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Current Status and Trend of Landfill Technology -- Quantitative Analysis of Landfill Profiles Based on Histcite

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Abstract: Analyzing the development in China's landfill technology research ranges from 1997 to 2020 at the aspects of chronological distribution, high-yield journals, high-yield research institutions and keyword hotspot through Histcite, which sets landfill relevant studies in Web of Science as statistical samples. The result indicates: 1) The engineering application of landfill has declined, but the interest in landfill academic research has increased per year. 2) Although China's landfill technology is globally highly researched, the depth and recognition of research need to be further improved from the facets of cited times. 3) Landfill articles published in JOURNAL OF HAZARDOUS MATERIALS have the highest impact factor and better recognition. 4) Tongji University is the critical institute of landfill technology research. 5) The research hotspots in recent 24 years are leachate treatment methods, leachate composition analysis, landfill gas treatment and oxidation repair technology, etc.

1. Introduction

Since the 1980s, landfill technology has always been the major way of processing domestic waste in China. Compared with incineration and composting, landfill holds the advantages of simple operation, low cost, and the capability of treating different types of waste simultaneously. It is closely related to China's current state of technology development. Although in recent years, in order to achieve more effective waste reduction, the application of landfill has been decreasing year by year, and the incineration technology has been increasing year by year, but the academic research on landfill technology has been increasing.

Bibliometrics is a discipline that uses both statistical and mathematical methods to analyze the development trend of certain technical topics quantitatively. Bibliometrics can quantify and model big data and reflect the research process objectively. Therefore, it has been adopted by many disciplines [1]. However, at present, there are fewer documents analyzing the research status of domestic landfill technology from the perspective of bibliometric analysis. Therefore, this paper

uses papers from the core journals of environmental science on Web of Science as the data source, through bibliometric and visualization methods, relevant research on landfill technology are analyzed, so as the research trends of China's landfill technology in recent 24 years, including the distribution of papers, high-yield journals, and high-yield research institutions. It is expected to let researchers to take a better grasp of the development process of landfill technology and to provide universities a reference for the construction of disciplines and future trends.

2. Data Source and Research Method

2.1 Data Source

SCI paper statistics from Web of Science core collection, with searching keyword of Landfill. The search shows that a total of 9278 papers meet the search requirements (the search date is December 04, 2020), and the time interval of searching papers is 1997-2020.

2.2 Research Method and Tool

HistCite (History of Cite) is an efficient and agile citation map analysis software. In recent years, HistCite has been applied in bibliometrics as an important research method. The main advantage of this software is that it can show the relationship between different papers in the field of landfill technology in the form of legends and reflect the historical progress of development of the field, marking important papers and publication time nodes during this period [2]. This paper mainly uses HistCite citation map analysis software to visualize and analyze the related research on landfill in the core collection of Web of Science.

Specific operation steps include: Downloading papers regarding to landfill technology in the past 24 years from the core journals of Web of Science, importing it into HistCite software, then performing statistical analysis on the year distribution, country distribution, journal distribution, classic papers, hot keywords of the published papers regarding to landfill technology. It will help us to understand the research history and hotspots in this field in a relatively comprehensive way, to compare the trends of research contributions in this field between China and other countries in the world, as well as the research status of its major research institutions in the world.

3. Paper Publishing Trend in the Field of Landfill Technology

3.1 Publishing Year Distribution

Figure 1 reflects the distribution status of papers on landfill technology published in the core journals of Web of Science in the past 24 years. It can be seen that the published paper in the field of landfill technology generally presents an increasing trend year by year. From 1999 to 2014, the number of papers on landfill technology published per year were in fluctuant growth, where in year 1999, 2002, 2007, 2011, 2013 and 2014, it showed negative growth. From 1997 to 2019, research on landfill technology increased by 22.6 articles per year on average, where from 1997 to 1998 reached a maximum increment of 183. The annual publication volume of papers on landfill technology reached a peak of 687 in 2019, which is nearly a five-times increase compared to the 145 published in 1997. After 2016, the number of papers published every year have been sustaining on more than 600, and is still rising steadily. From 2019 to 2020, the enthusiasm in this field has declined.

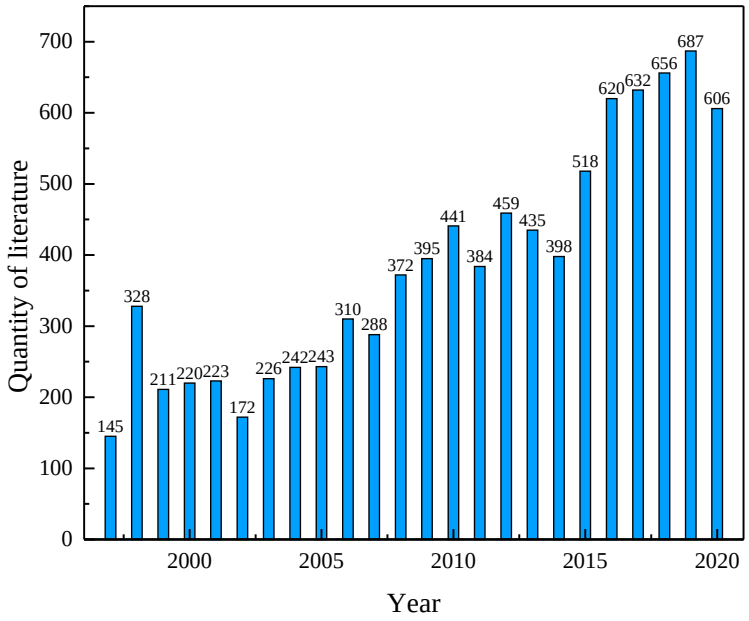
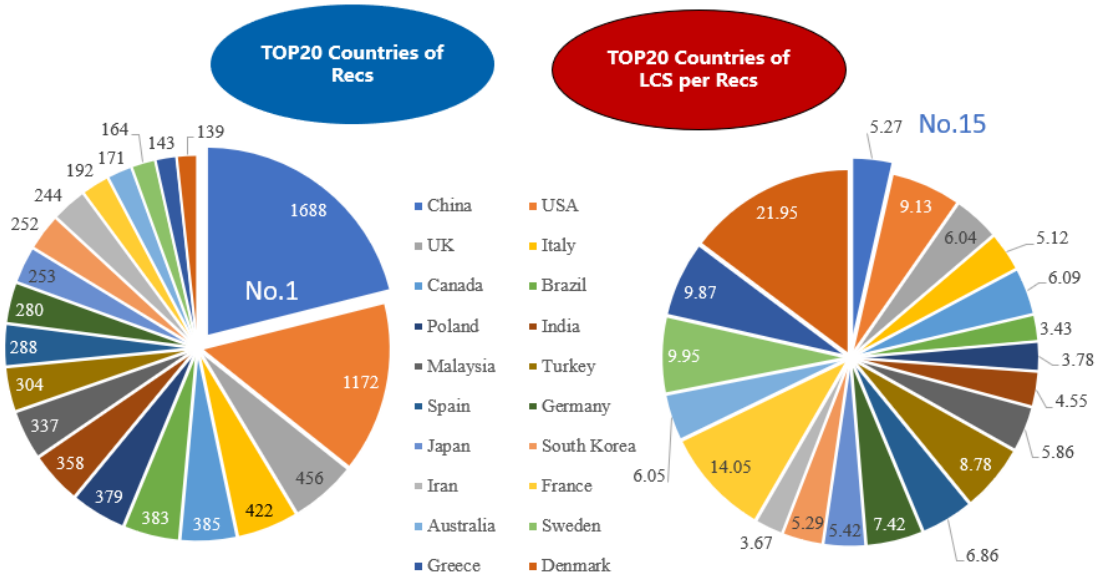


Fig.1 Annual Analysis and Statistics of Technical Research Literature on Landfills

3.2 Country Distribution

There is a total of 125 countries have published papers in the field of landfill technology. The top 20 countries and regions accounted for more than 86% of the total number of papers. From the top 20 countries shown in Figure 2, it can be seen that China and the United States exceeds other countries significantly regarding to the number of publishing, ranking first and second in the world and accounting for 18.2% and 12.6% of the total number of global publications respectively. Leading countries like China, the United States, the United Kingdom, Italy, and Canada, which rank the top in the number of publications, not only stand on the forefront in academic research related to landfill technology, but also have a lot of experience in the application of waste technology engineering. Although China ranks first in the world in terms of the number of papers published, the average number of citations of Chinese papers ranks only 15th, which still holds certain gap from Sweden, Denmark, France, Greece, the United States and other countries, indicating the quality of papers needs to be further improved.



Recs: Records LCS: Local citation score

Fig.2 The Top 20 Research Literature on Landfill Technology According to the Number of Articles Published and the Number of Citations Per Article

In Figure 3, it can be seen that from 1997 to 2020, the research papers in China hold an extremely fast growth rate, the research level and enthusiasm in landfill-related technology are keep rising.

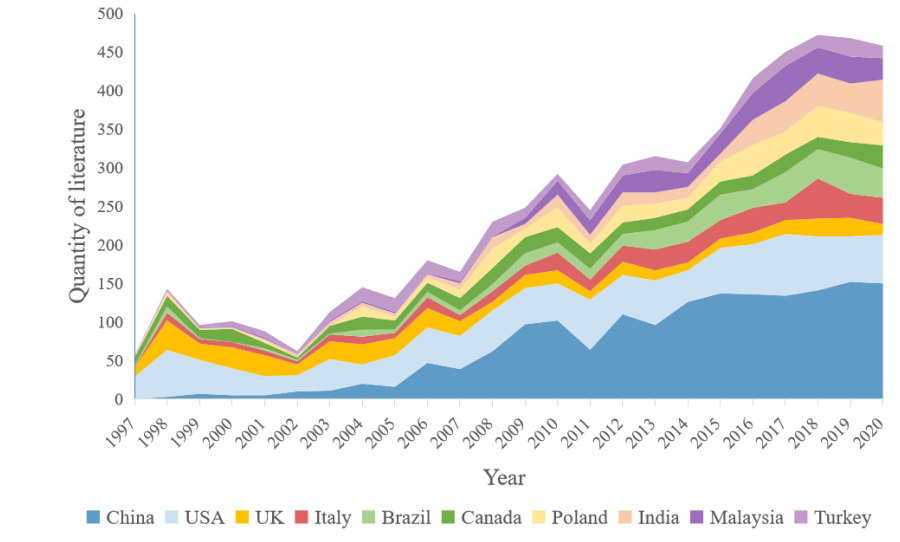


Fig.3 Annual Analysis and Statistics of the Top 10 National Documents in the Number of Published Articles

Figure 4 shows the comparison between the number of papers published by China and the United States during the last 24 years: From 1997 to 2020, the number of papers published in the United States fluctuated and declined, generally in a balanced situation. It indicates that for the United States, research in landfill technology has been relatively mature and has developed steadily. However, China's landfill technology was in the initial research stage from 1997 to 2005, the

number of publications was less than 20. During the same period, the number of SCI papers published by the United States was 5-20 times that of China; from 2006 to 2020, China started to enter the stage of rapid development in landfill technology research. Since 2006, the number of papers published has surpassed that of the United States. It fully shows that China is paying more and more attention to landfill technology, both research and development in this field are becoming more mature, and there is a trend to catch up and surpass the United States.

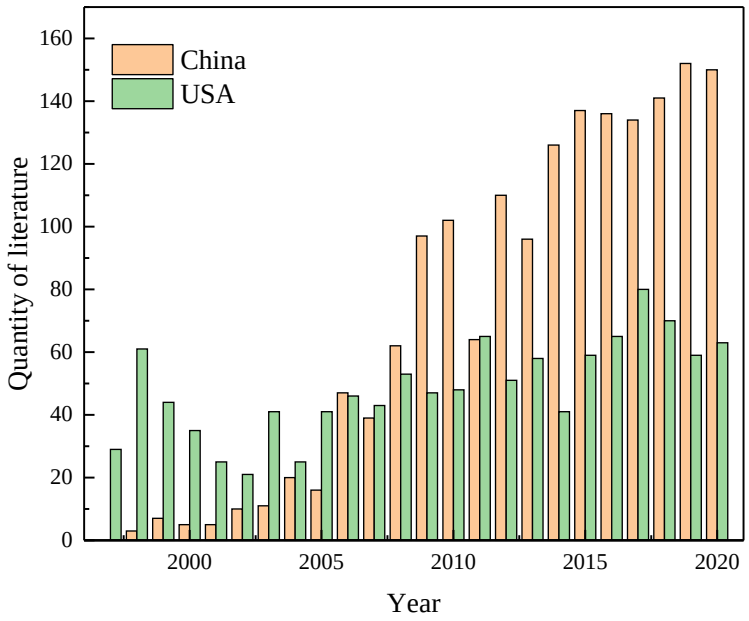


Fig.4 Annual Analysis and Comparison of the Number of Technical Documents Issued on Landfills in China and the United States

3.3 Distribution of Publication Journals

Within 9278 SCI papers in the statistics, a total of 1971 journals around the world included papers related to landfill technology. Table 1 only lists the top 10 journals with the number of published papers. The top ten journals have published a total of 2,370 papers, accounting for 25.4% of the total publication. “JOURNAL OF HAZARDOUS MATERIALS” that holds the highest impact factor hs published 193 papers, with an impact factor of 9.038 in 2016.

Table 1 Top 10 Periodicals in the Number of Publications of Landfill Technology Research Literature

No.	Journal	Impact Factor	Quantity
1	WASTE MANAGEMENT	5.448	783
2	WASTE MANAGEMENT & RESEARCH	2.771	374
3	JOURNAL OF HAZARDOUS MATERIALS	9.038	193
4	BIORESOURCE TECHNOLOGY	7.539	158
5	CHEMOSPHERE	5.778	154
6	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	3.056	152
7	SCIENCE OF THE TOTAL ENVIRONMENT	6.551	151
8	WATER SCIENCE AND TECHNOLOGY	1.638	145
9	ENVIRONMENTAL TECHNOLOGY	2.213	131

10	ENVIRONMENTAL SCIENCE & TECHNOLOGY	7.864	129

3.4 Distribution and Characteristics of Major Publishing Institutions

There are many research institutions related to landfill technology. This paper only lists the top 10 institutions with the number of published papers. From Table 2, it can be seen that Tongji University ranks first in the world in the number of published papers with a total quantity of 195. China occupies three in the Top10 list. It can be seen that from 1997 to 2020, China's enthusiasm in landfill technology research were kept growing, with the number of published paper far exceeding that of other countries.

Table 2 Ranking of The Top 10 Institutions in Terms of the Number of Publications on Landfill Technology Research Literature

No.	Publishing Institutions	Country	Quantity
1	Tongji Univ	China	195
2	Zhejiang Univ	China	166
3	Chinese Acad Sci	China	144
4	Tech Univ Denmark	Denmark	127
5	Univ Sains Malaysia	Malaysia	116
6	Chinese Res Inst Environm Sci	China	90
7	Univ Illinois	USA	89
8	Tsinghua Univ	China	88
9	Univ Florida	USA	82
10	Indian Inst Technol	China	64

4. Analysis on Frequently Cited Papers

The 20 papers listed in Table 3 represent an important developing status in the field of landfill technology at present. In 2001, the main research focus was on the biochemical characteristics of the leachate pollution plume [3]; from 2009 to 2010, attentions were paid to the landfill gas and the Fenton treatment technology regarding to the leachate by oxidation technology [4-6]; from 2012 to 2013, the emphasis was shifted on the geographical location and mining application of landfills [7-10]; in 2015-2020, research hotspots were both on various advanced oxidation and coagulation technologies of leachate [11-22]. It can be seen that the leachate generated in the landfill is the top priority of the treatment process.

Table 3 Top 20 Highly Cited Papers in Landfill Technology Research Literature

No.	Title	Journal	Time	Research Hotspot
1	Biogeochemistry of landfill leachate plumes[3]	APPLIED GEOCHEMISTRY	2001	Biological/geographical/chemical characteristics of the polluted plume of leachate
2	Microbial methane oxidation processes and technologies for mitigation of landfill gas emissions[4]	WATSTE MANAGEMENT & RESEARCH	2009	Oxidation technology of methane in landfill gas
3	Health risk assessment of BTEX emissions in the landfill environment[5]	JOURNAL OF HAZARDOUS MATERIALS	2010	Health risks of benzene series in landfill gas
4	Trends in the use of Fenton, electro-Fenton and photo-Fenton	WASTE MANAGEMENT	2010	Fenton/Fenton-like system to treat landfill leachate

	for the treatment of landfill leachate[6]			
5	Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average[7]	WASTE MANAGEMENT	2012	Geographic Information System Aided Landfill Site Selection
6	The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion[8]	WASTE MANAGEMENT	2012	Comparison of life cycle assessment of landfill and incineration plant
7	The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review[9]	JOURNAL OF CLEANER PRODUCTION	2013	Application of Energy Conversion Technology in Landfill Mining
8	Enhanced Landfill Mining in view of multiple resource recovery: a critical review[10]	JOURNAL OF CLEANER PRODUCTION	2013	Resource recovery during landfill mining
9	Mature landfill leachate treatment by coagulation/flocculation combined with Fenton and solar photo-Fenton processes[11]	JOURNAL OF HAZARDOUS MATERIALS	2015	Fenton/like Fenton combined with coagulation technology to treat landfill leachate
10	Physico-chemical and biological characterization of urban municipal landfill leachate[12]	ENVIRONMENTAL POLLUTION	2017	The physical, chemical and biological properties of landfill leachate
11	A novel simultaneous partial nitrification Anammox and denitrification (SNAD) with intermittent aeration for cost-effective nitrogen removal from mature landfill leachate[13]	CHEMICAL ENGINEERING JOURNAL	2017	Simultaneous removal of COD and nitrogen in landfill leachate by intermittent aeration
12	Modeling of energy consumption and environmental life cycle assessment for incineration and landfill systems of municipal solid waste management - A case study in Tehran Metropolis of Iran[14]	JOURNAL OF CLEANER PRODUCTION	2017	Energy consumption analysis and life cycle assessment of landfill and incineration
13	Removal of selected PPCPs, EDCs, and antibiotic resistance genes in landfill leachate by a full-scale constructed wetlands system[15]	WATER RESEARCH	2017	Constructed wetland to remove emerging pollutants and drug resistance genes in landfill leachate
14	Degradation of refractory organic contaminants in membrane concentrates from landfill leachate by a combined coagulation-ozonation process[16]	CHEMOSPHERE	2019	Ozone oxidation technology combined with coagulation technology to treat landfill leachate
15	Landfill leachate treatment in Brazil - An overview[17]	JOURNAL OF ENVIRONMENTAL MANAGEMENT	2019	Summary of Leachate Treatment Technology in Brazil
16	Recent advances in nitrogen removal from landfill leachate using biological treatments - A review[18]	JOURNAL OF ENVIRONMENTAL MANAGEMENT	2019	Biotechnology to remove nitrogen from landfill leachate

17	Treatment of landfill leachate nanofiltration concentrate after ultrafiltration by electrochemically assisted heat activation of peroxydisulfate[19]	SEPARATION AND PURIFICATION TECHNOLOGY	2020	Electrochemical-assisted thermally activated persulfate technology to treat leachate concentrated liquid in nanofiltration system
18	Impact of landfill leachate on the groundwater quality in three cities of North India and health risk assessment[20]	ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY	2020	The impact of landfill leachate on groundwater quality and health risks in India
19	Recent advances in municipal landfill leachate: A review focusing on its characteristics, treatment, and toxicity assessment[21]	SCIENCE OF THE TOTAL ENVIRONMENT	2020	Characteristics, treatment technology and toxicity of landfill leachate
20	Two-year evaluation of hydraulic properties of biochar-amended vegetated soil for application in landfill cover system[22]	SCIENCE OF THE TOTAL ENVIRONMENT	2020	Study on the application of biochar-doped planting soil as cover layer of landfill closure

5. Analysis on Technical Topics

5.1 Distribution of Technical Topics

Main keywords in the field of landfill technology are sorted out in this paper. As shown in Figure 5, the top 20 keywords in the field of sewage treatment are “landfill”, “leachate”, “waste”, “treatment”, “urban”, “methane”, “soil”, “oxidation”, “organic”, “System”, “Evaluation”, “Emissions”, “Groundwater”, “Bioreactor”, “Water”, “Sanitary”, “Application”, “Model”, “Fenton”, and “Mining”. In the field of landfill technology, the frequency of the keyword “oxidation”, “bioreactor” and “mining” have exceeded 200 times. Among them, the keyword of “oxidation” has been mentioned most, with a frequency of 414 times, followed by “bioreactors”, which has been mentioned 358 times. The keywords that co-occur the most with “oxidation” are “leachate”, “methane” and “soil”. It can be seen that the scientific research hotspots of landfills mainly revolve around leachate treatment methods, leachate composition analysis, landfill gas treatment and oxidation repair technology [23-30].

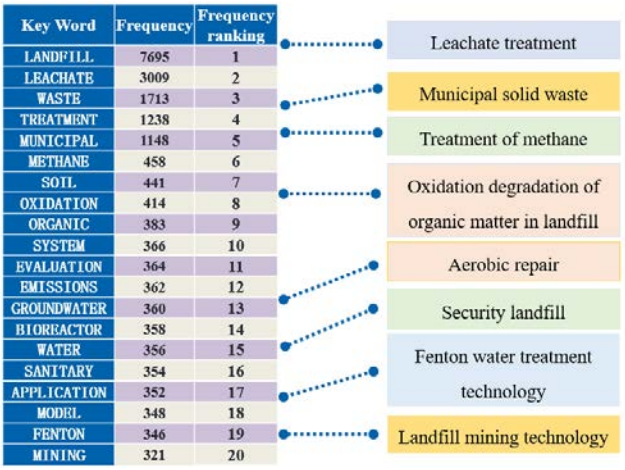


Fig.5 Ranking of the Top 20 Keywords in Terms of Frequency of Landfill Technology

5.2 Clustering Analysis on Technical Topics

It can be seen from Figure 6 that the top 30 papers that are cited most are distributed from 1997 to 2012. The first part and the second part are correlated, while the third part is relatively independent. The first part focuses on the change of leachate composition, the second part focuses on landfill leachate treatment technology, and the third part focuses on landfill gas treatment technology. The larger the circle, the higher number of the citation. The number in the circle represents the chronological order of the papers. It can be told that the main research object of landfill technology is the treatment and disposal of leachate and landfill gas generated in the landfill. Around those research objects, aerobic remediation technology, Fenton technology and landfill mining technology are developed.

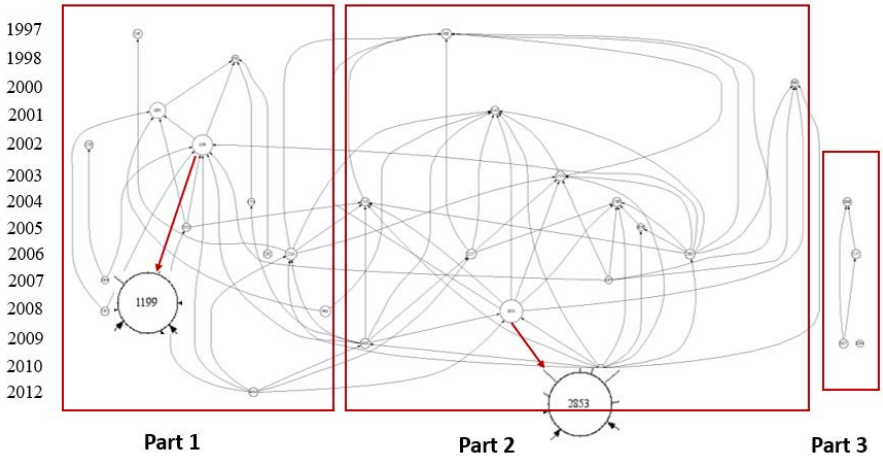


Fig.6 Time Sequence Diagram of Landfill Technology Citation Relationship

6. Conclusion

(1)The actual application of landfill technology has been decreasing year by year, while the incineration technology has been increasing. Although the engineering application has declined, the academic research interest in landfills has increased year by year.

(2)The landfill technology in China hold a high global research interest. However, from the quantity of citations, the depth of research and recognition needs to be further improved compared with European and American countries.

(3)Papers published on the “JOURNAL OF HAZARDOUS MATERIALS” have the highest impact factor and relatively higher recognition.

(4)The main research institution of landfill technology in the past 24 years is Tongji University, which holds the largest number of publications and relatively more frequent citation.

(5)The research hotspots of landfills mainly focus on leachate treatment methods, leachate composition analysis, landfill gas treatment and oxidation repair technology.

7. Acknowledgment

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