International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
Volume 7 Issue 23 (December 2025) PP. 417-432
DOI 10.35631/IJIREV.723027

INTERNATIONAL JOURNAL OF INNOVATION AND INDUSTRIAL REVOLUTION (IJIREV)
www.ijirev.com

BIBLIOMETRIC ANALYSIS ON RESEARCH TRENDS IN LANDFILL LEACHATE TREATMENT TECHNOLOGIES

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Article Info:

Article history:
Received date: 22.10.2025
Revised date: 10.11.2025
Accepted date: 01.12.2025
Published date: 21.12.2025

To cite this document:

Hamzah, N., Akbar, N. A., Mohd Zin, N. S., Alias, S., Mohamad Zailani, L. W., & Haron, N. F. (2025). Bibliometric Analysis on Research Trends in Landfill Leachate Treatment Technologies. *International Journal of Innovation and Industrial Revolution, 7* (23), 417-432.

Abstract:

Landfill leachate treatment remains as one of global environmental challenges due to the complex composition of leachate which contains high concentrations of organic matter, ammoniacal nitrogen, heavy metals and refractory pollutants that threaten water quality and ecological systems. Despite the growing number of studies addressing this issue, a comprehensive understanding of the research landscape is limited, making it necessary to systematically map trends, influential contributions and emerging themes. This study conducts a bibliometric analysis of leachate treatment technologies to identify scientific progress and intellectual structures shaping the field. Data were collected using the Scopus database through an advanced search with the keywords “landfill leachate” and “leachate treatment,” yielding 784 final records published between 2000 and 2025. The dataset was cleaned and harmonized using OpenRefine, statistical trends were analyzed with the Scopus analyzer, and knowledge structures were visualized using VOSviewer software. The results reveal a steady increase in publications with a notable surge after 2015, indicating growing global attention to leachate management. China leads research output, followed by Malaysia, Iran, and India, reflecting country priorities where landfilling remains the dominant waste disposal method.

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Citation analysis highlights highly influential works focusing on electrochemical oxidation, advanced oxidation processes, adsorption, and biological technologies, while keyword co-occurrence mapping identifies emerging themes in electro-Fenton processes, membrane bioreactors, microbial community dynamics, and integrated treatment approaches. Collaboration patterns suggest increasing international partnerships, particularly among Asian and European countries. Hence, this study contributes to the body of knowledge by providing a holistic overview of research trends, influential publications and thematic clusters offering valuable insights for policymakers, landfill practitioners and researchers to advance sustainable solutions in landfill leachate treatment.

Keywords:

Landfill Leachate, Leachate Treatment, Bibliometric Analysis

Introduction

Landfill leachate is a byproduct of the decomposition of waste in landfills, which poses significant environmental and public health risks due to its complex composition and high pollutant concentrations. As urbanization and waste generation continue to increase, the effective treatment of landfill leachate has become a critical concern for waste management systems worldwide (Singh et al., 2023; Yu et al., 2022). Leachate contains a mixture of organic and inorganic compounds, including heavy metals, ammonia, and various emerging contaminants, which can contaminate soil, groundwater, and surface water if not properly managed (Fang et al., 2021; Xiang et al., 2025). Consequently, the development and implementation of efficient leachate treatment technologies are essential to mitigate these risks and ensure environmental protection.

The treatment of landfill leachate involves a variety of technologies broadly categorized into physical, chemical, biological, and advanced treatment processes. Physical treatment methods such as screening, sedimentation, and filtration are often used as preliminary steps to remove suspended solids and reduce the load on subsequent treatment stages (Fu et al., 2022; Singh et al., 2023). Chemical treatments including coagulation, flocculation, and chemical oxidation are employed to neutralize and stabilize the leachate, effectively removing heavy metals and other contaminants (Chelliapan et al., 2020; Ramprasad et al., 2019). Biological treatments utilizing microorganisms to degrade organic matter are widely used due to their cost-effectiveness and ability to handle large volumes of leachate. Common biological methods include aerobic systems like activated sludge and sequencing batch reactors (SBRs), as well as anaerobic processes such as up-flow anaerobic sludge blanket (UASB) reactors (Li et al., 2007; Zhang & Surampalli, 2016).

Furthermore, advanced treatment such as advanced oxidation processes (AOPs) has gained attention for its ability to degrade refractory organic pollutants and reduce secondary pollution. Technologies such as electrochemical oxidation, Fenton processes and three-dimensional electrode systems have shown promising results in treating complex leachate compositions (Deng et al., 2020; Feng et al., 2020; Yu et al., 2022). Membrane technologies including microfiltration, ultrafiltration, nanofiltration and reverse osmosis, are also extensively employed due to their high efficiency in removing a wide range of contaminants. However, the membrane fouling issue and the need for frequent maintenance remain significant challenges (Brito et al., 2024; Li et al., 2010; Zhang & Surampalli, 2016).

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Recent studies have explored the integration of multiple treatment technologies to enhance the overall efficiency and effectiveness of leachate treatment systems. For instance, combining electrochemical and oxidation processes with sand filtration has been suggested as an ideal multi-stage treatment approach (Long et al., 2009). Similarly, the use of membrane bioreactors (MBRs) in conjunction with nanofiltration has demonstrated high removal efficiencies for chemical oxygen demand (COD) and color, meeting stringent effluent discharge standards (Li et al., 2010; Li et al., 2007). These integrated systems leverage the strengths of individual technologies to address the diverse and complex nature of landfill leachate.

Despite the advancements in leachate treatment technologies, several challenges remain. The variability in leachate composition influenced by factors such as the age of the landfill and the type of waste deposited requires specific treatment solutions (Ramprasad et al., 2019; Xiang et al., 2025). Additionally, the presence of emerging contaminants such as microplastics and pharmaceuticals requires innovative approaches to ensure their effective removal (Brito et al., 2024; Fang et al., 2021). Continuous research and development are essential to optimize existing technologies, explore new treatment methods and address the economic and technical challenges associated with large-scale implementation (Fang et al., 2021; Xiang et al., 2025).

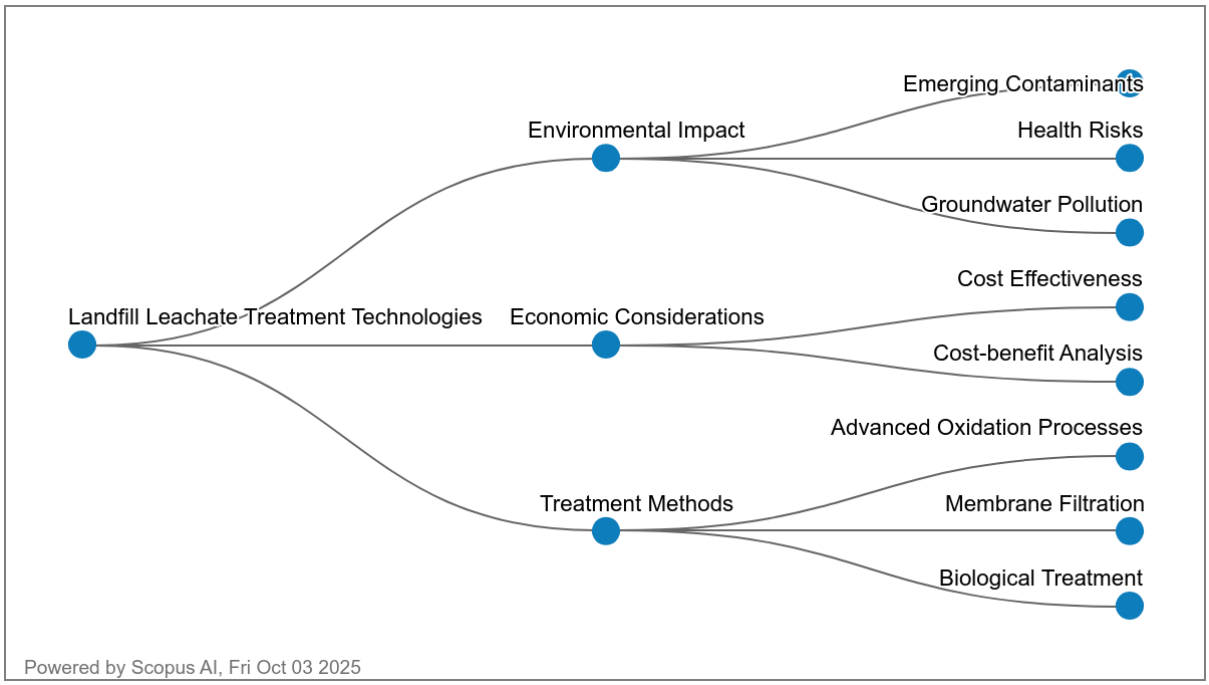

Figure 1: Conceptual Map of Landfill Leachate Treatment Technologies

Figure 1 illustrates the key components in landfill leachate treatment technologies generated from Scopus Ai, highlighting (1) environmental impact, (2) economic aspect and (3) technical considerations. From an environmental standpoint, leachate is related to emerging contaminants, groundwater pollution and potential health risks emphasizing the urgency of effective treatment to mitigate ecological and public health impacts. Economically, cost effectiveness and cost-benefit analysis are central to evaluating the feasibility and sustainability of treatment methods, particularly in the limitation of resources, where landfill operations must balance performance efficiency with affordability. Moreover, technological approaches are categorized into advanced oxidation processes, membrane filtration, and biological treatment, reflecting a broad spectrum of physico-chemical treatment and biological methods currently

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explored to enhance pollutant removal efficiency. The integration of these methods is often necessary due to the complex composition of landfill leachate which contains high loads of refractory organics, ammoniacal nitrogen, salts, and heavy metals. Overall, the map emphasizes that landfill leachate treatment is not solely a technical challenge but also an environmental and economic concern requiring multidisciplinary approaches that align effective pollutant removal with sustainable cost management and minimized ecological risk. In conclusion, the treatment of landfill leachate is a multilayered challenge that requires a combination of physical, chemical, biological and advanced oxidation processes. The integration of these technologies along with ongoing research and innovation, is crucial to developing efficient and sustainable solutions for managing landfill leachate and protecting environmental and public health.

Hence, this study addresses five key research questions (RQ) to systematically map the knowledge trends of landfill leachate treatment technologies. The first **RQ1** focuses on research trends in landfill leachate treatment over time, examining how publication output has evolved over the year, which highlights phases of growing scientific attention. The second **RQ2** identifies the ten most highly cited journal articles providing insights into the influential studies that have shaped theoretical and methodological advancements in this research field. The third **RQ3** explores the top ten contributing countries reflecting the geographical distribution of research output and regional priorities in waste management. The fourth **RQ4** analyzes the most frequently used keywords to discover dominant themes and emerging research topics. Finally, the fifth **RQ5** investigates international co-authorship networks to disclose patterns of collaboration as cross-country partnerships are increasingly important in addressing complex environmental challenges. These research questions will offer a comprehensive framework to evaluate progress, influence and collaboration in landfill leachate treatment research field.

Methodology

Bibliometrics has evolved into a powerful research methodology that systematically collects, organizes and analyzes bibliographic data from scientific publications (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). Moving beyond descriptive statistics such as journal distributions, publication trends and prolific authors (Wu & Wu, 2017), bibliometric analysis now involves advanced techniques, including co-citation and network mapping, to uncover intellectual structures and research frontiers. A rigorous bibliometric review requires an iterative process of defining appropriate keywords, conducting structured searches and performing in-depth analytical synthesis (Fahimnia et al., 2015). High-impact publications serve as the foundation for such reviews, as they provide critical insights into the theoretical frameworks and evolving paradigms of the field. To ensure both comprehensiveness and accuracy, Scopus was selected as the primary database, given its extensive coverage and established reliability (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017). To maintain scholarly quality, the dataset was restricted to peer-reviewed journal articles, excluding books, lecture notes and non-indexed materials (Gu et al., 2019). The analysis focused on publications from 2000 to October 2025, ensuring the inclusion of the most recent and relevant contributions.

Data Search Strategy

The dataset for this bibliometric analysis was systematically compiled from the Scopus database, chosen for its extensive coverage of peer-reviewed literature and its reliability in providing high-quality bibliographic records. An advanced search strategy was employed to

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ensure precision and reproducibility, using the following search string; TITLE ("leachate" AND "treatment" AND ("landfill leachate treatment" OR "leachate treatment")) AND PUBYEAR > 1999 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "final")), as shown in Table 1. This query was specifically designed to retrieve publications that explicitly focus on landfill leachate treatment, thereby excluding studies outside the intended scope such as broader wastewater treatment contexts.

Table 2 summarizes the selection criteria in the data searching process from the Scopus database. The search was limited to publications from the year 2000 through 2025 to capture 25 years of research development, while excluding earlier studies that may not align with present technologies or methodological standards. Language was restricted to English to ensure accessibility and consistency in analysis, with non-English studies excluded. To maintain academic accuracy, the search was limited to journal articles, while conference papers, book chapters and reviews were excluded on the grounds that they may either lack full peer review or do not present original contributions. Furthermore, to ensure accuracy and stability of data, only publications marked as "final" were considered, excluding "in press" documents that may be subject to revisions or incomplete citation information. This search was conducted in October 2025, establishing a definitive cut-off point for inclusion. Following these systematic screening criteria, the search yielded a total of 784 eligible journal articles. This dataset represents a robust body of original and peer-reviewed research output, providing a comprehensive foundation for bibliometric mapping analysis. By applying inclusion and exclusion parameters, this study minimizes bias, enhances replicability and ensures that the resulting dataset offers reliable insights into research trends, knowledge structures and emerging directions in the field of landfill leachate treatment. To further improve accuracy and reliability, the dataset was cleaned and harmonized using OpenRefine. This step allowed for the correction of inconsistencies in author names, institutional affiliations, keywords and other metadata ensuring that duplicate entries and fragmented variations of the same entities were merged into standardized formats. This refinement was critical to avoid analytical distortions, particularly in keyword co-occurrence, citation tracking and collaboration mapping.

Table 1: The Search String

Database	Search string	Result
Scopus	TITLE ("leachate" AND "treatment" AND ("landfill leachate treatment" OR "leachate treatment")) AND PUBYEAR > 1999 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final"))	784 articles

Table 2: The Selection Criterion in Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2000 – 2025	< 2000
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

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Data Analysis

VOSviewer developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands, is one of the most widely recognized tools for bibliometric visualization and analysis (van Eck & Waltman, 2010, 2017). Designed to combine methodological consistency with user accessibility, the software enables the generation of insightful network visualizations, clustering of related items, and the construction of density maps. Its versatility allows researchers to examine co-authorship, co-citation, and keyword co-occurrence networks, thereby providing a comprehensive overview of the intellectual and thematic structures within a research field. The platform's interactive interface, coupled with continuous development, facilitates efficient exploration of large datasets, while its ability to compute metrics, customize outputs, and integrate multiple bibliometric sources ensures its enduring value for both novice and advanced scholars. A distinctive feature of VOSviewer is its capacity to transform complex bibliometric data into visually interpretable maps and charts. With a strong emphasis on network visualization, the software excels in detecting keyword co-occurrence patterns, clustering related research themes, and illustrating knowledge structures through density mapping. Its adaptability to various bibliometric data types, including co-authorship and citation networks, positions VOSviewer as an indispensable tool for uncovering research frontiers and generating meaningful insights.

In this study, datasets containing publication year, title, author, journal, citation, and keyword information in PlainText format were extracted from the Scopus database for the period 2000 to October 2025. These records were processed using VOSviewer version 1.6.19, employing clustering and mapping techniques to generate research maps. Unlike the conventional Multidimensional Scaling (MDS) approach, which relies on similarity measures such as cosine and Jaccard indices, VOSviewer applies a normalization method based on association strength (AS_{ij}) (van Eck & Waltman, 2010), (Van Eck & Waltman, 2007). This measure is expressed as:

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}$$

where C_{ij} is the observed co-occurrence of items i and j, and w_i and w_j are their respective frequencies, reflects the ratio of observed to expected co-occurrences under statistical independence (Van Eck & Waltman, 2007). By employing this method, VOSviewer ensures that spatial proximity in visualizations accurately represents item relatedness, offering a robust and reliable alternative to MDS (Appio et al., 2014).

Results and Findings

RQ 1: What Is the Publication Trend in Landfill Leachate Treatment Research Over Time?

Figure 2 illustrates the publication trend on landfill leachate treatment technologies from 2000 to 2025 based on the datasets extracted from the Scopus database. The research trend demonstrates a clear upward trajectory, reflecting the growing global recognition of leachate management as an urgent environmental challenge. In the early 2000s, research activity was relatively modest, with fewer than 10 publications annually, suggesting limited awareness and fewer technological solutions being explored at the time. A gradual increase began around 2010 to 2015, corresponding with the rising emphasis on environmental sustainability, stricter waste management regulations and the global impulse toward achieving Sustainable Development

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Goals (SDGs). During this period, the number of studies consistently doubled compared to the early years, indicating a shift from exploratory research to more structured investigations into treatment technologies. By 2019, research output surged to 38 papers and showed steady growth, reflecting stronger scientific interest and collaborative networks in this field.

The sharp increase between 2020 and 2023, peaking at 72 documents, suggests heightened global attention to landfill leachate treatment, likely driven by advancements in analytical methods, the integration of physico-chemical and biological technologies, and the need for innovative, cost-effective solutions in response to high salinity and refractory pollutants in leachate. The COVID-19 pandemic may have indirectly influenced this growth, as waste generation dynamics has changed and researchers focused more on environmental monitoring and waste treatment. The slight decline observed in 2024 (64 papers) and 2025 (51 papers, up to October) may reflect incomplete data capture for the final year rather than a true reduction in research output. Overall, the trend underscores the transition of landfill leachate treatment from a niche research area in the early 2000s to a globally significant field of inquiry, propelled by regulatory pressures, technological innovation and the urgent need for sustainable waste management practices.

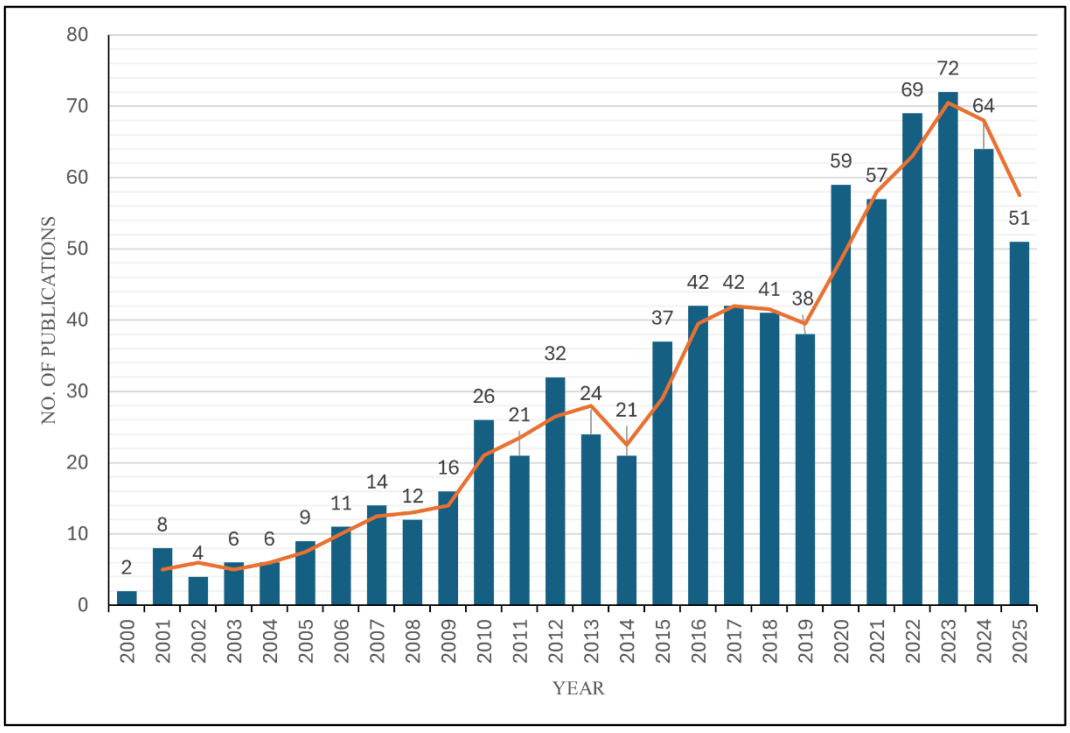

Figure 2: Number of Publications from Year 2000 to 2025

RQ 2: What Are the Top 10 Highly Cited Articles in This Field?

Table 3 shows the most cited works in landfill leachate treatment research highlight a clear emphasis on advanced physico-chemical processes and innovative hybrid technologies. Deng & Englehardt (2007) tops the list with 357 citations for their work on electrochemical oxidation, a process that directly addresses the challenge of refractory pollutants, marking a milestone in the application of electrochemical methods for leachate treatment. Similarly, Tizaoui et al., (2007) with 324 citations, demonstrated the effectiveness of ozone and ozone/hydrogen peroxide systems, reflecting the scientific interest in advanced oxidation processes (AOPs) during the mid-2000s. The prominence of Halim et al., (2010) with 312

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citations underscores the importance of adsorption studies, comparing zeolite, activated carbon and composite adsorbents, which remain highly relevant due to their cost-effectiveness and adaptability. These articles are highly cited across diverse journals such as *Waste Management*, *Journal of Hazardous Materials*, and *Desalination*, demonstrate the community's focus on pollutant removal efficiency and environmental sustainability, positioning these studies as foundational references in the field.

The trend also shows that articles published in reputable journals addressing either optimization (Mohajeri et al., 2010), 275 citations) or integrated treatment approaches (Amor et al., 2015), 298 citations; Wang et al., 2010, 250 citations) attract sustained attention. Particularly, Trébouet et al. (2001) remains highly influential with 260 citations despite its early publication date, indicating the long-term relevance of nanofiltration and combined physicochemical processes. More recent works, such as Xie et al., (2014) on anaerobic dynamic membrane bioreactors (246 citations), highlight the growing importance of biological and hybrid membrane-based systems, while Yalçuk & Ugurlu (2009) emphasize the application of constructed wetlands (204 citations) in natural treatment approaches. Collectively, these citation patterns suggest that impactful studies are those that not only introduce innovative treatment methods but also demonstrate their applicability at pilot or full scale. High citation counts can therefore be attributed to the novelty of methods, broad applicability across regions, and the urgent need for sustainable solutions to address the complex composition of landfill leachate.

Table 3: Top 10 Cited Articles During 2000 To 2025

Rank	Authors	Year	Source	Total Citation
1	Deng & Englehardt, (2007)	2007	Waste Management	357
2	Tizaoui et al., (2007)	2007	Journal of Hazardous Materials	324
3	Halim et al., (2010)	2010	Desalination	312
4	Amor et al., (2015)	2015	Journal of Hazardous Materials	298
5	Zhang et al. (2013)	2013	Waste Management	278
6	Mohajeri et al. (2010)	2010	Journal of Hazardous Materials	275
7	Trébouet et al., (2001)	2001	Water Research	260
8	Wang et al., (2010)	2010	Journal of Hazardous Materials	250
9	Xie et al., (2014)	2014	Bioresource Technology	246
10	Yalçuk & Ugurlu, (2009)	2009	Bioresource Technology	204

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RQ 3: Where Are the Top 10 Countries Based on The Number of Publications?

The distribution of publications by country as shown in Figure 3, indicates that China is the clear leader in landfill leachate treatment research, contributing 208 documents, more than double the output of the second-ranking country, Malaysia with 96 citations. China's dominance can be attributed to its rapid urbanization, high generation of municipal solid waste (MSW) and the persistent environmental concerns associated with managing hundreds of active landfills. Strong government policies, extensive research funding and the prioritization of environmental technologies in China's national agenda have likely fueled this productivity. Malaysia's significant contribution is also notable, ranking second globally which reflects its unique context as a developing country with a high reliance on landfilling, including the prevalence of non-sanitary landfills and the environmental challenges posed by sites such as Pulau Burung Sanitary Landfill. This high research output aligns with Malaysia's efforts to address local leachate issues while building regional leadership in waste management research. Meanwhile, Iran with 69 citations, India (47 citations) and Turkey (46 citations) follow closely, highlighting the importance of landfill management in regions facing population growth and emerging environmental regulations.

In contrast, developed nations such as the United States (40 citations), Canada (29 citations) and South Korea (26 citations) contribute comparatively fewer publications which may be explained by their more advanced waste management systems that prioritize incineration, recycling and resource recovery over landfilling. Consequently, landfill leachate treatment has become a less central research focus compared to developing nations, where landfill remains the dominant disposal method. Brazil (37 citations) and Poland (26 citations) represent emerging contributors, most likely driven by increasing urban waste production and growing regulatory frameworks. Overall, the distribution reflects a clear pattern where countries experiencing high landfill dependency and facing immediate leachate challenges tend to produce more research, whereas countries with advanced integrated waste management systems often generate fewer studies in this specific area. This geographic difference underscores the role of socio-economic development, waste management practices, and national priorities in shaping global research trends on landfill leachate treatment.

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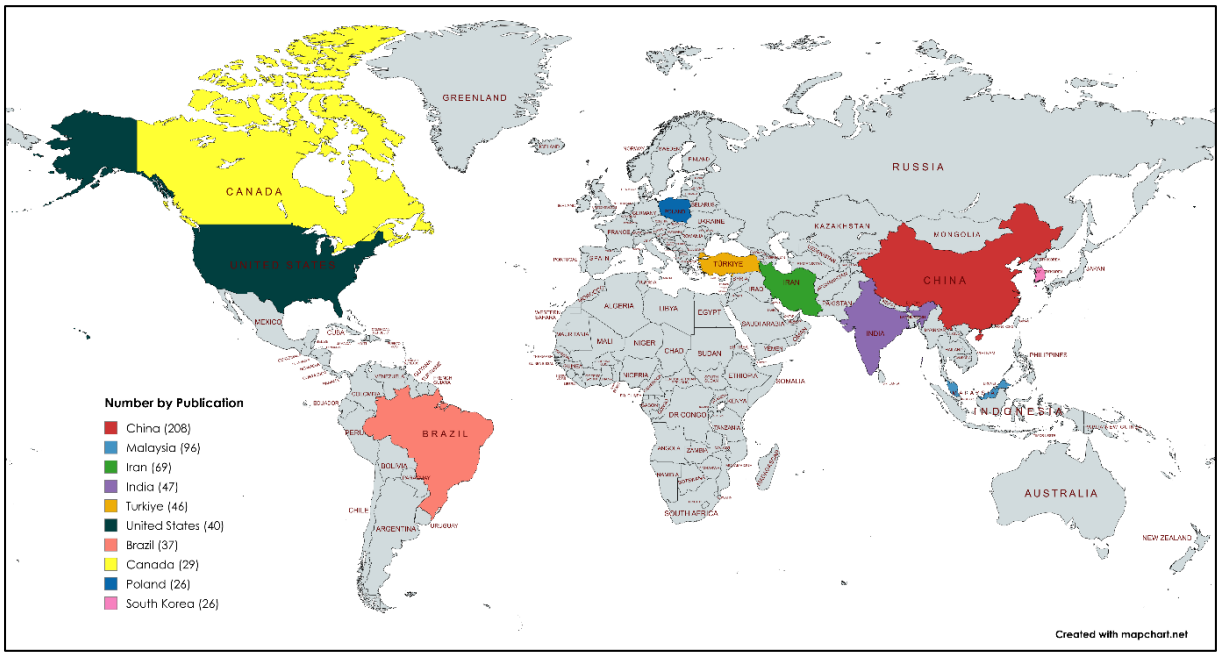

Figure 3: Country Mapping Based on Number of Publications

RQ 4: What Are the Popular Keywords Related to The Study?

Co-occurrence analysis of author keywords in VOSviewer is a bibliometric technique that identifies how frequently terms appear together across a body of literature, thereby mapping conceptual linkages and thematic structures within a research domain. By applying the full counting method with a minimum threshold of five occurrences, a total of 3,556 keywords were initially retrieved, of which 682 met the inclusion criteria. The setting of a minimum cluster size of five further refined the network into seven distinct clusters, each representing interconnected research themes. In this context, high-frequency keywords such as *landfill leachate* (494 occurrences, total link strength 11,671), *leachate treatment* (482 occurrences, total link strength 12,210), and *chemical oxygen demand* (311 occurrences, total link strength 8,403) emerged as central nodes, demonstrating their pivotal role in structuring the field. The clustering algorithm grouped related terms such as *ammonia*, *oxidation*, *bioreactors*, *electrochemical oxidation*, *adsorption*, and *constructed wetlands* into thematic clusters, indicating the diversity of technological approaches and analytical frameworks that dominate landfill leachate research. This methodological design ensures that the resulting visualization not only highlights the most influential concepts but also explains the interconnected of emerging and established keywords, hence creating a comprehensive overview of the intellectual research field. Figure 4 visualizes the co-occurrence network map based on the frequent keywords in landfill leachate treatment.

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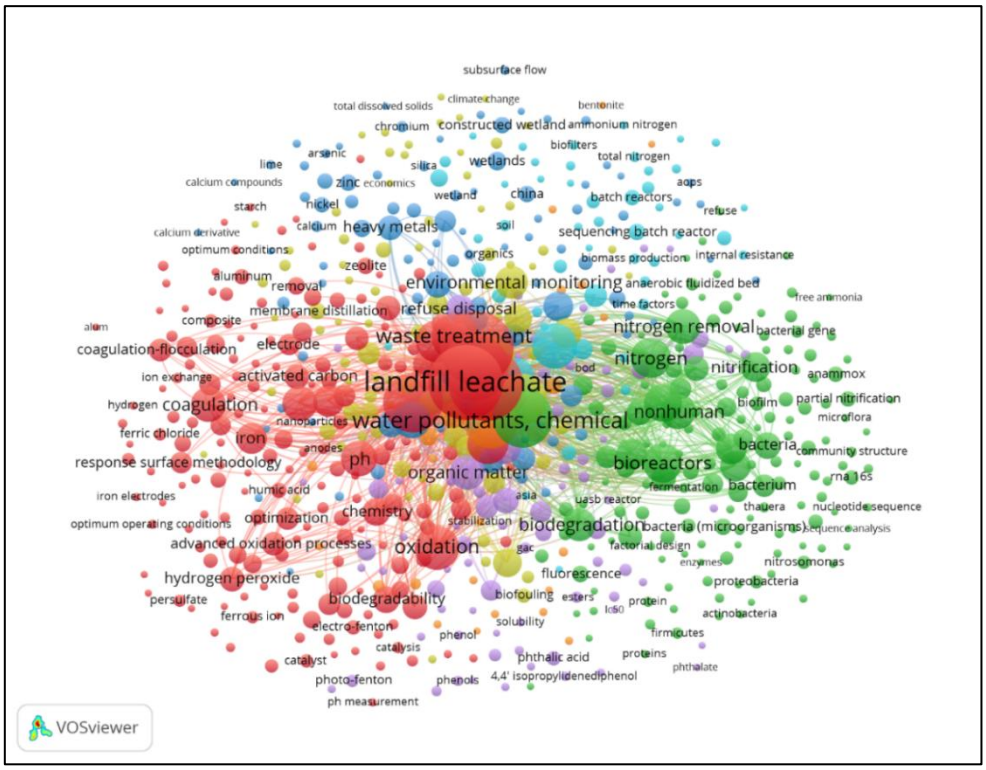

Figure 4: Network Visualization Map of Keywords' Co-Occurrence

The findings contribute significantly to the body of knowledge by illustrating both the maturity and the diversification of landfill leachate treatment research. The dominance of keywords related to pollutant indicators such as COD, BOD, ammonia, heavy metals underlines the longstanding focus on characterizing and mitigating leachate's complex composition. Meanwhile, the importance of leachate treatment such as electrochemical oxidation, adsorption, coagulation-flocculation, membrane bioreactor, and advanced oxidation processes, reflects the evolution of treatment strategies from conventional to advanced and hybrid technologies. Moreover, the presence of biological and ecological terms such as biodegradation, microbial community, denitrification, constructed wetlands, and bioremediation indicates a strong interdisciplinary shift towards sustainable, nature-based, and integrated solutions. The visualization also demonstrates geographic and methodological expansions with terms like "China, Malaysia, and optimization" highlighting regional research leadership and a growing emphasis on efficiency modelling. Besides, this co-occurrence analysis provides an evidence-based map of how the leachate field has evolved over time, identifies thematic clusters that represent current and emerging research frontiers and offers valuable insights in guiding future studies toward unexplored intersections between advanced treatment technologies, environmental monitoring and sustainable waste management practices.

RQ 5: What Is the Co-Authorship by Countries' Collaboration*?*

In bibliometric mapping, co-occurrence analysis of countries in VOSviewer also identifies the extent of research collaboration and intellectual linkages between nations, based on how frequently they appear together as author affiliations in publications. Network visualization positions each country as a node, with the strength of connections representing the frequency and intensity of co-authorship links across national boundaries. In this case, the analysis was generated using the full counting method, where each co-occurrence is given equal weight,

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with a minimum threshold of five documents per country. From a total of 71 nations, 42 met this threshold. A minimum cluster size of five was applied and the algorithm grouped them into seven clusters, reflecting regional or thematic collaboration networks. This approach not only represents productivity but also reveals how research on landfill leachate treatment is distributed and connected globally, highlighting the relationship between leading and emerging research communities.

The findings as shown in Figure 5 indicate that countries such as China (208 documents; 5,825 citations; total link strength 62) and Malaysia (96 documents; 3,268 citations; total link strength 70) emerge as major pivots, with Malaysia showing particularly strong network connectivity, suggesting frequent international collaboration. Established research economies such as the United States, United Kingdom, Japan and Canada demonstrate steady contributions but often with lower link strengths reflecting more independent or regionally concentrated research efforts. Meanwhile, developing nations like India, Iran, Turkey, Indonesia and Thailand contribute significantly. This can be explained by the pressing environmental challenges posed by landfilling in these regions, combined with increasing research capacity and local funding initiatives. The clustering patterns develop the body of knowledge by exemplifying that landfill leachate treatment is not confined to advanced economies only but instead, it has become a globally shared research agenda especially in countries where landfilling remains the dominant waste disposal method. This geographic spread underscores the urgent, worldwide relevance of leachate treatment, while the link strengths highlight pathways of international collaboration that foster technology transfer, methodological innovation and comparative studies across diverse landfill contexts.

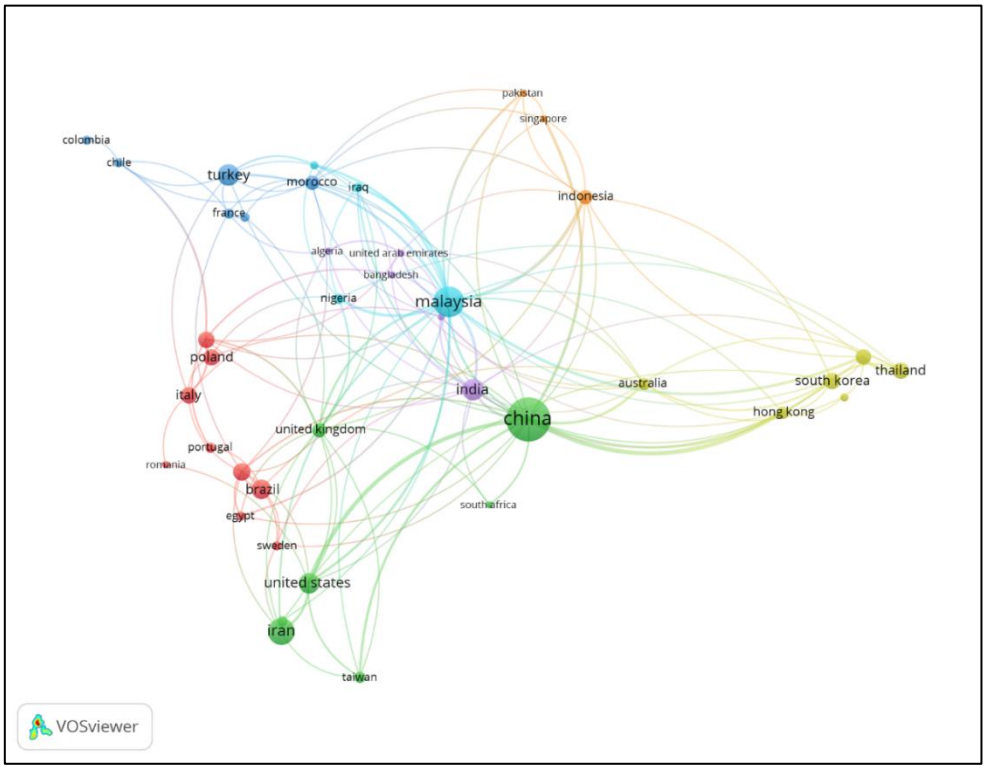

Figure 5: Co-Authorship by Countries

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Conclusion

The key goal of this study was to systematically map and analyze the global research landscape on landfill leachate treatment technologies through bibliometric methods. By addressing key questions on publication trends, highly cited works, top leading countries, keyword patterns, and international collaborations, the bibliometric analysis provides a comprehensive overview of scientific progress in this leachate treatment field. The findings demonstrate a steady rise in scholarly output from 2000 to 2025, with a notable surge after 2015, reflecting increasing global recognition of landfill leachate as a critical environmental challenge. China emerged as the dominant contributor, followed by Malaysia, Iran, and India, underscoring the prominence of regions where landfilling remains the primary waste disposal method. Moreover, citation analysis revealed that highly influential works focused on electrochemical oxidation, advanced oxidation processes, adsorption, and hybrid systems, which continue to shape the direction of treatment innovation.

This research also contributes to the field by clarifying knowledge structures and identifying emerging themes, including electro-Fenton processes, membrane bioreactors, microbial community studies, and integrated treatment combining physico-chemical and biological processes. These insights highlight a transition from conventional treatment to advanced and sustainable treatment strategies, aligning with global efforts to mitigate environmental risks and achieve stringent effluent discharge standards. The results convey important implications for on-site practice, offering guidance to policymakers, landfill engineers, and researchers in designing treatment systems that shall balance technical efficiency, cost effectiveness and environmental sustainability.

Nevertheless, this study has several limitations, including reliance on a single database, exclusion of non-English literature and restriction to only journal articles which may overlook relevant perspectives from conference proceedings, books or regional publications. Future research could expand the scope by incorporating multiple databases, multilingual datasets, and more extended analyses of emerging pollutants such as microplastics and pharmaceuticals. Despite these constraints, the study demonstrates the value of bibliometric analysis in advancing understanding of landfill leachate treatment technologies. By mapping intellectual structures and research frontiers, the analysis underscores the significance of continuous innovation and international collaboration to address the persistent and evolving challenges of landfill leachate management.

Acknowledgements

The authors would like to express their gratitude to the Institute of Postgraduate Studies, Universiti Teknologi MARA, Shah Alam and Universiti Teknologi MARA Cawangan Pulau Pinang for their support fund and assistance in fulfilling this study.

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IJIREV
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