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Mapping of Research Output on Medical Waste Management: A Bibliometric Study

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Abstract:

This paper aims to analyze a bibliometric study mapping of research output on Medical Waste Management (MWM). All articles relevant to MWM research have been retrieved using the Web of Science (WOS) database. Bibliometric analysis for co-citation, linking, scientific collaboration analysis, co-word analysis and visualizing bibliometric networks were used by many important bibliometric tools, such as Biblioshiny, ScientoPy and VOSviewer. The study's key results were that 944 research paper published in 2001-2020. The results show publications of medical waste management gradually increased but the average number of citation are not increased. The USA is a top of the list among the countries with 215 publications, 5112 citations and 331 total link strength. The Peoples R China on 2nd rank with 104 publications and 1715 citations; The University of Northampton (England) is on the top of the list with 16 publications, 227 citations and total link strength 97 where as the University Tehran Medical Science (Iran) occupy the 2nd rank with 16 publications, with 124 citations. The Journal "Waste management" is highly influential journal, producing maximum 78 publications, 2867 citations, 33 H Index, 51 G Index and 1.83 M Index. Whereas "Waste management & research" is on the 2nd rank with 70 publications, 979 citations 19 H Index, 24 G Index and 1 M Index. The top six keywords are (Medical Waste, Waste Management, Waste, Management, Healthcare Waste, and Hospital) have strong relation with top 10 countries. The UK emerged top collaborator with Italy (11 publications), followed by the USA with China (10 publication), USA with UK (10 publication).

Keywords: Medical Waste, Medical Waste Management, Bibliometrics, Trend Analysis, Factor Analysis

Introduction

Waste material is stated as medical waste that has been solid or liquid derived from the hospital activities at containing pathogenic microorganisms, chemicals toxic and radioactive materials. The medical waste volume is not as much as domestic waste, however, it has a greater negative impact on the environment and human health. medical waste becomes more need attention, as compared to other waste for medical waste, consists of pieces of human bodies, the blood waste, body fluids, infusion bottles, antibiotics residual, drug waste, needles used, radioactive fluids and discharges laboratories, as well as expired medicines, was. In order to look at the composition of the medical

waste, it is classified into hazardous and toxic waste.(Muliarta, 2016) The management of medical waste has been of major concern due to potentially high risks to human health and the environment. In the past, medical wastes were often mixed with household wastes and disposed in municipal solid waste landfills.(Shareefdeen, 2014) There is growing awareness worldwide of the need to impose stricter controls on the handling and disposal of wastes generated by health care facilities. In developed countries, legislation and good practice guidelines define medical wastes and state the various possible ways for collection, transport, storage and disposal of such wastes. Also, the best available technologies are used for the development of alternatives for proper disposal of medical wastes with minimal risks to human health and the environment.(El-salam, 2010)

Bibliometric analysis is used as a tool for mapping published scientific research records. Nowadays, it is widely recognized as a method to evaluate research in a particular area. Bibliometric analysis is also an essential approach to identifying the research trends in an area.(Bador, Abdel-Magid, Ahmad, & Akhter, 2020) Therefore, the main aim of the present study is to evaluate global scientific literature on of MWM. This study combined MWM bibliometric study with modern visualization techniques to get a clear picture of global MWM research output.

Literature Review

(Jin, Yuan, & Chen, 2018) Sustainable treatments of construction and demolition (C&D) wastes have become an increasingly urgent social, environmental, and economic issue worldwide. Based on a filter of 370 articles related to C&D waste management, this review-based study adopted a science mapping approach to evaluating the recent decade's C&D waste management research. Through a three-step workflow consisting of bibliometric literature search, scientometric analysis, and qualitative discussion, this study identified the most influential journals, scholars, articles, and countries that have been active and influential in the C&D waste management research since 2009.(Chen & Jiang, 2015)In this study, a bibliometric approach is applied to identify global trends related to the waste management (WM). As a key topic for environmental protection and resource utilization, WM has received considerable attention in the scientific community over the past decades, reflecting by the vast peer-reviewed articles on WM can be retrieved by accessing the web of science database. The implications for current trends and recent hotspots were presented and discussed. Furthermore, a contrastive analysis between the topics of concern in the industrialized and developing countries was carried out.(Chen et al., 2015)This study uses a bibliometric approach to identify global trends related to the municipal solid waste (MSW). The research outputs of MSW had steadily increased in the field of energy fuels, engineering chemical and biotechnology applied microbiology, especially environmental sciences and engineering environmental. The predominance of Chinese institutions in terms of article count and a predominance of industrialized countries' institutions in terms of citation score were compared. (Zyoud et al., 2015)The aim of this study was to assess the volume and impact of Arab scientific output published in journals indexed in the Science Citation Index (SCI) on solid waste. Despite the expected increase in solid waste production from Arab world, research activity about solid waste is still low. Governments must invest more in solid waste research to avoid future unexpected problems. Finally, since solid waste is a multidisciplinary science, research teams in engineering, health, toxicology, environment, geology and others must be formulated to produce research in solid waste from different scientific aspects.(Yang, Chen, Liu, Wan, & Wang, 2013)Municipal solid waste (MSW) management in China draws particular attention as China has become the largest MSW generator in the world. The paper analyzed the growth and development of MSW research productivity in China in terms of publication output as reflected in science citation index for the period 1997–2011. The study revealed that the output of MSW research in China has rapidly increased over the 15 years in contrast with USA. The results could help

researchers understand the characteristics of research output and search hot spots of MSW field in China.(Fu, Ho, Sui, & Li, 2010)study is a bibliometric analysis of solid waste research to evaluate the current trends, using the literature in the Science Citation Index (SCI) database from 1993 to 2008. The most common subject category is environmental science and the most productive journal is Waste Management. The USA with most publications and China with the highest growth rate were compared. Finally, author keywords, words in title, and 'Keywords Plus' were analyzed to provide research emphasis, the results showed that mainstream research was centered on the following methods: recycling, land filling, composting and waste-to-energy. Heavy metals, fly ash and sewage sludge were considered recent research hotspots.

Objectives

1. To identify the publishing trends in medical waste management.
2. To identify the most productive countries, organizations, and authors.
3. To identify the preferred journals of researchers in medical waste management.
4. To explore the most frequently used keywords and co-occurrence network in medical waste management
5. To identify the highly influential research papers concerning citation count on medical waste management.
6. To find out the relationship exists based on three-factor analysis (countries, keywords, organizations).
7. To find out the Country collaboration Map of medical waste management researchers.

Methodology

This paper is based on the Web of Science (WoS) web database, Science Citation Index Expanded (SCI-E). To analyze the global research output of MWM literature, data were retrieved from the Web of Science database, and the current research analysis used bibliometric and visualization techniques. Web of Science database was selected as it is one of the largest and core bibliometric databases of peer reviewed scientific literature. The search date denoted 07/02/2021. The content of the search is TS= (medical waste or medicine waste) AND (medical waste management)). The data was retrieved from 2001-2020 and the process produced total 944 documents published in different type document, this is related to the article, book chapter, article; book chapter proceedings paper, article; proceedings paper, editorial material, letter, review. The data analysis was performed with MS Excel, Biblioshiny, ScientoPy and VOSviewer software.

Analysis of the overall growth trend

Figure 1 shows the year wise frequency of publications and citations published from 2001 to 2020. There were 944 documents published by 497 journals, written by 3611 authors, affiliated with 1346 institutions and 74 countries.

Analysis of the overall growth trend is portrayed in Figure 1. This has been done for numbers of total publications between 2001 and 2020 is presented. It shows that 2001 was the starting year for research publication on MWM. The trend shows that publication and citation have not gradually increased. Publication of MWM gradually increased but average numbers of citation are not increased. The years 2001-2007 were disappointing years as there were very less publications in those periods and between the years 2015-2019 significant growth has been observed. In the year 2020 marvelous as in that year's highest number of research publications were produced. Trend shows that the 2001-2007 were minimum average citation in that period and in the year of 2009

maximum. The trend shows that in the year 2010- 2016 average growth has been observed and then 2017 again increased. The years 2018-2020 were disappointing years as there number of citation were up and down.

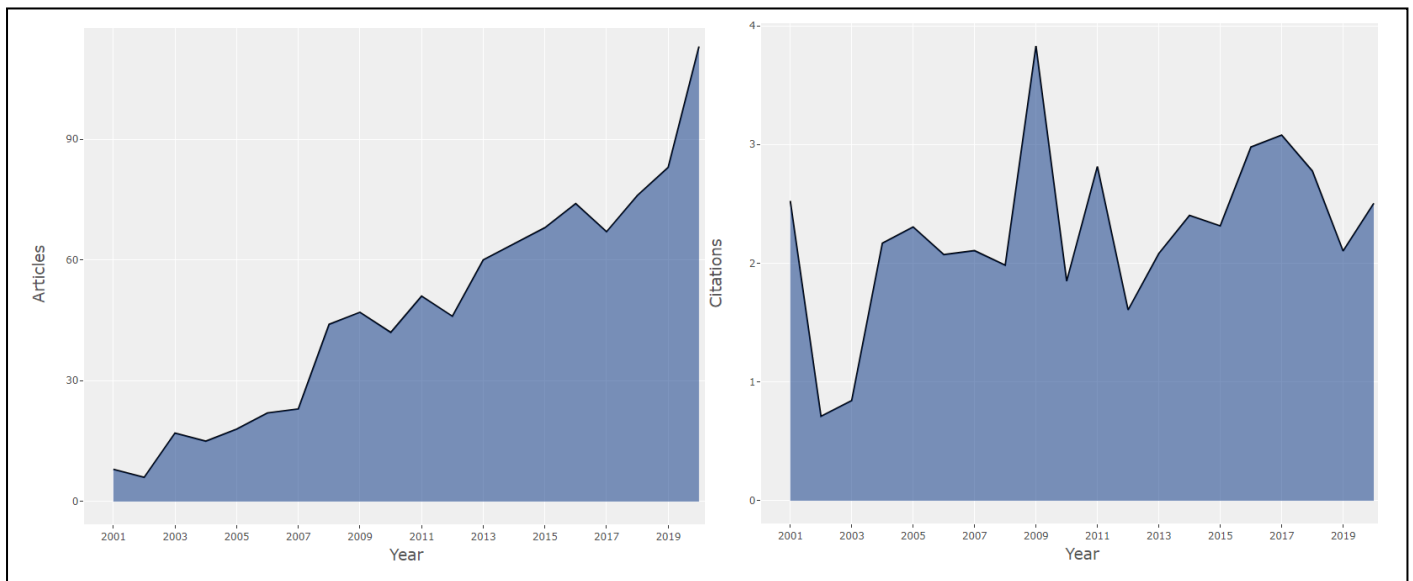


Figure 1: Publication and citation trend on medical waste management (2001-2020)

Top Twenty Influential Countries on Medical Waste Management

Top twenty (20) highly publishing countries on MWM literature were as presented in Table 1. The result shows that the USA is a top of the list with 215 publications, 5112 citations and 331 total link strength. The Peoples R China on 2nd rank with 104 publications and 1715 citations; however, it received highest total link strength (691). England is on 3rd rank with 90 publications with 2457 citations and total link strength with 539 which is better than USA's total link strength (331). The result shows that the Iran and India two countries ranking 4th and 5th position. Jordan and Bangladesh are on the bottom of the list, with 5 and 8 publications, respectively.

Table 1: Top Twenty Influential Countries on Medical Waste Management Literature

Country	TP	TC	Total Link Strength
USA	215	5112	331
Peoples R China	104	1715	691
England	90	2457	539
Iran	59	588	497
India	57	1031	248
Brazil	43	512	280
Turkey	41	795	336
Italy	38	674	222
Japan	33	430	255
Taiwan	32	428	147
Greece	29	435	267

South Korea	21	441	207
Canada	20	477	100
Pakistan	18	179	214
Malaysia	16	234	148
Egypt	9	148	93
Israel	9	124	115
Nigeria	9	154	83
Bangladesh	8	222	100
Jordan	5	215	153
Key: TP = total publication, TC = total citation			

Top Twenty Highly Productive Organizations

Top twenty (20) organizations producing research publications on MWM are given in Table 2. It shows that University of Northampton (England) is on the top of the list with 16 publications, 227 citations and total link strength 97. University Tehran Medical Science (Iran) on 2nd rank with 16 publications, 124 citations and total link strength 97; however, it received same publication and citation like University of Northampton (England) only difference between two intuitions are total link strength. Democritus University Thrace (Greece) on 3rd rank with 11 publications, 190 citations and total link strength 66. Followed by University of Sao Paulo (Brazil), with 11 publications, 140 citation and total link strength 54; Southeast University (China), with 11 publications, 177 citation and total link strength 98.

Table 2: Top Twenty Highly Productive Organizations

Organization	TP	TC	Total Link Strength
University Northampton	16	225	97
University Tehran Medical Science	16	124	97
Democritus University Thrace	11	190	66
University Sao Paulo	11	140	54
Southeast University	11	177	98
Beihang University	9	13	38
Shiraz University Medical Science	9	129	66
Tabriz University Medical Science	8	165	75
Birzeit University	7	75	70
University Brescia	7	113	81
University Tokyo	7	131	46
Aristotle University Thessaloniki	6	104	34
Chinese Acad Science	6	205	24
Hellen Open University	6	83	35
Jordan University Science & Technology	6	261	95

University Exeter	6	208	40
University Sains Malaysia	6	167	30
China Med University	5	106	33
Iran University Medical Science	5	49	64
Yildiz Technology University	5	128	59
Key: TP = total publication, TC = total citation			

Top Twenty Most Prolific Authors

Table 3 highlights the top twenty (20) most prolific authors on MWM; based on their total publications, total citations, G Index, H Index and M Index. The list of most prolific authors shows that Tudor T.I. is the most productive authors with 10 publications, 251 citations, 10 G Index, 9 H Index and 0.529 M Index. Followed by Liu H., Tudor T. and Yao Z. with 8 publications each but total number of citation, G Index, H Index and M Index are different. It is noted that Aguayo V.M. is the bottom of this list with 4 publications. It is also observed that maximum number of authors has 4 to 6 publication and G Index, H Index and M Index are minimum difference.

Table 3: Author Impact

Author	TP	TC	G Index	H Index	M Index
Tudor T.I.	10	251	10	9	0.52
Liu H.	8	12	3	3	0.6
Tudor T.	8	106	8	5	0.38
Yao Z.	8	12	3	3	0.6
Al-Khatib I.A.	7	75	7	5	0.31
Vaccari M.	7	113	7	5	0.71
Ali M.	6	100	6	5	0.35
Askarian M.	6	133	6	5	0.27
Komilis D.	6	109	6	5	0.45
Ab Kadir M.O.	5	64	5	5	0.5
Ab Rahman N.N.	5	64	5	5	0.5
Hossain M.S.	5	166	5	5	0.45
Kumar A.	5	30	5	3	0.37
Kuroiwa C.	4	53	4	3	0.17
Mol M.P.G.	5	18	4	3	0.6
Singh K.	5	354	5	4	0.36
Taghipour H.	5	114	5	3	0.23
Wang J.	5	34	5	3	0.5
Yan J.H.	5	72	5	4	0.30

Aguayo V.M.	4	62	4	4	0.5
Key: TP = total publication, TC = total citation					

Highly Influential Research Journals

The journals impact in respect of number of publications and citations including are highlighted in Table 4. It shows that the Journal “Waste management” is highly influential journal producing maximum 78 publications, 2867 citations, 33 H Index, 51 G Index and 1.83 M Index. “Waste management & research” is on 2nd rank with 70 publications, 979 citations 19 H Index, 24 G Index and 1 M Index, followed by “Fresenius environmental bulletin” with 17 publications, 21 citations, 3 H Index, 4 G Index and 0.15 M Index. Its shows that rest of the other journals in the list were minimum number publications. The "Journal of Environmental Health Science and Engineering" is at bottom of the list and has produced 6 publications and received 41 citations 4 H Index, 6 G Index and 0.44 M Index.

Table 4: Top Twenty Highly Influential Research Journals

Source	TP	TC	H Index	G Index	M Index
Waste management	78	2867	33	51	1.83
Waste management & research	70	979	19	24	1
Fresenius environmental bulletin	17	21	3	4	0.15
Journal of cleaner production	15	170	8	13	1
Health physics	14	36	4	4	0.19
International journal of environmental research and public health	14	67	4	8	0.4
Journal of material cycles and waste management	14	149	8	12	0.61
Science of the total environment	14	652	7	14	0.43
Resources conservation and recycling	12	246	8	12	0.53
Iranian journal of public health	10	26	4	5	0.4
Journal of hazardous materials	9	302	8	9	0.53
BMC health services research	8	51	4	7	0.36
Journal of environmental management	8	431	8	8	0.5
BMC public health	7	108	5	7	0.35
Chemosphere	7	91	6	7	0.42
Environmental engineering and management journal	7	29	4	5	0.33
Journal of environmental protection and ecology	7	53	4	7	0.25
Sustainability	7	5	1	2	0.25
American journal of infection control	6	90	5	6	0.23

Journal of environmental health science and engineering	6	41	4	6	0.44
Key: TP = total publication, TC = total citation					

Co-Occurrence Network of Author Keywords

Frequently used authors' keywords in MWM research are highlighted in Figure 2. The keywords analysis has been performed in VOSviewer software. The minimum number of 5 keywords occurrence is selected and hence only 70 keywords meet the threshold out of total 2745 keywords. The distance and size of the bubble indicates the number of keyword occurrence and associational links. 'Medical Waste' is the most frequently and representative keyword as it appears 154 times followed by 'Waste Management' that appear 100 times, 'Incineration' and 'Healthcare Waste' both keywords are appear 31 times, 'Infectious Waste' that appear 25 times.

Additionally, we also generated the most frequent keywords in last 20 years to observe the latest trends in MWM research. The result presented at figure 3 shows that 'Medical Waste', 'Waste Management', Healthcare Waste', 'Waste', 'Management' are the main keywords that are repeated most frequently in MWM literature from 2001 to 2020.

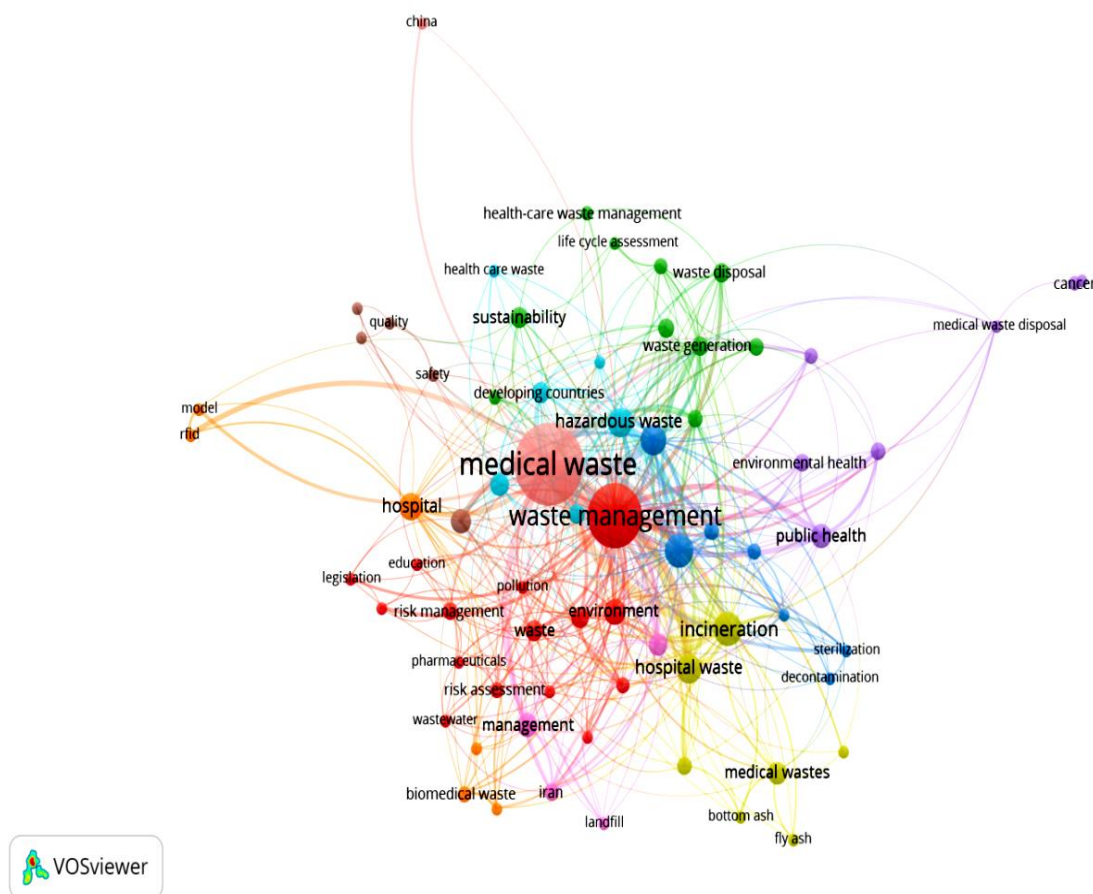


Figure 2: Co-Occurrence Network of Author Keywords

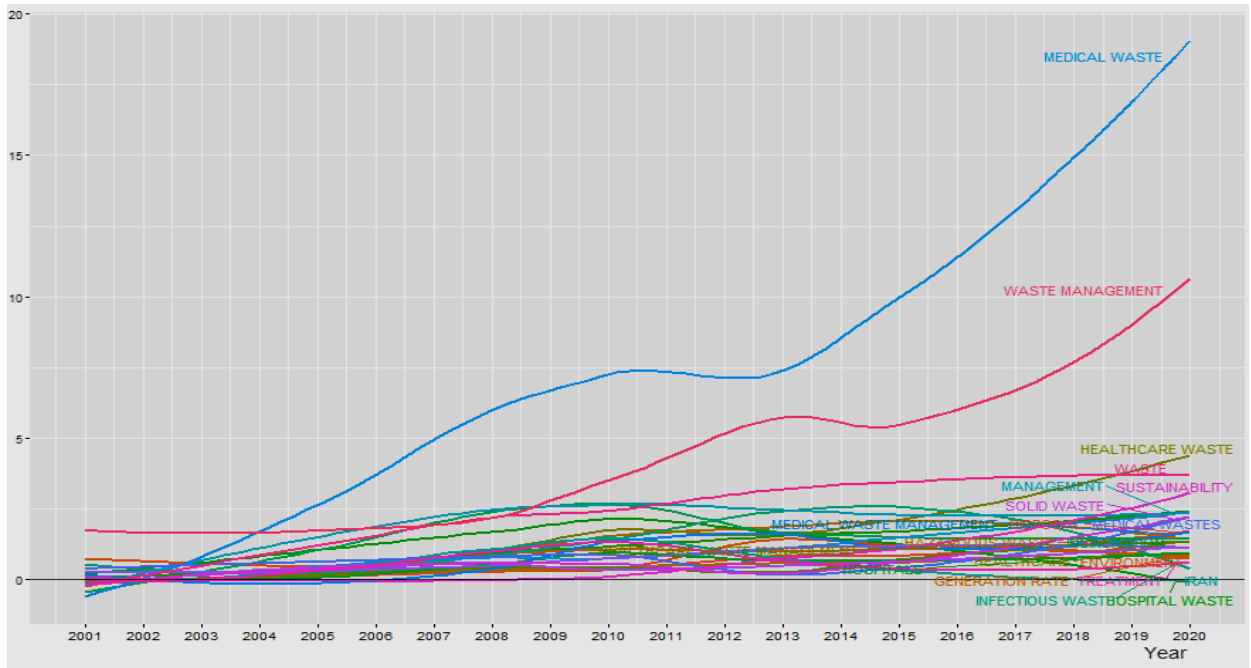


Figure 3: Author Keyword Analysis (2001-2020)

Term Analysis

Frequently used all keywords in MWM research are highlighted in Figure 4. The keywords analysis has been performed in VOSviewer software. The minimum number of 5 keywords occurrence is selected and hence only 222 keywords meet the threshold out of total 4776 keywords. This term 'Management' is the most frequently and representative keyword as it appears 277 times followed by 'Medical Waste' that appear 223 times; 'Waste Management' that appear 107 times; 'Disposal' that appear 80 times; 'Hospitals' that appear 66 times.

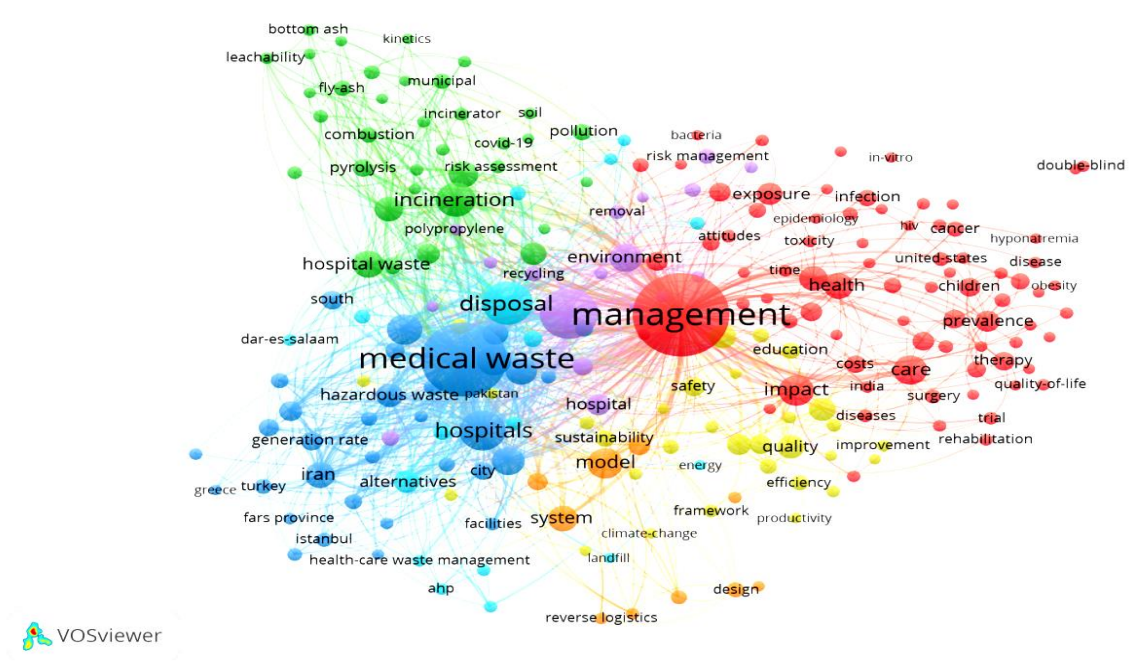


Figure 4: Term Analysis

Top Twenty Highly Cited Articles

The bibliographic information of top twenty (20) most cited articles is indicated in Table 5. There are five articles in this list that received more than 250 citations. The publications years' range is between 2001 to 2016 and majority of the articles in this list are published after 2005. The articles entitled "Plastics, the environment and human health: current consensus and future trends" by Richaer C.H. published in 2009 in "The Royal Society" is on the top of the list with 885 citations. It is noted that "Characterization of medical waste from hospitals in Tabriz, Iran" is the bottom of this list, written by Taghipour H. published in 2009 in "Science of the total environment" with 100 citations. It's observed that total six article published from "Waste management", that is highest number of article published from one journal.

Table 5: Highly Cited Top 20 Articles

Paper	Author	Source title	Year	TC
Plastics, the environment and human health: current consensus and future trends	Richaer C.H.	Philosophical transactions of the royal society	2009	885
Industrial applications of crustacean by-products (chitin, chitosan, and chitooligosaccharides): A review	Imen H.	Trends in food science and technology	2016	317
Organic chemicals in sewage sludges	Harrison E.Z.	Science of the total environment	2006	315
Removal of synthetic textile dyes from wastewaters: A critical review on present treatment technologies	Singh K.	Critical reviews in environmental science & technology	2011	292
A prospective survey of nutritional support practices in intensive care unit patients: What is prescribed? What is delivered?	De Jonghe B.	Critical care medicine	2001	254
Selenium: environmental significance, pollution, and biological treatment technologies	Tan L.C.	Biotechnology advances	2016	145
Alternatives for treatment and disposal cost reduction of regulated medical wastes	Lee B.K.	Waste management	2004	143
Engaging Physicians and Consumers in Conversations About Treatment Overuse and Waste	Wolfson D.	Academic medicine	2014	133
Information centric services in Smart Cities	Piro G.	Journal of system and software	2014	133
Medical waste management in Korea	Jang Y.C.	Journal of environment management	2006	122
Medical waste management – A review	Windfeld E.S.	Journal of environment management	2015	120
Medical wastes management in the south of Brazil	Da Silva C.E.	Waste management	2005	118

Clinical solid waste management practices and its impact on human health and environment – A review	Hossain M.S.	Waste management	2011	115
Medical wastes characterisation in healthcare institutions in Mauritius	Mohee,R.	Waste management	2005	113
Medical waste management in Turkey: A case study of Istanbul	Birpinar M.E.	Waste management	2009	111
Treatment of organic waste using thermal plasma pyrolysis technology	Huang J.H.	Energy conversion and management	2004	108
What are the most effective strategies for improving quality and safety of health care?	Wolf L.	Internal medicine journal	2012	106
Assessment of medical wastes management practice: A case study of the northern part of Jordan	Bdour A.	Waste management	2007	105
Hazardous waste generation and management in China: A review	Duan H.B.	Journal of hazardous materials	2008	102
Characterization of medical waste from hospitals in Tabriz, Iran	Taghipour H.	Science of the total environment	2009	100
Key: TC = total citation				

Three-Factor Analysis (Country, Keyword and Organization)

Three -Factor Analysis (Country, Keyword and Organization) in MWM research are highlighted in Figure 5. The three-factor diagram has been generated of top 10 keywords, countries, and organizations on literature MWM research. The size of the block shows the associational relationship with each factor. The top six keywords (Medical Waste, Waste Management, Waste, Management, Healthcare Waste, and Hospital) have strong relation with top 10 countries. Accordingly, other keywords have minimum relation with countries. The keyword ‘Medical Waste’ has strong relation with top 10 countries and organization and ‘Hazardous waste’ has less relation with top 10 countries and organization.

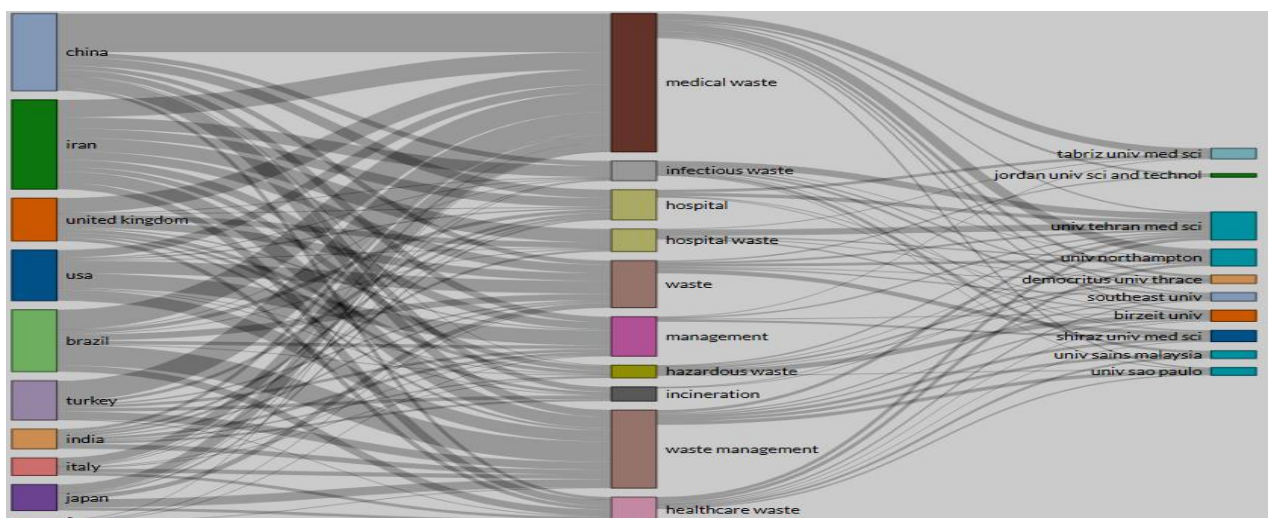


Figure 5: Three-factor analysis of relationship among Country (left), Keyword (middle), and Organization (right)

Country Collaboration Map

Figure 6 shows the Country Collaboration Map on MWM research. The UK emerged a top collaborator with Italy (11 publications), followed by USA with China (10 publication), USA with UK (10 publication), China with Pakistan (7publications) and others. The least collaborator countries among 20 collaborators were Australia with Bangladesh (2 publications)

Country Collaboration Map

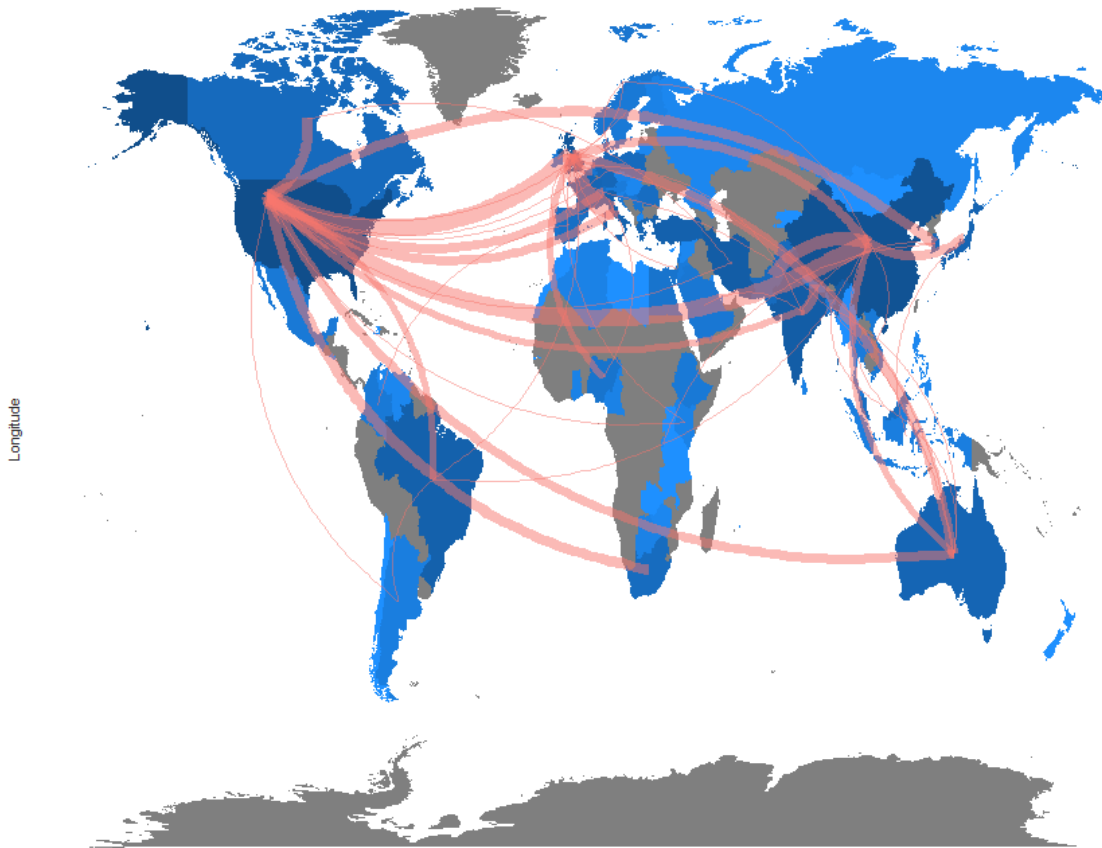


Figure 6: Country Collaboration Map

Conclusion

The current research review used bibliometric and visualization methods to analyze the literature on MWM published in the Web of Science during 2001-2020. Computer packages biblioshiny, ScientoPy, Excel, and VOSviewer were used for data processing and extraction of bibliometric indicators. An overview of the research in the MWM field was presented with the information related to most productive countries, organizations, and authors; preferred types of sources of researchers; most frequently used author keywords; co-occurrence network in MWM research; citations and use of influential research; top-ranked papers; Three-Factor Analysis (Country, Keyword and Organization); Country collaboration Map based on collected data.

Total of 944 document forms were examined from different sources during the research. USA is noted for the higher rate of total publications, total citations, but Peoples R China ranked the highest for the total link strength. The University of Northampton (England) and University Tehran Medical Science (Iran) are observed to be a highly research-producing organization on MWM. Tudor T.I. was noted to have the most prolific author impact through total publications, citations influence, G index, H index and M index. ‘Waste management’ is observed to be a highly research influencing journal through total publications, citations influence, G index, H index.

'Medical Waste' is the most frequently and representative keyword as it appears in MWM research. The article 'Plastics, the environment and human health: current consensus and future trends' received the highest globally citation among twenty articles. The map of country collaboration suggested a major collaboration between the fringes of USA with China and USA with UK. Generally this study's results have shown that the proportion of MWM research is on the rise.

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