1: Year Wise Analysis

Table 1: Annual Scientific Production

Year	Doccuments	Year	Doccuments
1974	1	2001	6
1975	1	2002	7
1978	1	2003	11
1979	5	2004	10
1980	6	2005	15
1981	18	2006	13
1982	17	2007	16
1983	15	2008	24
1984	18	2009	21
1985	20	2010	24
1986	29	2011	30
1987	24	2012	29
1988	17	2013	26
1989	26	2014	21
1990	33	2015	24
1991	19	2016	26
1992	24	2017	35
1993	27	2018	48

1994	15	2019	81
1995	13	2020	89
1996	15	2021	169
1997	20	2022	212
1998	23	2023	243
1999	22	2024	168
2000	13		
Total Articles		1770	

An author can evaluate the impact of future research and comprehend present research patterns with the aid of current analysis. For instance, if a trend analysis showing continuous growth in the literature means that research topic is targeted by several researchers, performing research in this type of fields will a researcher to create impact in the research community and gain citations. However, if the dropping of trend line shows the studies on the field was already done and its impact was reduced, doing research in this type of fields will not helpful to a researcher. In some cases, even though topic is old and has a great impact on the research community and society but omitted by the researchers. Triggering this type of topics also helpful for the researchers.

3.2Countries and Publications

Articles from 136 different countries and territories worked on waste management methodologies. **Table 2** lists the top fifteen nations/territories and the overall number of citations along with the published articles with the finalized search items. It might be because, effective waste management has become crucial as these nations strive more for industrial and economic expansion. As a result, these nations may be formulating plans for their unique circumstances.

Table 2: Details of Countries and Publications

S. No	Country	Documents	Citations
1	United States	340	7208
2	India	260	6399
3	China	150	4895
4	United kingdom	95	4864
5	Iran	68	2510
6	Turkey	65	2082
7	Malaysia	56	1768
8	Australia	54	1844
9	Indonesia	53	1169
10	South Korea	53	1940
11	Italy	51	1256
12	Thailand	49	1496
13	Canada	47	2198
14	Germany	43	1617
15	Saudi Arabia	40	1088
Total		**1424**	**42334**

As per the **Table 2**, United States has the most publications overall 340 articles with 7208 citations. India comes next, with 260 publications and 6399 citations. It is because India is having low financial resources that lead to lack of scientific and technical knowledge on waste management [32]. After India, China occupied third place with 150 articles and 4895 citations. As China is facing waste management issues with high population and people migration from rural to urban.[33]

To date, one hundred thirty-six countries have contributed to the body of research. Out of 1,770 articles, 1,424 (representing 80% of the total) were contributed by 15 nations listed in the **Table 2** out of the 136 nations involved in the analysis. Nevertheless, 58 nations produced five or more publications as research outputs, 25 nations produced two - four publications as research outputs and 50 nations produced only one publication as research outputs (**Figure 2**).

The following criteria were used for the analysis:

- Co-author and country criteria to gain total number of countries that contributed more in this field.
- Unselected the dialog box “Ignore documents co-authored by a large number of countries
- Minimum number of documents of a country “1”

- Minimum number of citations of a country "0"
- All the countries (136) are selected with these criteria.

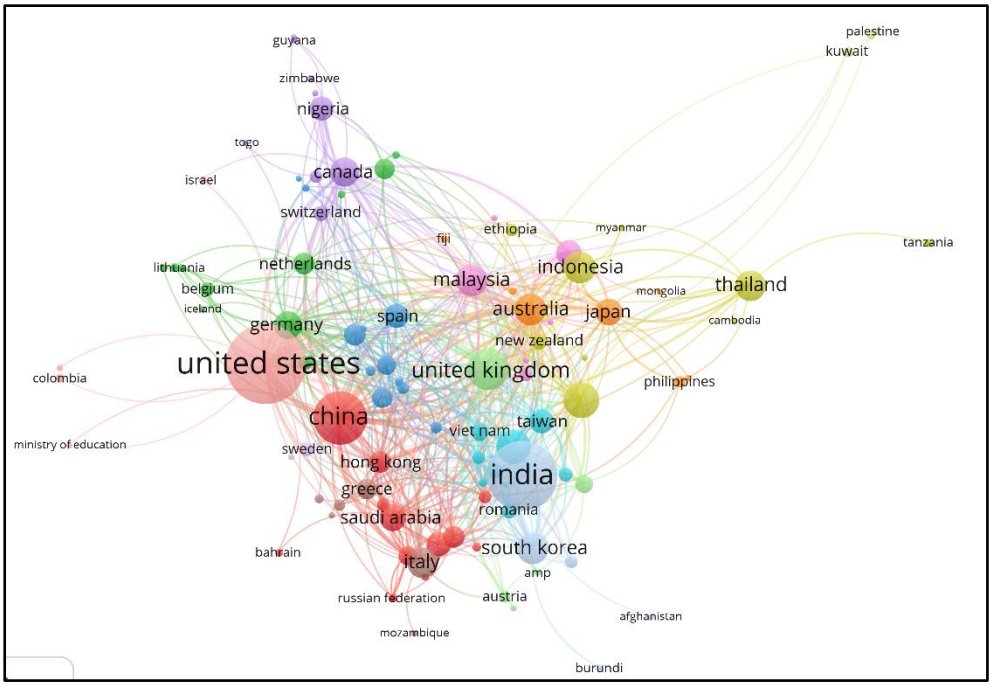

Figure 2: Network visualization of Country wide details of distribution

3.3Authors and Publications

The following criteria have been selected to analyze the authors and their publications in the field of waste management, providing a comprehensive understanding of their contributions and the impact of their research. These criteria will help identify key trends, influential works, and emerging areas within the discipline, offering valuable insights into the progress and direction of waste manage **(Figure 3)**.

Criteria:

- To understand author contribution in this field we selected co-author and author criteria.
- Minimum number of documents of an author "2"
- Minimum number of citations of a country "0"
- From 1696 authors, 38 authors meet criteria

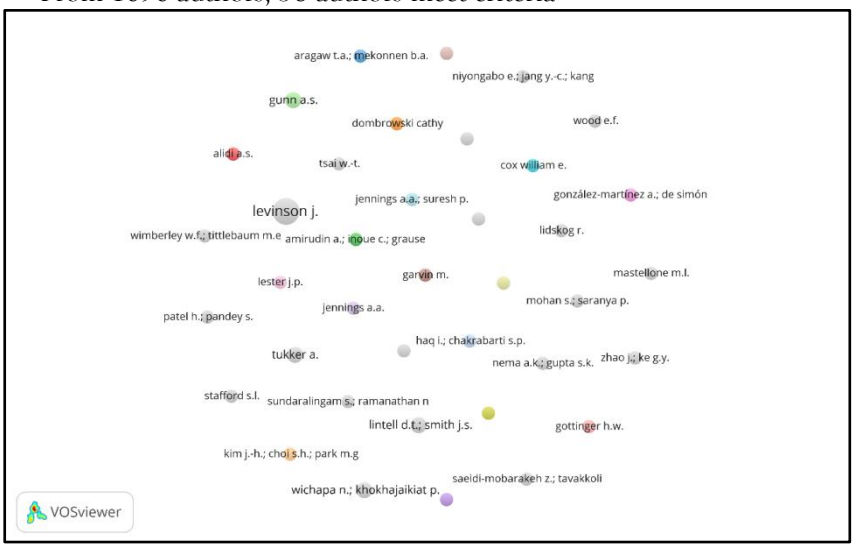

Figure 3: Details of Authors and Publications

The network visualization diagram **(Figure 3)** shows all 33 authors without any connections, explaining the absence of lines connecting them.

Table 3 current study presenting top 5 authors based on their number of publications. "levinson j" is contributed more in this field with 8 articles but the author receives only 3 articles which is much lower than wichapa n ; khokhajaikiat p whose publications are only 3 but citations are 59. Similarly "tukker a" also have 3 publications and 23 citations. However, "lintell d.t ; smith j.s" and "gunn a.s" have 3 publication each but citations are 2 and 0

Table 3: Details of top 5 authors and their contributions

S. No.	Author	Documents	Citations	Total link strength
1	levinson j.	8	3	0
2	gunn a.s.	3	0	0
3	lintell d.t.; smith j.s.	3	2	0
4	tukker a.	3	23	0
5	wichapa n.; khokhajaikiat p.	3	59	0

The analysis based on author will enable future researchers to build a network with the existing prominent authors to gain knowledge and contribute in the field for better insights.

3.4Co-citation of Authors of at least 20 Publications

In the bibliometric analysis, citation and co-citation analysis are techniques used to gauge the influence and connections among publications. Monitoring the quantity and calibre of citations a publication obtains from other scholarly works is called citation analysis. This indicates the significance and authority of a specific article or researcher. Co-citation analysis, on the other hand, looks at how frequently citations appear in two or more publications. This can be used to find developing fields, adjacent study areas, and the connections between institutions and researchers.

A co-citation network is created whenever two publications appear simultaneously in a publication's reference list. The co-citation analysis only considers highly cited sources and removes articles too recent or specialised from its subject groups. Co-citation analysis allows one to identify theme clusters in addition to the most influential articles. The listed papers serve as the basis for these theme groups. Co-citation analysis, on the other hand, focuses exclusively on highly-cited works, excluding current or specialized works from its thematic clusters. Co-citation analysis is, therefore, helpful for researchers working in waste management since it helps them understand the foundations of influential work and knowledge. **(Figure 4 & Table 4)**

Criteria:

- Minimum number of citations of an author "30"
- Out of 98191 authors 699 meets the criteria.

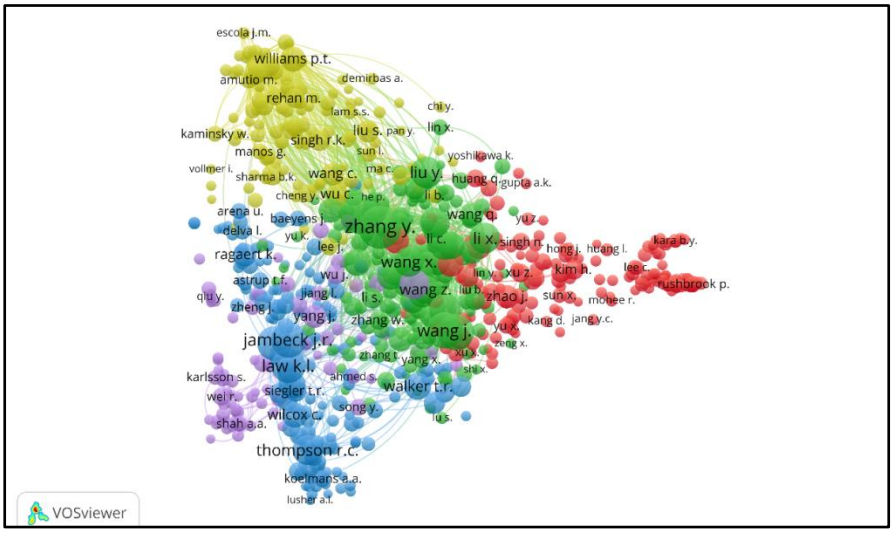

Figure 4: Co-citation Analysis

Table 4: Details of 5 top 5 co-cited authors

S. No.	Author	Citations	Total link strength
1	zhang y.	566	64006
2	wang y.	454	48318
3	wang j.	410	41875
4	li j.	396	33601
5	jambeck j.r.	376	27797

3.5Co-occurrence of Keywords

This is also populated as Keyword co-occurrence network (KCN), which is a process of making the article keywords into individual nodes and each occurrence of pair of the keywords are designed as link of the respective keywords. Additionally, the weight of the liked pairs was calculated based on co-occurrence frequency [34]. The KCN analysis used in conceptual and empirical studies to understand

research areas and its relation with particular scientific field [35]. This can be performed for both author keywords and indexed keywords. [36]

3.5.1 Author keywords

Author keywords are the words that are provided by an author at the time of submission or in an article to flag the research main focus and core concept. These are uncontrolled vocabulary means based on authors perception and desire. [37]

Criteria:

- "Co-occurrence" and "author keywords"
- Minimum number of occurrences of a keyword "5"
- Out of 3710 keywords 154 meets criteria.

It may also be deduced from **Figure 5** that the authors' chosen keywords exhibit strong link strength and connections and that there are comparatively more keywords overall that meet the criterion. It suggests that authors have used several commonly used terms that have been categorized by databases such as Scopus as their primary keywords. These terms can also be investigated, and it would be intriguing to look at how the presence of such terms and their inquiry in the relevant field affects the advancement of the field.

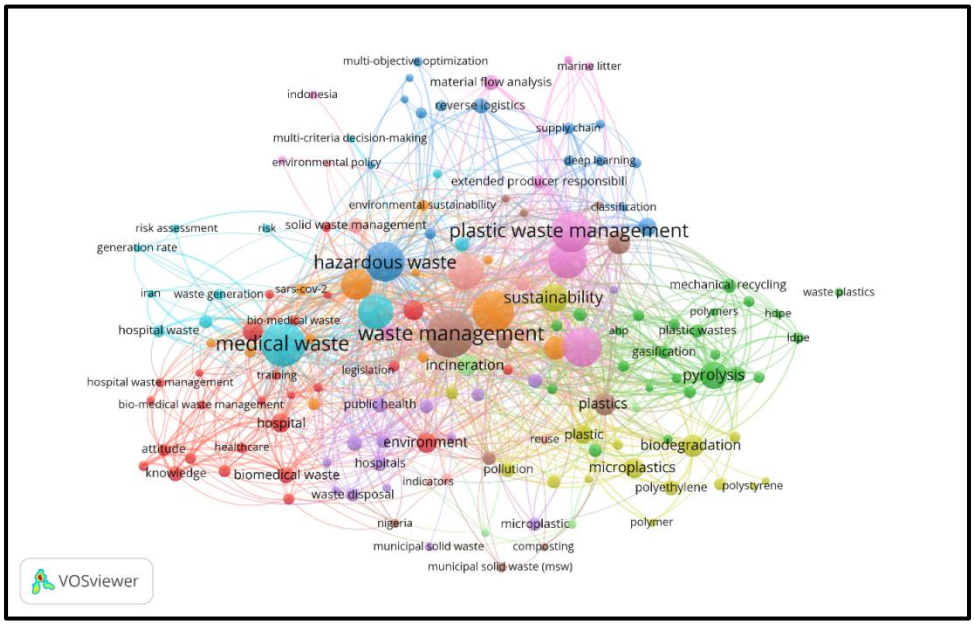

Figure 5: Author Keyword Co-occurrence

In the **Table 5**, the study provided top 10 author keywords that will be helpful for the future researchers in identifying relevant articles for their studies. Also including these keywords in article will helps in accessibility.

Table 5: Top 10 author keywords

S. No	Keyword	Occurrences	Total link strength
1	waste management	141	280
2	medical waste	127	239
3	plastic waste	109	199
4	plastic waste management	102	156
5	recycling	98	248
6	hazardous waste	97	137
7	circular economy	94	196
8	hazardous waste management	82	64
9	medical waste management	82	103
10	covid-19	63	119

Concerning **Table 5**, the current study found that waste management occupied first place with total strength of 280, stating that it has a strong connection with the other keywords. Medical waste and plastic waste occupied second and third position with 127 and 109 occurrences along with 199 and 156 link strength. However, Plastic waste management, recycling, hazardous waste, and circular economy

positioned at fourth, fifth, sixth and seventh places, but have 156, 248, 137 and 196 link strength which is higher than plastic waste. Simultaneously, medical waste management and hazardous waste management were comes next with slight variation in occurrence but medical waste management link strength is 103 which was much higher than hazardous waste management. Lastly, covid-19 occurrence is 63 but its strength 119 is greater than medical waste management whose position is 9th.

3.5.2 Indexed keywords with co-occurrence link

Indexed keywords are the terms used for indexing purposes, which were selected and stabilized by Scopus databases obtained from Elsewhere [38]. The mismatch of searched and indexed keywords will fail relevant data extraction. It will hinder the scientific community and consume much time with unrelated data [39.] Hence, we intended to find the indexed keywords with co-occurrence links used in waste management. It will provide an understanding of standard keywords for upcoming researchers to retrieve relevant information. **(Figure 6 & Table 6)**

Following are the criteria to retrieve indexed keywords

- Selected co-occurrence and indexed keywords.
- Minimum number of occurrences of keywords 20 times
- Out of 8887 keywords 201 meets the criteria

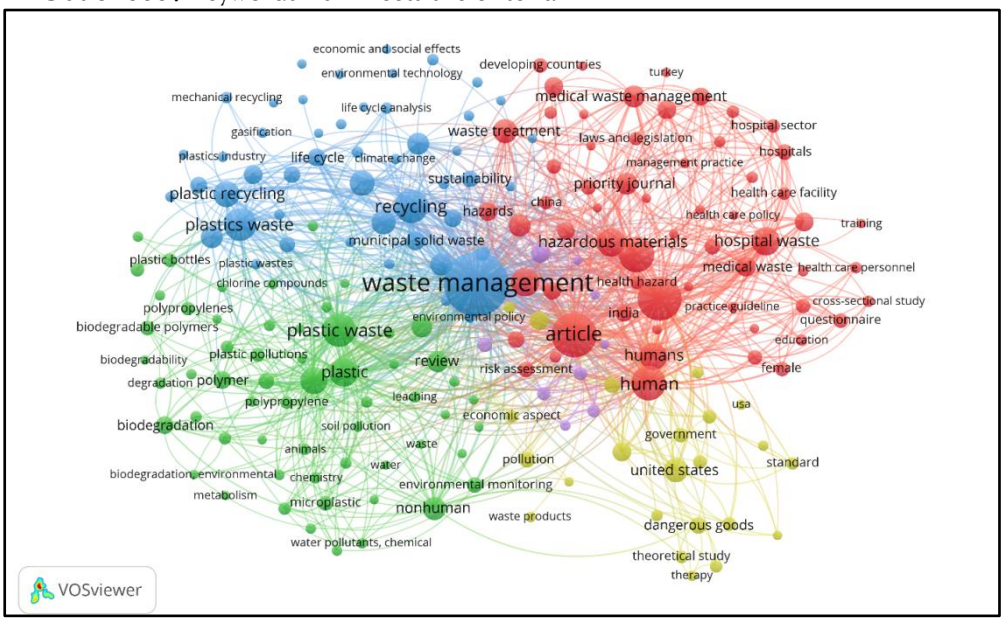

Figure 6: Indexed keywords co-occurrence

Figure 6 shows the connection strength between indexed keywords; if the distance is larger, the connection strength is less, and when the distance is small, the connection strength is high. **Figure 6** also represents various keyword clusters. Each color represents each cluster, and the higher the circle size, the more occurrences there are. The following table 3 shows the top 10 cited keywords with occurrence and connection strength.

Table 6: Top 10 indexed keyword

S. No.	Keyword	Occurrences	Total link strength
1	waste management	901	8403
2	article	440	5383
3	waste disposal	424	4414
4	hazardous waste	272	2589
5	human	266	3400
6	recycling	249	2934
7	plastic waste	241	3152
8	plastics waste	232	2388
9	hazardous materials	177	1403
10	hospital waste	177	2236

Table 6 shows that waste management is the most common keyword with strong connection strength; keywords like article and water disposal have a very low difference in occurrence. However, the strength of the "article" is higher than that of "waste disposal." Similarly, Hazardous waste and Human keywords

have slight variations in occurrence, but the link strength of humans is stronger than hazardous waste. The remaining keywords, such as recycling, hospital waste, hazardous materials, and hazardous waste management, simultaneously display a continuous reduction in occurrence and strength.

The top 10 less used keywords so that future researchers can understand that these keywords are less used which means they might not know to the users who are searching for information or these keywords might be ignored by the researchers; this will help as a gap for the researchers.

Table 7: Top 10 less occurred indexed keywords

S. No.	Keyword	Occurrence	Total Link strength
1	biodegradability	20	286
2	catalysis	20	258
3	chemical analysis	20	240
4	disinfection	20	306
5	economic analysis	20	225
6	environmental concerns	20	186
7	environmental economics	20	264
8	epidemiology	20	375
9	european union	20	198
10	global warming	20	252

Table 7 consists of keywords that occur less (as per minimum occurrence criteria of 20), and each keyword has a strength between 198 and 375. In the list of keywords, we can see several essential keywords in waste management, but they occurred a few times compared to other keywords in plastic, medical, and toxic waste streams. However, although the occurrence and connection strengths are less than others, they must be addressed. So, future researchers can use this keyword to contribute more theoretically and practically in this field.

3.6Term analysis

In contrast to the co-occurrence of authors and indexed keywords analysis, the current study is entirely different. Since they are arranged according to author or journal, the analysis will enable us to examine abstracts and titles that summarize the main idea and research findings. It will give upcoming researchers a place to look for pertinent literature.

The process of analysis as follows:

At first launched VOSviewer application and selected create option. Secondly, we chosen "create a map based on text data", this allows a researcher to find co-occurrence of keywords based on text data. Thirdly, the option called read data from bibliographic data files was opted as this research used scopus dataset. Once it done, authors inserted scopus dataset and proceed further. The next step involves in selection of title and abstract by excluding copyright statements and structures abstract labels. Later, the study chooses full count that counts occurrence of the terms. In order to provide better visualization, the minimum occurrence of the term "20" was places that lead to filtration of 608 out of 34102. After that among 608 items, only 365 were processed further based on relevant score generated by VOSviewer. Finally after exporting the resulted terms with cooccurrence and link strength, the authors got the network visualization diagram that shown below.

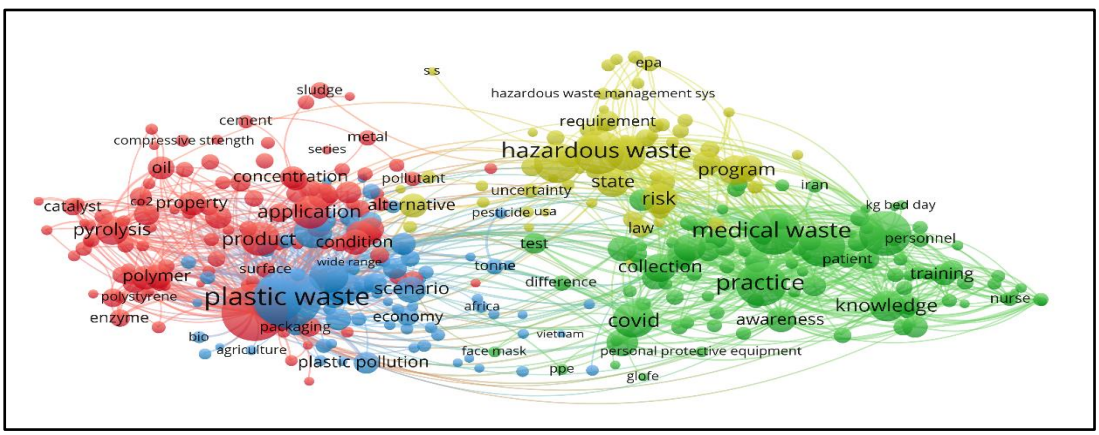

Figure 7: Analysis of Keywords

The top 10 terms that are generated from term analysis based on number of occurrences are shown in table 7

Table 8: Top 10 Terms based on occurrence

S. No	Term	Occurrences	Relevance Score
1	plastic waste	1024	0.6993
2	plastic	923	0.8464
3	medical waste	621	0.8950
4	hospital	592	1.5380
5	plastic waste management	570	0.7558
6	practice	564	0.7210
7	hazardous waste	559	0.5856
8	medical waste management	471	1.1624
9	hazardous waste management	455	0.4561
10	covid	374	0.4252

The terms plastic waste and plastic or occupied 1 and 2 places but the relevant score of plastic is higher than plastic waste. The third, fourth, fifth and sixth positions are captured by "Medical waste, Hospital, plastic waste management, and practice" with occurrence 621, 592, 570 and 564, however the term "hospital" have high relevant score of 1.5380 which is higher than all the other terms in the table. Finally, the seventh, eighth, ninth and tenth positions are acquired by "Hazardous waste, Medical waste management, Hazardous waste management and Covid". Additionally, the study also found that the terms such as practice is related to action towards waste management, so this study can say that most studies are targeted on practice in the waste management activities.

3.7Document citation analysis

Five distinct units of analysis—document, sources, authors, nations, and affiliation institution—can be used in bibliometric analysis to do citation analysis. However, analysing waste management trends and trajectory was the study's primary goal so the authors decided to employ the papers (document) for this investigation. **(Figure 8 & Table 9)**.

Below, the study provided the process as criteria to provide directions for the future researchers to dig deep into this research.

Criteria:

- Chosen "citation" and "document"
- Minimum number of citations of a document "20"
- Out of 1770 documents 451 meet the threshold

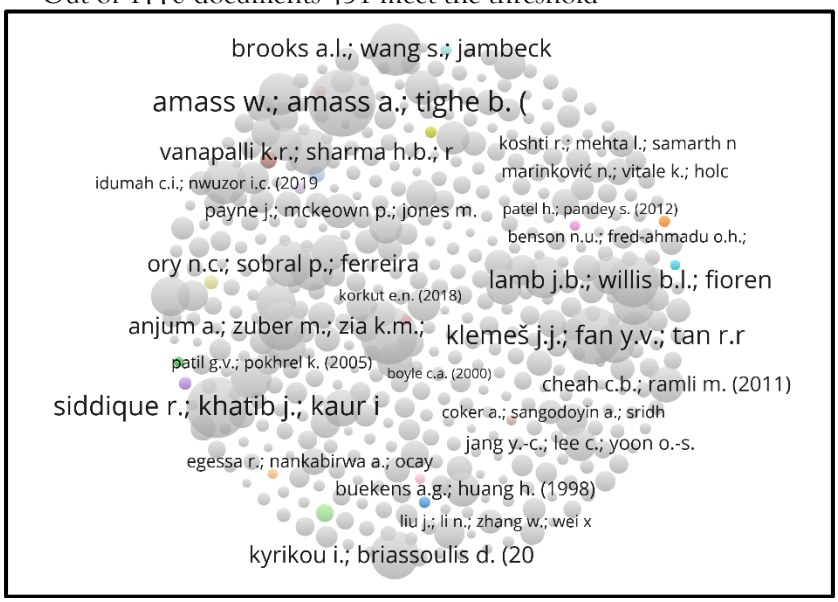

Figure 8: Document citation analysis

The network visualization diagram **(Figure 8)** shows multiple articles based on the number of citations; the size of each circle (node) shows the number of citations which means if larger the circle than the

citations are also more. However, there is no connection between articles, leads to lack of connected lines.

To gain better understanding, this research provided 5 highly cited articles with their citation count. Besides it will not present link strength as there is no connection between articles results in "0" in link column. I order to provide better research directions for future researchers, the study also providing DOI (Authors verified DOI with title)

Table 9: Top 5 Cited articles

S. No	Document	Citations
1	amass w.; amass a.; tighe b. (1998)	941
2	siddique r.; khatib j.; kaur i. (2008)	796
3	klemeš j.j.; fan y.v.; tan r.r.; jiang p. (2020)	693
4	panda a.k.; singh r.k.; mishra d.k. (2010)	686
5	brooks a.l.; wang s.; jambeck j.r. (2018)	574

When an article has a high number of citations, it indicates that it has been frequently referenced by other scientists in their research. This suggests that reading these highly-cited articles can offer valuable insights and may help clarify certain research-related issues, serving as a useful guide in the field.

3.8Author Bibiliographic Coupling

Bibliographic coupling is used to identify the links between the publications, which means two publications have a common third publication in their reference, known as a coupling strength of two provided publications. [40] In simple terms, a bibliographic coupling analyzes the conceptual relatedness with the help of common references between articles.[41-43] We intended to analyze the authors' bibliographic coupling to understand their relatedness based on the commonality of the references. For this, in Vosviewer, we followed a specific criterion, as shown below.

- Selected bibliographic coupling and authors
- Selected Minimum number of documents of an author "2". (if I select 1, it includes 1696 authors, or if 1 select 3, it gives 5 authors, so 1 selected 2 to get better results)
- Minimum number of citations of an author "10."
- Out of 1696 authors, 21 authors are filtered.
- However, among 21 authors, three authors are connected.

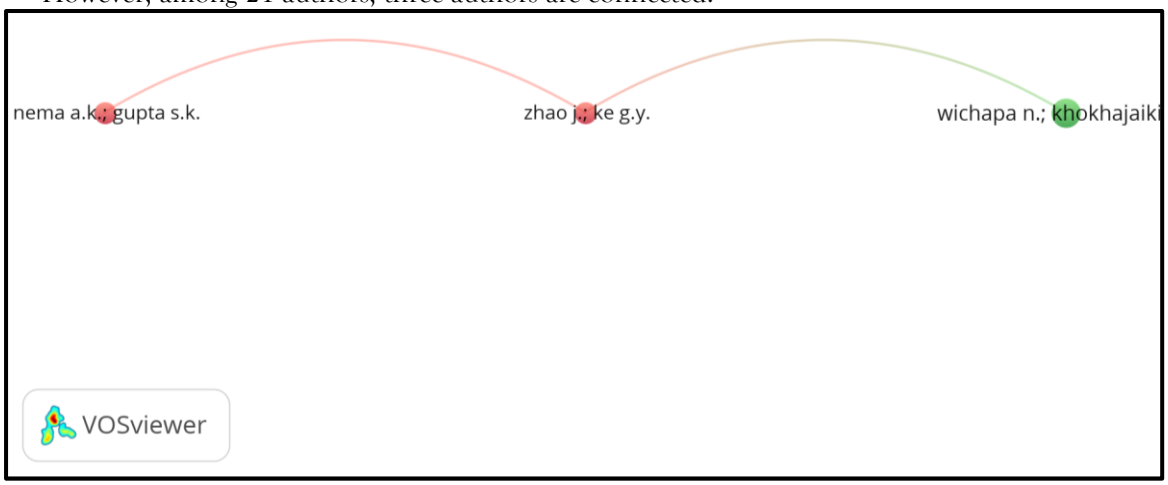

Figure 9: Bibliographic coupling of authors

With the help of this analysis, we found that "Zhao j.; ke g.y" had a similar reference with "Nema a.k.; gupta s.k" and "Wichapa n.; khokhajaikiat p" with link strength 2. Similarly, Nema a.k.; gupta s.k and "Wichapa n.; khokhajaikiat p" also have a connection with "Zhao j.; ke g.y" with 1 connection strength each, which was shown in the below table

Table 10: Authors bibliographic coupling

S. No	Author	Documents	Citations	Total link strength
1	zhao j.; ke g.y.	2	86	2
2	nema a.k.; gupta s.k.	2	210	1
3	wichapa n.; khokhajaikiat p.	3	59	1

4. Practical implications

Primarily, the study tries to cover literature as much as possible to provide a complete overview of waste management, particularly in medical, plastic, toxic and hazardous waste. So, researchers can use five decades of study to gain knowledge and track research trends. Furthermore, it helps find relevant articles and collaborate networks with prominent authors to enhance the quality of research. It also provided the top 5 highly cited documents, which will be added to do constructive research.

5. Abbreviations /Nomenclatures

Bibliographic Coupling: It occurs when two works reference a common third work in their bibliographies.
GHG Emissions: Greenhouse Gas Emissions
Indexed Keywords: The terms used for indexing purposes
IT Tools: Information Technology Tools
MS Office 365: Microsoft Office 365
Network Visualization Diagram: A data visualization method that allows users to easily understand relationships
Scopus: A multidisciplinary abstract and citation database
VOS Viewer: A software tool for constructing and visualizing bibliometric networks
Web of Science: A platform that provides access to multiple databases in data.

6. CONCLUSIONS

The current study scrutinizes the trajectory of research in waste management spanning from 1974 to 2024, leveraging the Scopus database and specific keywords. Over the past five decades, this field has witnessed a surge in research activity, with a notable proliferation of publications. Our analysis encompasses 1770 articles authored different scholars from diverse institutions across 136 nations. In delineating emerging trends, we identify seven pivotal keywords that wield substantial influence over the waste management landscape (**refer to Table 1**). These keywords serve as compass points guiding research endeavours and contribute significantly to unravelling the complexities of this environmental challenge.

An evolving discourse on methodologies, tools, and strategies underscores the imperative of waste management. Collaboration emerges as a hallmark of research efforts, with interdisciplinary cooperation spanning multiple authors, organizations, and countries. As we confront escalating environmental pollution, the imperative for further scholarly inquiry, spearheaded by researchers, scientists, and institutions, becomes increasingly pronounced. The future promises a heightened commitment to unravelling the intricacies of waste management, driven by an unwavering dedication to safeguarding our planet.

7. LIMITATIONS AND FUTURE DIRECTIONS

This study has various limitations

- At first is only focused on plastic, toxic and medical waste, so it suggests future researchers to focus on other fields, also considering long period of times in those fields will be add on advantage.
- Second, the study limited to English language, including other languages in research will contribute more in this field.
- Third, the study only used VOSviewer and MS office 365 for analysis, taking support from other application such as R studio will add addition benefits for the research
- Fourth, it performed few analyses using VOSviewer, future researchers can conduct other analysis such as bibliographic coupling of authors, sources and more.
- Fifth, for the current analysis only scopus was used, so using other database for research is also needed.
- Sixth, it is limited to limited to bibliometric analysis including other analysis along with this will provide better findings.

This article delves deeply into the complexities of waste management, offering comprehensive insights that are valuable to young researchers aiming to contribute to sustainable development goals. By exploring various aspects of waste management, from innovative technologies to policy implications, this study equips researchers with essential knowledge to address pressing environmental challenges. The findings presented here underscore the importance of effective waste management strategies in

mitigating environmental impact and fostering sustainable practices. Moreover, this research serves as a catalyst for further exploration and innovation in waste management methodologies, encouraging the development of practical solutions that align with global sustainability objectives. Overall, the article aims to inspire a new generation of scholars and practitioners to engage critically with waste management issues, driving forward meaningful contributions towards sustainable development.

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