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Review

Greenhouse Gas Emissions from Landfills: A Review and Bibliometric Analysis

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Abstract: The landfill is an important method of disposal of municipal solid waste. In particular, the landfill is especially vital in many developing countries, with it being the main biodegradable waste disposal method due to its simple management and ability for mass manipulation. Landfills have recently been shown to be an important source of greenhouse gas (GHG) emissions by researchers in different countries. However, few reviews have been conducted within the related fields, which means that there is still a lack of comprehensive understanding related to relevant study achievements. In this study, a bibliometric analysis of articles published from 1999 to 2018 on landfill GHG emissions was presented to assess the current trends, using the Web of Science (WOS) database. The most productive countries/territories, authors and journals were analyzed. Moreover, the overall research structure was characterized based on co-cited references, emerging keywords and reference citations by means of bibliometric analysis. Due to the increasing amount of attention being paid to the GHG emissions and their mitigation methods, this study provided comprehensive bibliometric information on GHG emissions from landfills over the past two decades and highlighted the importance of the development and dissemination of updated knowledge frameworks.

Keywords: bibliometric analysis; greenhouse gas; landfills; CiteSpace

1. Introduction

At the beginning of the twentieth century, the simple dumpsite was the most common method for the disposal of solid waste. However, concomitant environmental problems have become increasingly serious. In the 1930s, the concept of a "sanitary landfill", which originated from the United States of America, emerged [1]. Previous environmental problems that were associated with simple dumpsites seemed to be greatly eased as a result of this concept. However, with the explosion of the population and waste generation per capita, the generation of municipal solid waste (MSW) increased dramatically, which created new problems [2]. Landfills became an important contributor to anthropogenic climate change, accounting for approximately 5% of global greenhouse gas (GHG) emissions [3].

GHGs, such as CH_4, N_2O and CO_2, are produced from the aerobic and anaerobic biodegradation of MSW. CH_4 generated in a landfill is the largest source of GHGs, accounting for 1–2% of total GHG emissions [4]. The second largest sources are CH_4 and N_2O emissions produced in leachate treatment systems [5]. Extensive studies on GHG emissions from landfills have been conducted and aim to utilize CH_4 and reduce other GHGs generated from landfills. Although barriers still exist, some achievements have been made with the development of innovative technologies and equipment [6]. Firstly, numerous field measurements and laboratory studies have been conducted, which revealed the factors that influence the characteristics of GHG emissions [7–10]. The quantity of GHG emissions from landfills is influenced by multiple factors, including landfill volume, organic content, moisture, temperature and the age of the waste. The major factors that influence GHG production differ in the different stabilization stages of MSW [11]. After focusing on the estimation of GHG emissions and their influential factors, the literature began to concentrate on the in-situ treatment of GHGs. Landfill gas (LFG) treatment systems vary with time and depend on the manner in which the landfills are designed, operated and regulated [12]. The majority of the current treatments fall into four categories: flaring, absorption, permeation and cryogenic treatments. The central treatments are physical adsorption, chemical adsorption, pressure swing adsorption, membrane separation and cryogenic separation [2]. Studies have summarized GHG generation from landfills from different perspectives and in different countries [13–16]. Due to the increasing interest in landfills environmental problems, numerous scientists have evaluated the research trends in this field [17]. However, there have only been a few attempts to gather data on scientific landfills research conducted worldwide using bibliometric analysis as introduced by Narin et al. [1]. Bibliometric analysis is a mathematical and statistical method to display up-to-date and on-going knowledge that has been applied in many disciplines of science and engineering [18–22]. This approach can evaluate the performance of each research topic and indicate the impact of authors or their contributions to their respective fields [23]. Researchers can select their fields of investigation more purposefully and feasibly through a bibliometric analysis. In addition, this approach is convenient to recognize academic collaborators and to identify appropriate institutes [6].

Although the research on the GHG emissions from landfills has covered many aspects, ranging from field measurements to emission reduction measures, it is still not systematic and detailed enough. In particular, no study has provided an overview of the relevant research outcomes in this field. In this study, the status and trends of studies on GHG emissions from landfills published during the period of 1999–2018 were analyzed. The review aims to help researchers to better understand the development of research in this area, identify the most cited scholars and papers and predict potential future research directions.

2. Data Sources and Methods

Undertaking a review of the literature is an important part of any research project. The researcher should both map and assess the relevant intellectual territory in order to specify a research question that can be used to further develop the knowledge base [24]. Structured literature reviews are typically completed through an iterative cycle of defining appropriate search keywords, searching the literature and completing the analysis [25]. In this study, a sequence of steps was taken for literature selection and a thorough assessment of landfill GHG emissions, with the aim of providing a general picture of the field [26]: (1) definition of the search criteria, keywords and time period; (2) selection of the Web of Science database; (3) adjustment and refinement of research criteria; (4) full export of results; (5) analysis of the information and discussion of the results. The academic publications on GHG emissions from landfills were collected in December 2018, using the Science Citation Index (SCI) of the Web of Science (WOS) database maintained by Clarivate Analytics. The topic search, which was referred to as the core dataset, was used and subsequently expanded through citation links. The keywords used were 'greenhouse gas' and 'landfill', and all literature was retrieved from the period of 1999–2018. To investigate the quality and quantity of articles in the relevant field, it is first necessary to establish which measurement index should be used in the bibliometric analysis [27]. The total number of articles and the percentage of articles in the dataset were first determined. Moreover, it was found that citation index counting would help to reduce the bias toward highly referenced fields, such as biomedicine and biochemistry, and to increase the range of subject matters covered by clusters [28,29]. Thus, the total citations (TC) and the average number of citations per paper (TC/P) were used in the assessment of source countries, key authors and productive journals. The h-index is defined as the maximum value of h such that the given author/journal has published h papers that have each been cited at least h times [30]. It is an author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar [31]. As a complement, this index was used in this paper to improve upon the simple investigations of the total number of citations and publications.

The key findings related to the core dataset were first highlighted before a more detailed study of the expanded dataset was conducted using various visual analytic functions implemented in CiteSpace [32,33]. CiteSpace, a Java-based software for visualization in science, was used to extract and identify the information on related literature before visualizing this information in the form of a co-citation network, which draws on article citations to reveal the structure of a field or fields [34]. Many software programs have been developed to visualize knowledge domains in recent decades, but CiteSpace is one of the most balanced and powerful packages [35]. The resultant network can be divided into clusters (i.e., groups of entities) such that entities within the same group are more similar to each other than they are to entities from different groups [32]. In this study, the co-occurrence networks of keywords and subject categories and co-citation networks of references and journals were produced and analyzed using CiteSpace [36].

3. Results and Discussion

3.1. Performance of Article Output

During 1999–2018, 1007 papers were identified as relevant literature, among which there were 785 articles (77.95% of the total) and 192 proceedings. The rest included reviews (7.35%), conference abstracts, editorial materials, news items, etc. Only the articles were taken into account because they usually provided more original research findings and included more information on authors and their affiliations. Moreover, to ensure the universality and authenticity of the data obtained, non-English writing publications were excluded [6]. After this screening process, 770 papers remained, which were subsequently used for bibliometric analysis by CiteSpace. The total number of citations was 12,860 over the period selected (1999–2018), and the average number of citations per publication was 17.29. The trends in the quantity of articles and citations identified by WOS that were related to GHG emissions from landfills in the last 20 years are shown in Figure 1. Due to increasing concern about climate change and the effects of global warming, GHG emissions have also emerged as a hot topic in research on source identification and management [37,38]. Hence, it is obvious that the numbers of published articles and citations about GHG emission from landfills clearly increased from 1999 to 2018, with two remarkable leaps in publications in 2008 and 2017, which reflects that more attention was devoted to this area during the past decade.

The GHG emissions were partially due to landfilling, which remains an effective primary treatment method for waste disposal in parts of developed countries and most developing countries. Thus, countries with the ability among them have dedicated themselves to undertaking frontier research in this field [39]. An analysis of the source countries of the articles shows that the USA had the most publications and had more substantial contributions to the quantity of publications and total citations (Table 1). According to the Intergovernmental Panel on Climate Change (IPCC), landfills remain the mainstream technology for the disposal of waste in the USA [5]. The USA Environmental Protection Agency (EPA) and numerous American scholars have estimated the amount of GHG emissions produced from waste treatment [40–43] and have developed new mitigation technologies, such as energy recovery [44], gas capture [45], biologically active cover [46] and microbial methane oxidation technology [47]. As one of the major developing countries, China had the second highest number of publications. In developing countries, such as China, due to the advantages of low costs and easy operation, 80% of MSW is landfilled or dumped [48]. Hence, the environmental impacts of GHG emissions from landfills have been highlighted, which was aided by the Kyoto mechanisms [49]. However, the TC and TC/P for China were relatively low, with high-quality articles remaining scarce. This is possibly due to the relative lack of scientific research capability compared with developed countries. Considering other indices, such as the TC/P and the h-index, the list appears to be more mixed, with other countries, such as Denmark, Australia, England and Canada, also playing a leading role in addition to the US. The striking case of Denmark, with a TC/P of 30.04, was partially due to a large number of citations of two articles, one on the life cycle assessment (LCA) of waste management systems [50] and the other determining the greenhouse gases and global warming contributions [51]. The high TC/P value of Australia was the result of multiple high-quality articles. Figure 2 shows the distribution of citations by country.

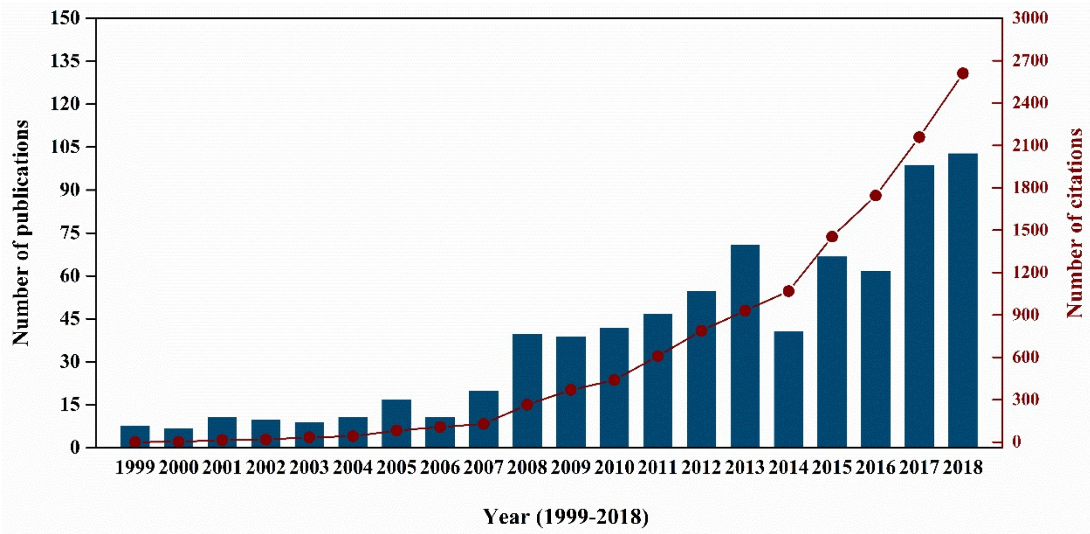


Figure 1. Trends in the quantity of articles and citations identified by Web of Science (WOS) that are related to greenhouse gas (GHG) emissions from landfills from 1999 to 2018.

Table 1. Top ten most productive countries in terms of relevant articles from 1999 to 2018.

	Country	*Pubs* [a]	% [b]	*TC* [c]	*TC/P* [d]	h-index
1	USA	183	23.77	3482	19.03	33
2	China	107	13.9	1363	12.74	21
3	Canada	63	8.18	1211	19.22	19
4	England	51	6.62	1302	25.53	22
5	Australia	46	5.97	1314	28.57	17
6	Italy	37	4.81	637	17.22	15
7	Japan	35	4.55	527	15.06	13
8	Spain	28	3.64	495	17.68	12
9	Denmark	26	3.38	781	30.04	17
10	South Korea	25	3.25	310	12.4	8

Note: *Pubs* [a] (Publication): total number of publications related to GHG emissions from landfills. % [b] (Percentage): percentage of publications relative to the total dataset of 770 papers. *TC* [c]: the total citations for a country. *TC/P* [d]: average number of citations per paper for a country.

Analysis of the country/territory information based on authors' affiliations could contribute to a better understanding of the distribution of countries studying the GHG emissions from landfills [36]. In this study, a total of 2484 different authors were identified, and they each published between one and 15 papers. Table 2 displays the top ten most productive authors, who published 10% of the total publications. According to the data, Mortan Barlaz and Peter Kjeldsen dominated the list of publications and citations. There are other relevant authors in this field, such as Charlotte Scheutz (7 h-index, 9 articles), Haslenda Hashim (6 h-index, 8 articles) and Martin Schroth (6 h-index, 8 articles) among others. Moreover, it should be noted that Peter Kjeldsen and Charlotte Scheutz were co-authors on many articles. Similarly, Hashim, Ho, Lee and Lim were also co-authors of a number of relevant articles. However, compared with other fields, there is still a lack of transdisciplinary and interdisciplinary collaborations. Most of the collaborations were between the scholars from the same country or from the same laboratory based on the data analysis from WOS.

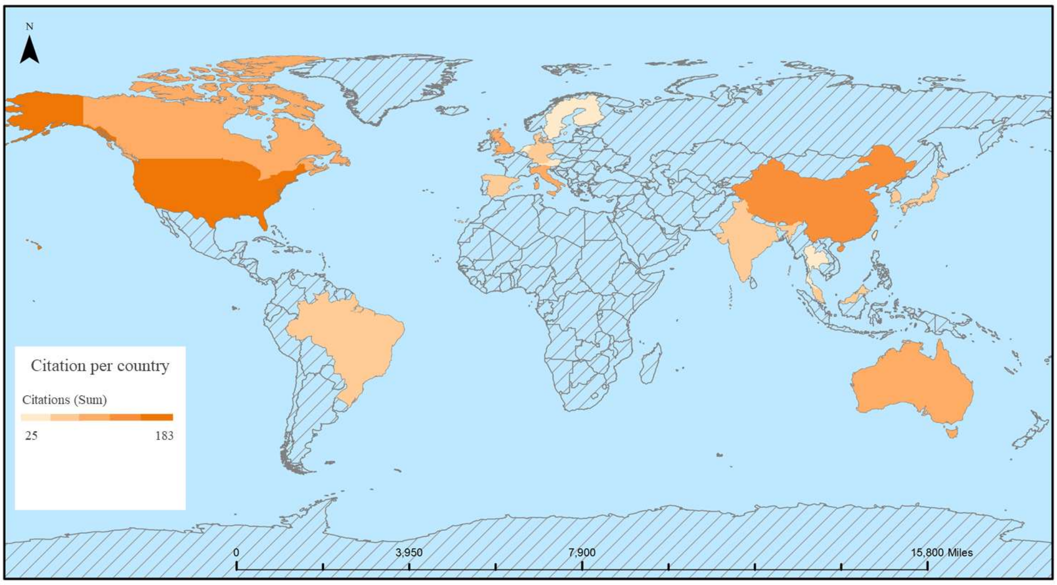


Figure 2. Total citations per country.

Table 2. Key authors reporting greenhouse gas (GHG) emissions from landfills.

	Author	*Pubs* [a]	% [b]	*TC* [c]	*TC/P* [d]	h-index
1	Mortan Barlaz	15	1.95	437	29.13	9
2	Peter Kjeldsen	9	1.17	241	26.78	7
3	Charlotte Scheutz	9	1.17	217	24.11	7
4	Haslenda Hashim	8	1.04	201	25.13	6
5	Martin Schroth	8	1.04	117	14.63	6
6	Wai Shin Ho	7	0.91	192	27.43	5
7	Thomas Christensen	6	0.78	315	52.50	5
8	Chew-Tin Lee	6	0.78	188	31.33	5
9	Jeng-Shiun Lim	6	0.78	138	23	5
10	Mika Horttanainen	6	0.78	60	10	4

Note: *Pubs* [a] (Publication): total number of publications related to GHG emissions from landfills. % [b] (Percentage): percentage of publications relative to the total dataset of 770 papers. *TC* [c]: the total citations for a country. *TC/P* [d]: average number of citations per paper for a country.

The 770 selected articles on landfill GHG emissions appeared in 202 journals. Generally speaking, the number of citations for a paper could reflect its influence, although errors in counting may sometimes occur [6]. As a journal's impact may vary between research fields, the TC/P in relevant research, which only considers citations within one field, is a relatively suitable measure of a journal's relative importance in a specific field [20]. Thus, the available surrogate parameters of TC and TC/P between 1999 and 2018 are also shown in Table 3. Moreover, the influential factor (IF), Scimago Journal and Country Rank (SJR) and h-index of these journals are also shown to measure their value according to their roles and statuses in scientific communication. As indicated by journal performance, there was a greater concentration of articles within the major journals. The top ten (4.95% out of the 202) journals published 343 (44.56%) of the total of 770 articles and received 7158 (53.75%) of the total 13316 citations. Waste Management had the highest output, with a total of 101 papers, followed by the Journal of Cleaner Production (69 papers) and Waste Management Research (51 papers). Energy Policy had the highest TC/P score (59.90), followed by Environmental Science & Technology (38.85) and Science of the Total Environment (21.56).

Table 3. Top ten productive journals in terms of related studies.

Journals	*Pubs* [a]	% [b]	*TC* [c]	*TC/P* [d]	h-index	IF	SJR
Waste Management	101	13.12	2080	20.59	24	4.723	1.456
Journal of Cleaner Production	69	8.96	1340	19.42	21	5.651	1.467
Waste Management Research	51	6.62	852	16.71	15	1.631	0.519
Resources Conservation and Recycling	28	3.64	492	17.57	14	5.120	1.462
Environmental Science & Technology	26	3.38	1010	38.85	18	6.653	2.535
Journal of the Air Waste Management Association	18	2.34	155	8.51	6	1.742	0.744
Science of the Total Environment	16	2.08	345	21.56	9	4.610	1.546
Journal of Material Cycles and Waste Management	13	1.69	87	6.69	5	1.693	0.491
International Journal of Life Cycle Assessment	11	1.43	198	18.00	10	4.195	1.268
Energy Policy	10	1.30	599	59.90	10	4.039	1.994

Note: *Pubs* [a] (Publication): total number of publications related to GHG emissions from landfills. % [b] (Percentage): percentage of publications relative to the total dataset of 770 papers. *TC* [c]: the total citations for a country. *TC/P* [d]: average number of citations per paper for a country.

3.2. Emerging Trends and Developments

As previously analyzed by Bogner et al., there has been rapid progress in the work on GHG emissions from landfills around the world, and the growth of this field might be related to the advanced understanding of waste management and the dynamic processes of the formation, transfer and consumption of greenhouse gases [52]. Therefore, the interdisciplinary study normally involves numerous disciplinary areas but also demonstrates shifts in the intensity of publications in terms of abrupt changes in subject categories, keywords and their citations [34]. The disciplines involving landfill GHG emissions included a total of 48 unique subject categories of WOS, with the top ten subject categories being displayed in Figure 3. Among them, environmental sciences ranked first and accounted for 69.35% of all articles, followed by engineering environmental (47.53%) and green sustainable science technology (14.55%). The publications related to energy fuels, atmospheric sciences and meteorology and engineering chemical were also important components of all publications.

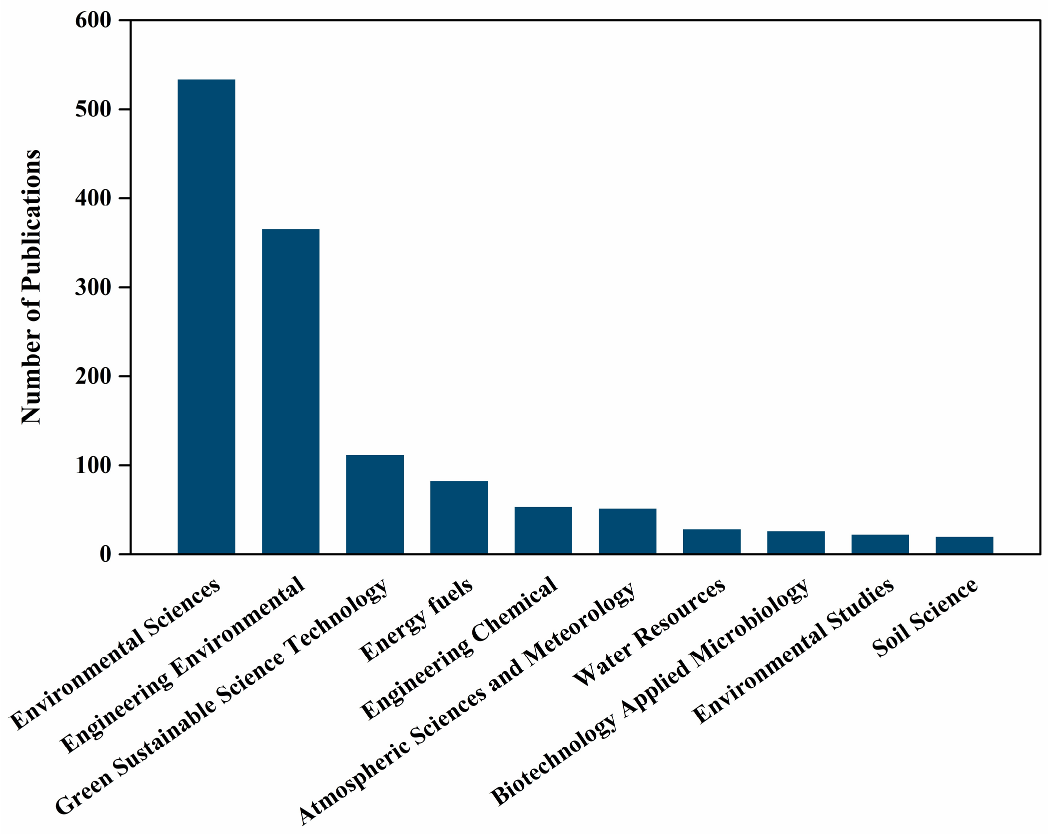


Figure 3. Top ten subject categories with the most articles over the twenty-year period.

The shift in keywords over time can also indicate the most active fields of publications on landfill GHG emissions. A total of 204 unique keywords appeared in the selected articles. The keywords with the strongest burst strength are shown in Figure 4; this time interval is depicted as a blue line. The period in which a keyword was found to exhibit a strong increase is shown as a red line, which indicates the beginning and the end year of the burst [34]. As shown in Figure 4, a large number of keywords with high citations burst in 1999. Initially, methane, waste disposal and greenhouse gases were the strongest keywords, while mitigation was the source of the most recent burst of keywords. The g m is the unit of the GHG emissions, namely g GHG m^2. But the CiteSpace cannot identify superscript. So, the Figure 4 showed g m as a keyword with the strongest strength citation burst.

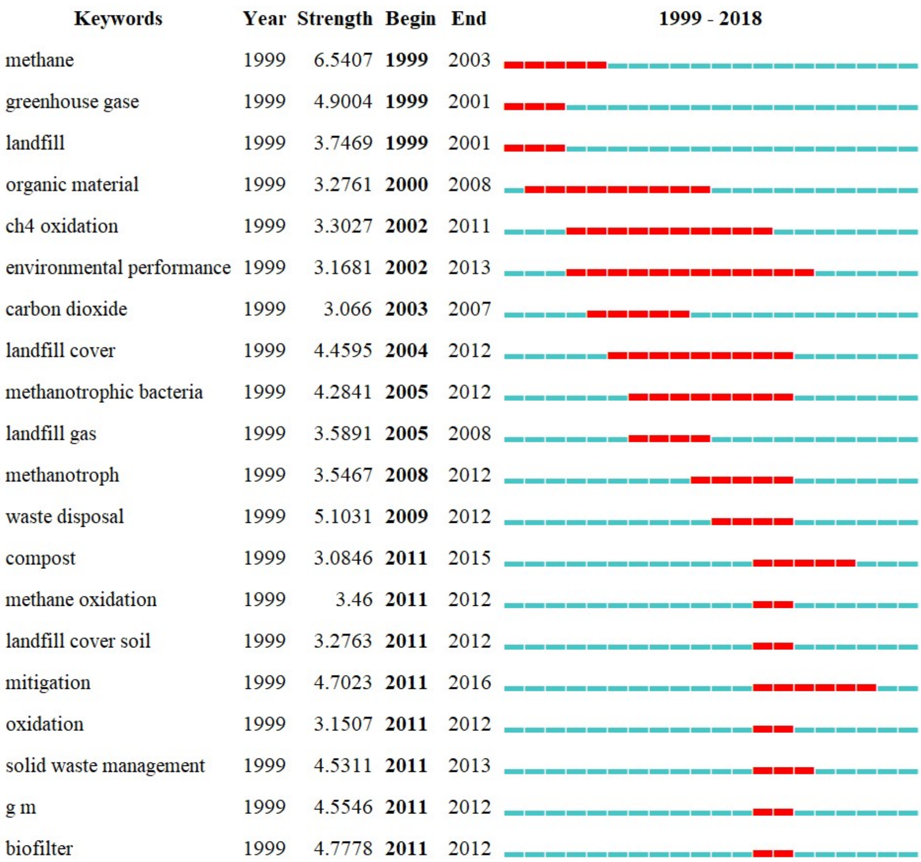


Figure 4. Top 20 keywords with the strongest strength citation burst.

3.3. Cluster Analysis of Citations by CiteSpace

CiteSpace represents the literature in terms of a network synthesized from a series of integrated individual networks before forming an overview of how a scientific field has evolved over time [53]. The structure of the research field on landfill GHG emissions was characterized in this study by a synthesized network of 770 references co-cited during 1999–2018 according to the top 50 most-cited articles. Every single node represents the references cited by each article in this field, and the connectivity between these nodes indicates how often they are referenced in the same article. The networks in this form have been proven to have the ability to capture the research emphases of the potential scientific community [34,53–55]. As shown in Figure 5, the landmark articles with citation bursts were all depicted as large citation rings in yellow. The thickness of the ring indicates the degree of its betweenness centrality, which is a measure associated with the transformative potential of a scientific contribution [53]. In addition, CiteSpace divides the co-citation network into a number of clusters of co-cited references such that the references are tightly connected within the same clusters but loosely connected between different clusters [53]. Table 4 lists all clusters shown in Figure 5 and sorts them by reference numbers in terms of their size. Each cluster is labelled by the noun phrases from keywords of the cited articles in the cluster [55]. CiteSpace provides three algorithms of label extraction, namely, LSI, LLR and MI. Among them, the cluster labels provided by LLR will be much more consistent with the actual situation and have less repetition [56]. However, it should be noted that the consistency of generated labels and the actual literature need to be reconfirmed irrespective of the algorithm used [57]. In order to more accurately measure the quality of a cluster, the silhouette score was also used. The silhouette values of every cluster in Table 4 are close to one, which means that all clusters are highly homogeneous.

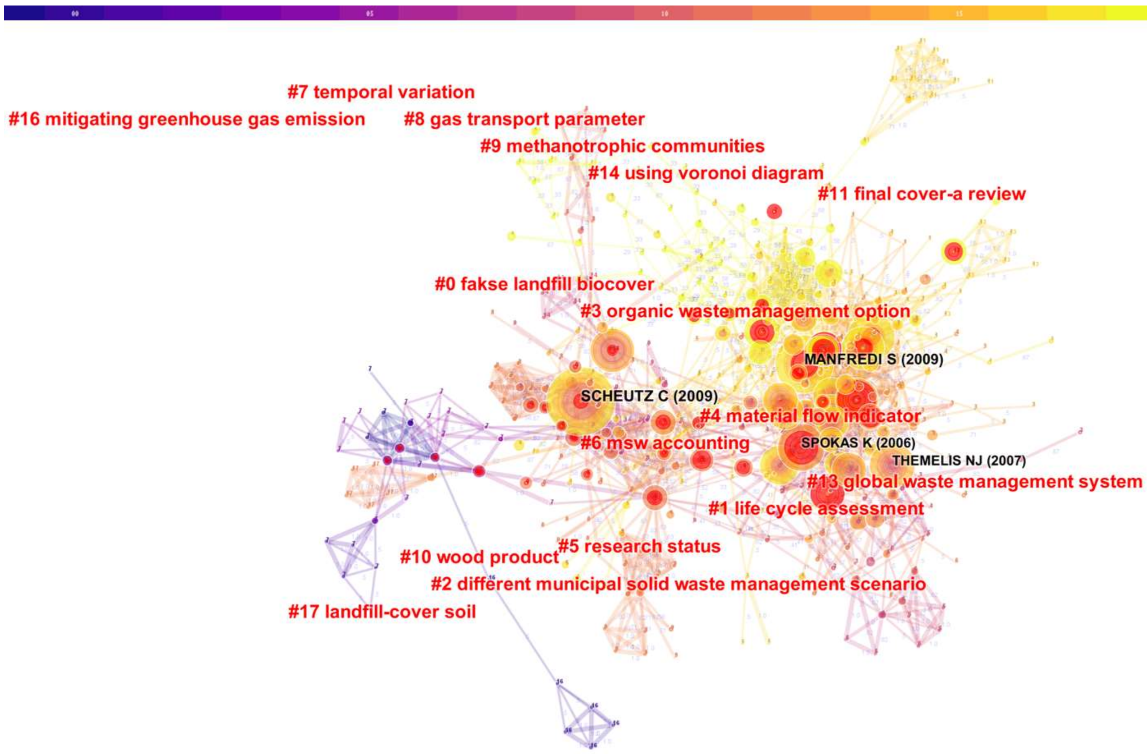


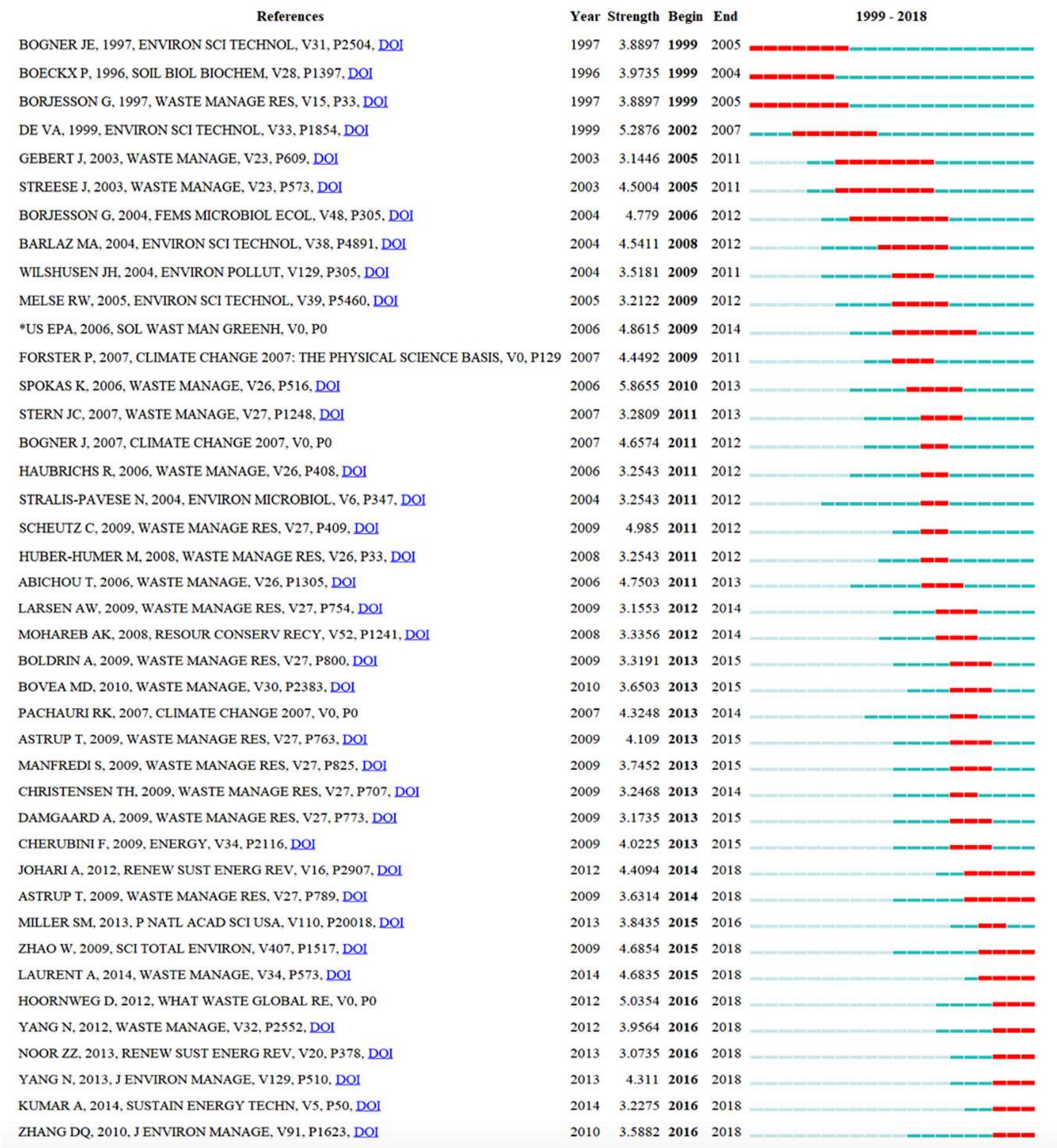
Figure 5. Map based on co-occurrence on the author topics from 1999 to 2018.

As shown in Figure 5, the largest cluster was the #0 Fakse landfill biocover, which contained 63 member-references. The homogeneity of the cluster that was measured by the silhouette score was 0.845, which was close to the highest value of 1.00 and suggests reliable quality [32]. Optimum environmental conditions are provided to microorganisms that exist in interim or long-term biocovers for methane mitigation [58]. Biocovers have been widely adopted as a method to counteract the rise in methane emissions due to their efficient capability in terms of methane capture and high energy recovery efficiency from captured gas [59]. The #0 Fakse landfill biocover cluster located in the center of the visualization also means that it has a high concentration of references and was significant in the study of landfill GHG emissions. The #1 life cycle assessment (LCA) cluster also attracted a large number of references (size: 53). The methodological development in LCA has been strong, and LCA has been broadly applied in practice in recent years to evaluate the life cycle environmental impacts of waste treatment [60–62]. Falcone and Imbert suggested that LCAs represent a valuable framework whose transdisciplinary nature clearly demonstrated the importance of integrating economic models as well as ecological and social theories [63].

Table 4. Clusters of co-cited references.

Cluster ID	Size	Silhouette	Label (LSI)	Label (LLR)	Label (MI)	Year Ave.
0	63	0.845	methane	Fakse landfill biocover	greenhouse gas effect	2006
1	53	0.733	life cycle assessment	life cycle assessment	greenhouse gas effect	2009
2	52	0.821	greenhouse gas emissions	different municipal solid waste management scenarios	greenhouse gas effect	2013
3	51	0.715	greenhouse gas emissions	organic waste management option	greenhouse gas effect	2007
4	50	0.763	greenhouse gas emissions	material flow indicator	greenhouse gas effect	2008
5	41	0.749	assessment	research status	greenhouse gas effect	2011
6	30	0.903	life cycle assessment	MSW accounting	greenhouse gas effect	2005
7	27	0.963	methane oxidation	temporal variation	greenhouse gas effect	1997
8	16	0.893	effects	gas transport parameter	greenhouse gas emission	2006
9	14	0.976	Tibetan plateau	methanotrophic communities	greenhouse gas emission	2008
11	11	0.998	production;	final cover review	greenhouse gas emission	2011
10	11	0.944	wood products	wood products	greenhouse gas emission	2010
13	8	0.968	resource	global waste management system	greenhouse gas emission	2012
14	7	0.972	situ quantification	using Voronoi diagram	greenhouse gas emission	2004
16	6	0.963	emissions	mitigating greenhouse gas emissions	greenhouse gas emission	1995
17	6	0.996	landfill-cover soil	landfill-cover soil	greenhouse gas emission	2007

As supplementary information, the references with the strongest citation bursts during 1999–2018 are shown in Figure 6. Specific growth areas in the field are characterized by articles that experienced citation bursts [34]. As shown, the article by Spokas K in 2006 with the burst strength of 5.8655 had the strongest citation burst. Moreover, the top five articles with the strongest citation bursts are displayed in Table 5. Apart from Reference 2, all articles started their citation bursts in or after 2009.



References	Year	Strength	Begin	End	1999 - 2018
BOGNER JE, 1997, ENVIRON SCI TECHNOL, V31, P2504, DOI	1997	3.8897	1999	2005	
BOECKX P, 1996, SOIL BIOL BIOCHEM, V28, P1397, DOI	1996	3.9735	1999	2004	
BORJESSON G, 1997, WASTE MANAGE RES, V15, P33, DOI	1997	3.8897	1999	2005	
DE VA, 1999, ENVIRON SCI TECHNOL, V33, P1854, DOI	1999	5.2876	2002	2007	
GEBERT J, 2003, WASTE MANAGE, V23, P609, DOI	2003	3.1446	2005	2011	
STREESE J, 2003, WASTE MANAGE, V23, P573, DOI	2003	4.5004	2005	2011	
BORJESSON G, 2004, FEMS MICROBIOL ECOL, V48, P305, DOI	2004	4.779	2006	2012	
BARLAZ MA, 2004, ENVIRON SCI TECHNOL, V38, P4891, DOI	2004	4.5411	2008	2012	
WILSHUSEN JH, 2004, ENVIRON POLLUT, V129, P305, DOI	2004	3.5181	2009	2011	
MELSE RW, 2005, ENVIRON SCI TECHNOL, V39, P5460, DOI	2005	3.2122	2009	2012	
*US EPA, 2006, SOL WAST MAN GREENH, V0, P0	2006	4.8615	2009	2014	
FORSTER P, 2007, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, V0, P129	2007	4.4492	2009	2011	
SPOKAS K, 2006, WASTE MANAGE, V26, P516, DOI	2006	5.8655	2010	2013	
STERN JC, 2007, WASTE MANAGE, V27, P1248, DOI	2007	3.2809	2011	2013	
BOGNER J, 2007, CLIMATE CHANGE 2007, V0, P0	2007	4.6574	2011	2012	
HAUBRICHS R, 2006, WASTE MANAGE, V26, P408, DOI	2006	3.2543	2011	2012	
STRALIS-PAVESE N, 2004, ENVIRON MICROBIOL, V6, P347, DOI	2004	3.2543	2011	2012	
SCHEUTZ C, 2009, WASTE MANAGE RES, V27, P409, DOI	2009	4.985	2011	2012	
HUBER-HUMER M, 2008, WASTE MANAGE RES, V26, P33, DOI	2008	3.2543	2011	2012	
ABICHOU T, 2006, WASTE MANAGE, V26, P1305, DOI	2006	4.7503	2011	2013	
LARSEN AW, 2009, WASTE MANAGE RES, V27, P754, DOI	2009	3.1553	2012	2014	
MOHAREB AK, 2008, RESOUR CONSERV RECY, V52, P1241, DOI	2008	3.3356	2012	2014	
BOLDRIN A, 2009, WASTE MANAGE RES, V27, P800, DOI	2009	3.3191	2013	2015	
BOVEA MD, 2010, WASTE MANAGE, V30, P2383, DOI	2010	3.6503	2013	2015	
PACHAURI RK, 2007, CLIMATE CHANGE 2007, V0, P0	2007	4.3248	2013	2014	
ASTRUP T, 2009, WASTE MANAGE RES, V27, P763, DOI	2009	4.109	2013	2015	
MANFREDI S, 2009, WASTE MANAGE RES, V27, P825, DOI	2009	3.7452	2013	2015	
CHRISTENSEN TH, 2009, WASTE MANAGE RES, V27, P707, DOI	2009	3.2468	2013	2014	
DAMGAARD A, 2009, WASTE MANAGE RES, V27, P773, DOI	2009	3.1735	2013	2015	
CHERUBINI F, 2009, ENERGY, V34, P2116, DOI	2009	4.0225	2013	2015	
JOHARI A, 2012, RENEW SUST ENERG REV, V16, P2907, DOI	2012	4.4094	2014	2018	
ASTRUP T, 2009, WASTE MANAGE RES, V27, P789, DOI	2009	3.6314	2014	2018	
MILLER SM, 2013, P NATL ACAD SCI USA, V110, P20018, DOI	2013	3.8435	2015	2016	
ZHAO W, 2009, SCI TOTAL ENVIRON, V407, P1517, DOI	2009	4.6854	2015	2018	
LAURENT A, 2014, WASTE MANAGE, V34, P573, DOI	2014	4.6835	2015	2018	
HOORNWEG D, 2012, WHAT WASTE GLOBAL RE, V0, P0	2012	5.0354	2016	2018	
YANG N, 2012, WASTE MANAGE, V32, P2552, DOI	2012	3.9564	2016	2018	
NOOR ZZ, 2013, RENEW SUST ENERG REV, V20, P378, DOI	2013	3.0735	2016	2018	
YANG N, 2013, J ENVIRON MANAGE, V129, P510, DOI	2013	4.311	2016	2018	
KUMAR A, 2014, SUSTAIN ENERGY TECHN, V5, P50, DOI	2014	3.2275	2016	2018	
ZHANG DQ, 2010, J ENVIRON MANAGE, V91, P1623, DOI	2010	3.5882	2016	2018	

Figure 6. References with the strongest citation bursts (1999–2018).

Table 5. Top five references with the strongest citation bursts during 1999–2018.

Rank	References	Citation Burst		
		Strength	Begin	End
1	Spokas [44]	5.8655	2010	2013
2	DeVaull [64]	5.2876	2002	2007
3	Hoornweg [65]	5.0354	2016	2018
4	USA EPA [40]	4.8615	2009	2014
5	Abichou [66]	4.7503	2011	2013

3.4. Achievements and Prospects

During the past twenty years, GHG emissions have been a hot topic along with the aggravation of the global greenhouse effect. Furthermore, GHG emissions from landfills have also received widespread attention. In some ways, the research on GHG emissions from landfills has covered many mainstream aspects in this field. More importantly, governments in a similar way to scholars have become increasingly aware of GHG emissions and have realized that the control of waste treatment sectors is not only a scientific issue but also a strategy to partially alleviate the increasingly worsening impacts of global warming and to potentially promote sustainable development. Most governments are improving the level of waste management and are enforcing new policies to restrict GHG emissions that occur along the entire waste life cycle [67].

Being different from the incineration and the treatment of domestic and industrial wastewater, the main component of the GHG released from landfills is CH_4, which accounts for 40–50% of the total emissions [5]. Hence, the studies on landfill GHG emissions mostly focused on model calculation, in-situ monitoring and emission reduction measures of CH_4 [68,69]. With respect to in-situ monitoring, most studies concentrated primarily on CH_4 emissions from the waste with different landfill ages and soil covering properties [66,70,71]. Moreover, the relationship between the environmental factors and CH_4 emission has also been a research focus [72]. However, compared to CH_4, the N_2O generated from landfills seems to have been relatively ignored and subsequently, landfills have long been considered to be a negligible release source of N_2O. Furthermore, the calculation methods of N_2O emissions from landfills are not provided in the emission inventory of IPCC [73]. However, there have been reports of high emissions of N_2O from some landfills, especially from the working face of landfills [4,74]. Similarly, GHG emissions from the leachate treatment system are not regarded as significant, so there are only a few relevant studies [75,76]. In addition, along with the technical enhancement of the covering materials, the covering soil is gradually replaced to increase the capacity and to extend the use time of landfills. However, GHG emissions from the surfaces of these covering materials have not been adequately studied. Finally, most of the existing articles use sanitary landfills as the target of the survey. However, it has been found that a considerable amount of GHGs is also generated from simple landfills [77]. Scholars have been less concerned about GHG emissions from simple landfills.

4. Conclusions

For the foreseeable future, landfills will remain as one of the main methods for solid waste disposal. Therefore, systematic and in-depth research on GHG emissions from landfill is needed. To comprehensively evaluate the articles related to GHG emissions from landfills and to provide a scientific basis and reference for GHG reduction, a bibliometric analysis was carried out, which focused on the publication country; the number of annual publications and citations; the most productive journals and key authors; and the major areas of research that the related articles were involved in. In addition, the historical evolution of the primary performance was presented. Based on the hot research topics, eighteen major clusters were identified using CiteSpace. The citation mode was determined in this research field for the past twenty years. Finally, the existing limitations in this field were discussed, aiming to provide relevant information and to assist future studies.

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