Journal of Environmental Management 318 (2022) 115594

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Future trends and patterns in leachate biological treatment research from a bibliometric perspective

Dhaneswara Ilmasari [a], Eri Sahabudin [a], Fatimah Azizah Riyadi [a], Norhayati Abdullah [a,b], Ali Yuzir [a,*]

[a] Department of Chemical and Environmental Engineering (ChEE), Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100, Kuala Lumpur, Malaysia
[b] UTM International, Aras 8 Menara Razak, Jalan Sultan Yahya Petra, 54100, Kuala Lumpur, Malaysia

ARTICLE INFO

Keywords:
Wastewater treatment
Leachate
Biological treatment
Bibliometric analysis
Scopus database

ABSTRACT

Leachate has become a great deal of concern due to its complex properties which are primarily caused by the high concentrations of organics and ammonia. Thus, proper leachate treatment is required prior to its discharge. Leachate can be treated in various ways, and biological treatment is one of the approaches. This treatment has been shown to be both effective and cost-efficient while offering the possibility of resource recovery in the form of bioenergy. In this study, the underlying patterns in publications related to leachate biological treatment were uncovered through bibliometric analysis. This study also lays the groundwork for a deeper understanding of the past, current, and future trends of the leachate biological treatment. Research publications from 1974 to 2021 were retrieved from the Scopus database, and it was identified that 2013 articles were published in the span of 47 years. From the analyzed publications, China played a leading role in publishing leachate biological treatment research articles as well as having the most productive institutions and authors. Meanwhile, the USA was found to be the most active country in initiating international collaborations with 33 countries. The research hotspots were also successfully identified using keyword co-occurrences analysis. Anaerobic digestion and constructed wetland were revealed to be the research hotspots. The critical role of biological treatment in removing nitrogen from leachate was also highlighted. Besides, numerous research gaps were identified in the application of aerobic granular sludge (AGS) for leachate treatment. This can be a potential area for research in the future. Finally, future research should be encouraged to focus on the use of sustainable treatment systems in which energy recovery in the form of biogases is promoted.

1. Introduction

The abundant amount of leachate from landfills is a substantial problem in municipal solid waste (MSW) management (Neczaj et al., 2008). Leachate characteristics vary depending on the MSW composition as well as the geographical location and degradation stage of landfills (Contrera et al., 2014; Miao et al., 2019). Its most crucial characteristics are associated with high levels of pollutants and toxicity, which may be ascribed to the existence of heavy metals and ammonia (Li et al., 2021). Moreover, the treatment of leachate is more complicated due to high-molecular organic compounds, hydrocarbons, and inorganic salts (Chen et al., 2018). Direct discharge of untreated leachate to the neighboring water bodies will cause severe pollution of surface water and groundwater, consequently endangering the soil and harming the ecosystem, including human health (Jagaba et al., 2021). Therefore, an effective leachate treatment is critical.

Attempts have been made to develop a leachate treatment method that is both effective and cost-efficient. Aside from its complex characteristics, other factors to consider when developing a leachate treatment method include enhancing total nitrogen removal and lowering operational costs (Show et al., 2019; Wang et al., 2018). While physical-chemical treatments are well-known for their efficacy in eliminating the majority of pollutants, they are rather costly and generate secondary contaminants (Del Moro et al., 2016). Conversely, biological treatments are often employed to remove many pollutants, such as high organic content and nitrogen from leachate, particularly ammonia, at a low cost without producing any secondary contaminants (Jokela et al., 2002; Kurniawan et al., 2010). Furthermore, the literature

* Corresponding author.
E-mail address: muhdaliyuzir@utm.my (A. Yuzir).

https://doi.org/10.1016/j.jenvman.2022.115594
Received 21 April 2022; Received in revised form 10 June 2022; Accepted 18 June 2022
Available online 24 June 2022

has shown that biological treatment can solve a variety of environmental water problems in a more cost-effective way (Zekker et al., 2020, 2021b). Activated sludge (Boonnorat et al., 2021; Fang et al., 2020), sequencing batch reactor (SBR) (Michalska et al., 2020; Qiu et al., 2019), membrane bioreactor (MBR) (Coppini et al., 2018; Ittisupornrat et al., 2021), and up-flow anaerobic sludge blanket (UASB) (Selvam et al., 2017; Tulun, 2020) are some of the biological treatment options that have been successfully employed to treat leachate, achieving satisfactory pollutant removal. Besides, another advantageous feature of biological treatment is that organic matter may be transformed into biogas through anaerobic pathways, and this biogas can be used for various purposes (Lebron et al., 2021). This further adds to the value of biological treatment since the focus of wastewater treatment has switched to resource recovery in recent years.

Throughout the years, researchers have made attempts to write review papers describing the efficiency, research gaps, and recent advancements in the biological treatment of leachate (Abdelfattah et al., 2020; Abuabdou et al., 2020; Kurniawan et al., 2010; Payandeh et al., 2017). However, no information has been provided on the overall research trends as determined by bibliometric analysis. The closest similar bibliometric analysis related to this study was performed on the overall trend of leachate treatment, and it did not focus on biological treatment (Reshadi et al., 2021). A bibliometric study is essential in determining the current status and development trend, in which the research gaps of a particular research field can be elucidated (Liu et al., 2020). Through bibliometric studies, it is possible to quantitatively evaluate publications by using mathematical, statistical, and graphical approaches (Reshadi et al., 2021). Numerous types of evaluations can also be carried out, such as assessing the contribution and co-authorship of countries, journals, authors, and institutions in publishing articles relating to a specific topic. More importantly, by evaluating keyword co-occurrence, the past, current, and potential future study trends of a research field may be determined (Saidulu et al., 2021).

In the present study, a bibliometric analysis was performed to disclose the underlying patterns in research publications related to the biological treatment of leachate. Based on the data retrieved from the Scopus database, an analyses of the leading countries, journals, authors, and academic institutions is presented. The international collaboration between countries in publishing related articles is also elucidated. Furthermore, past, present, and future research hotspots are illustrated to gain deep insights into leachate biological treatment by analyzing the keywords co-occurrences.

2. Materials and methods

2.1. Data collection and search strategy

Bibliometric data were retrieved from the online database Scopus on January 31, 2022. The central topic was searched by using the query string: TITLE-ABS (leachate*) AND TITLE-ABS-KEY (biological AND (treatment* OR process*)), covering documents from 1974 to 2021. All document types other than journals and articles were excluded, resulting in 2270 documents. This study focused only on research articles to assess the research trends in-depth. Thus, particular terms such as review, bibliometric, recent progress, and critical review were added to the central topic query string to identify the potential review papers. There were 42 identified documents, and their EID numbers, a Scopus unique article identifier, were noted and incorporated into the central topic query string by applying field code 'AND NOT' to exempt them from the search. As a result, a total of 2228 document results was obtained.

The main focus of this study is to identify leachate biological treatments specifically. Therefore, it was decided to conduct a more targeted search by looking for specific phrases that could be directly related to biological leachate treatment rather than broad terms. More specifically, articles that contained any of the terms listed in Table 1 were chosen for additional search. A total of 2013 document results were included as the final data sources. Lastly, the search results were exported in CSV format for bibliometric analysis, including citation information, bibliographic information, abstract, keywords, etc. Fig. 1 depicts the overall research framework.

Table 1
Specific keywords added to the sub-topic detailed search.

Condition	Search phrases
Articles with these keywords in their title, abstract, or keywords passed the screening	Sequencing batch reactor (SBR) Membrane bioreactor (MBR) Activated sludge Aerobic granular sludge (AGS) Trickling filter (TF) Rotating biological reactor (RBC) Up-flow anaerobic sludge blanket (UASB) Expanded granular sludge bed (EGSB) Fluidized bed bioreactor (FBBR) Aerated lagoon Constructed wetland Moving bed bioreactor (MBBR) Anaerobic ammonium oxidation (Anammox) Microbial fuel cell (MFC)
Articles with these keywords in their title, abstract, or keywords did not pass the screening	Physico-chemical treatment Physical treatment Chemical treatment

2.2. Data analysis

The data retrieved from the search string was subjected to various analyses such as research trends, the most explored subject areas, and the most productive countries, authors, and journals with the greatest number of publications. Microsoft Excel 365 software was used to perform these analyses and to create statistical graphics. Meanwhile, the exported CSV file was imported to VOSviewer version 1.6.18 (Leiden University, Leiden, Netherlands), a free program that processes phrase detection and creates bibliometric mappings from network data. Two types of bibliometric maps were created, including country co-authorship and keyword co-occurrence. Circles linked by network links typically depict a visualization of the bibliometric map. The diameter and distances between these circles portray the prominence of the terms as well as their reliance (Tan et al., 2021). Moreover, a number called link strength is assigned to each link in order to indicate its level of importance. A higher value of the link strength expresses a stronger relationship between the two terms.

In the case of country co-authorship, the minimum number of documents of a country was set to 5, ensuring that only countries that have made significant contributions to the research were presented on the map. This set resulted in 53 countries that met the threshold. Meanwhile, clustering was performed to classify the countries based on their continents, namely Asia, Europe, America, Africa, and Oceania. Additionally, the link strength value between two countries reflects the number of publications in which these countries have collaborated. Meanwhile, the total link strength of a country shows the total number of times that country has collaborated with other countries.

On the other hand, 4496 author keywords from 2013 publications were involved in the analysis of keyword co-occurrences. Prior to importing the data into VOSviewer, a catalog of synonyms was created to merge similar keywords into one. For instance, keywords such as 'leachates', 'landfill leachate', 'fresh leachate', 'old leachate', etc. were combined and named as 'leachate'. The minimum number of keyword occurrences was set to 5. This means that each keyword appeared in a

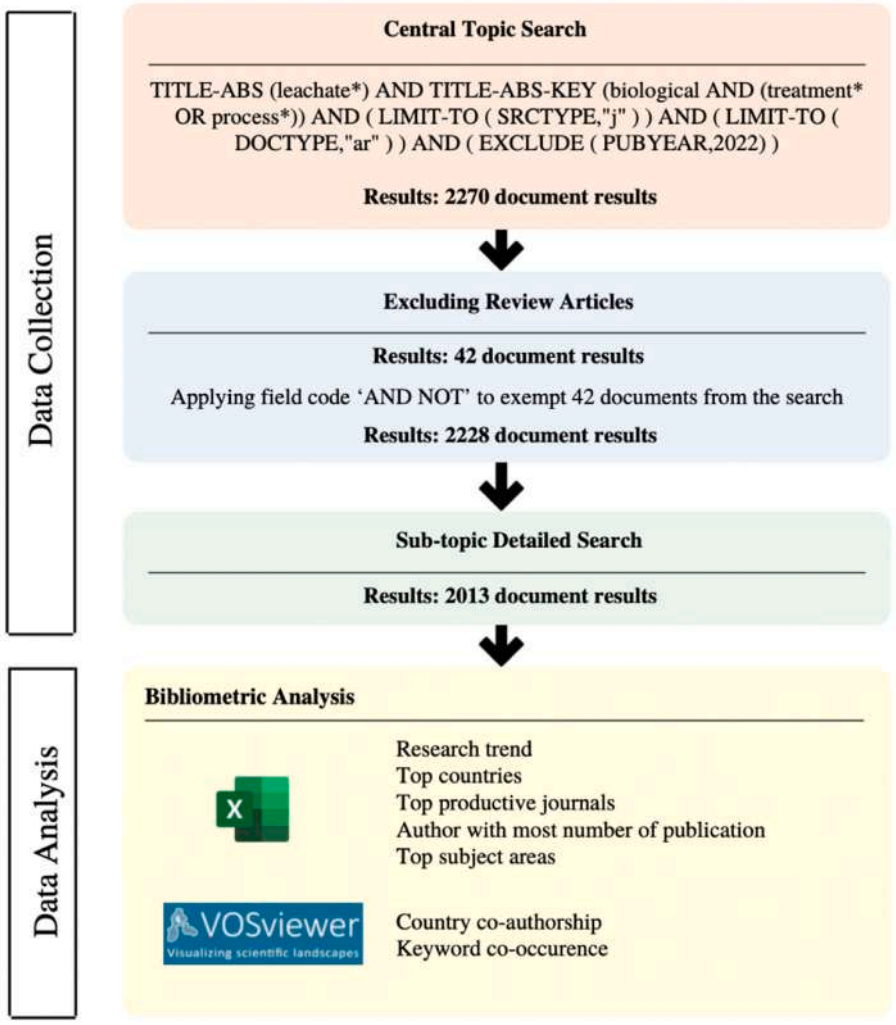

Fig. 1. Research framework.

minimum of 5 articles, which implies the significance of the keyword. The map was displayed based on the average publication year of the keywords by employing the overlay visualization mode in VOSviewer. Moreover, the link strength of the keyword co-occurrence demonstrates the connection between two keywords, with the value indicating the number of publications that contain both terms. More importantly, in order to know the keyword evolution from 1974 to 2021, the publications were divided chronologically into four groups (1974–2000, 2001–2010, 2011–2015, 2016–2021) to analyze the evolution of the keywords and the research hotspots.

3. Results and discussion

3.1. The publication trends and leading countries

The publication trend in the leachate biological treatment over the past 47 years is depicted in Fig. 2. The research on leachate biological treatment was started in 1974 and initiated by Boyle and Ham (1974), whereby only one article was published that year. Prior to 1996, despite the fluctuations, the publications increased moderately with the average of 6 articles published per year. In the next 10 years, the average number of publications annually increased by 300%, following the surge of research interest in the biological treatment of leachate. The number of publications further continued to develop rapidly since then, resulting in a significant increase in the cumulative number of publications. Although there was a sharp decline in 2020 as a result of the global COVID-19 pandemic, the number of scientific publications bounced back in 2021. Moreover, it was also discovered that in the last 12 years, the annual publications increased by an average of 100 articles per year. Hence it can be expected that the annual publications will keep increasing in the future.

Articles on leachate biological treatment have been published in 14 languages. The majority of the articles were published in English (87.1%), followed by Chinese (9.7%). Meanwhile, the rest of the articles were published in German, Portuguese, Polish, Spanish, French, etc. Regarding its accessibility, only 15.8% of the total articles were published in open access journals. In fact, the most cited article on leachate biological treatment is in a paid-access journal; it was entitled "Enrichment and characterization of an anammox bacterium from a rotating biological contactor treating ammonium-rich leachate". It was published in 2001 in the Archive of Microbiology journal, and it has been cited 509 times (Egli et al., 2001). Similarly, the first publication on leachate biological treatment entitled "Biological treatability of landfill leachate" was also published in a paid-access journal that has received 62 citations. It is noteworthy that open access publication has been linked to an increase in an article's citation rate because people immediately gain full access to the articles in the open access journals (Cuschieri, 2018).

On the other hand, the trend of research publications from 10 leading countries on leachate biological treatment is also depicted in Fig. 2. Based on the results, this topic has been studied in 91 countries worldwide. It was shown that China contributed the most with 496 articles or

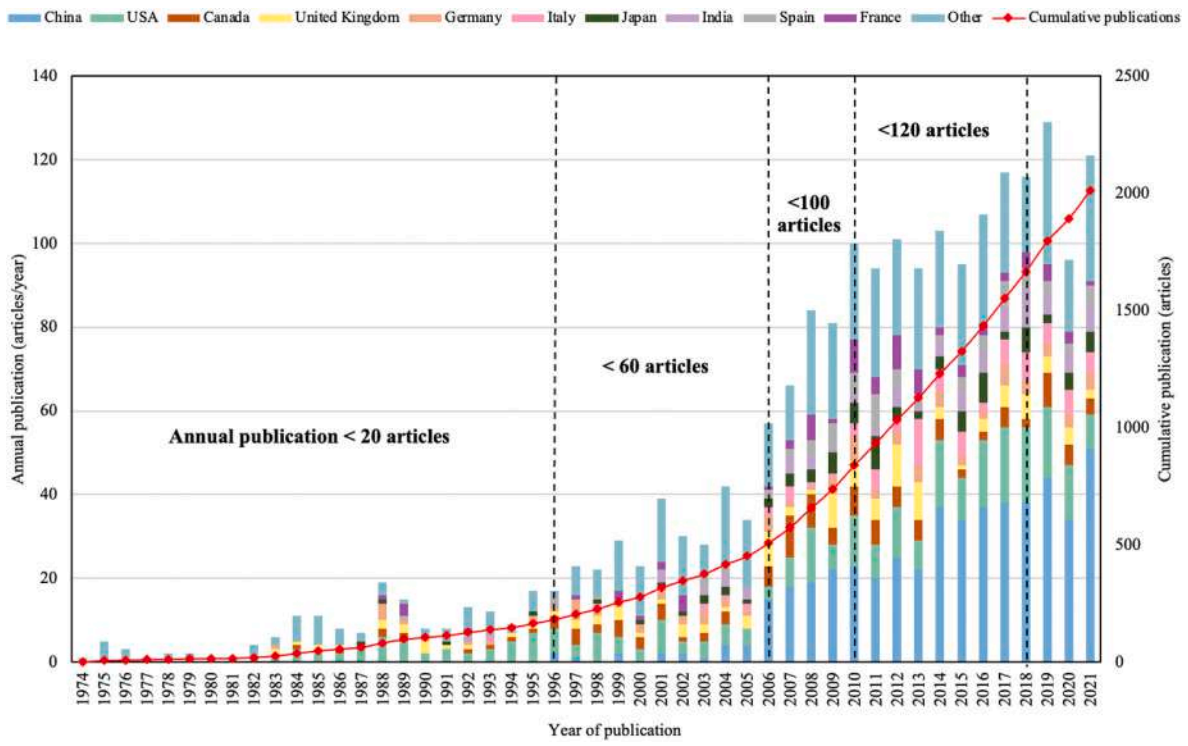

Fig. 2. Research trends of biological leachate treatment-related publications from the year 1974–2021.

about 24.6% of the total articles published, followed by the USA, Canada, United Kingdom, and Germany which contributed with about 13.9%, 6.0%, 5.7%, and 4.2%, respectively. From 1974 to 2005, the USA was the leading country before China took over the top spot in 2006. This phenomenon was influenced by the new legislation and policies of the Chinese government, whereby international collaboration on waste management and investment in waste management research and infrastructure were encouraged (Chen et al., 2015). Despite China's late entry into leachate biological treatment research, its research has grown swiftly, and it has maintained the pace as the leading country, implying that China is becoming one of the key countries in this research field. Meanwhile, based on Scopus online data, the USA, United Kingdom, Germany, Spain, and France have the highest average citation frequency per article (>25) among the top ten countries, indicating that their research has attracted significant attention among the researchers. Interestingly, China's average citation value per article was significantly lower, with only 15 citations per article.

Among the top 10 leading countries, seven belong to the Group of Seven (G7) countries known for their advanced industries and economies (Dai et al., 2015). These countries are the USA, Canada, United

Table 2
Top 10 most productive journals in leachate biological treatment research.

No	Source title	Total publications (%)	Total citations	CiteScore 2021	Highly cited article	Times cited	Publisher
1	Waste Management	130 (6.5)	4056	13.1	Bioreactor landfills: Experimental and field results	166	Elsevier
2	Bioresource Technology	122 (6.1)	4264	16.9	An anaerobic dynamic membrane bioreactor (AnDMBR) for landfill leachate treatment: Performance and microbial community identification (Xie et al., 2014)	160	Elsevier
3	Water Research	69 (3.4)	3551	17.6	Maintaining nitrite build-up in a system acclimated to free ammonia (Turk and Mavinic, 1989)	217	Elsevier
4	Water Science And Technology	57 (2.8)	795	3.4	Treatment of landfill leachate in on-site lagoons and constructed wetlands (Mæhlum, 1995)	71	IWA Publishing
5	Journal Of Hazardous Materials	49 (2.4)	1792	14.4	Simultaneous partial nitrification, anaerobic ammonium oxidation and denitrification (SNAD) in a full-scale landfill-leachate treatment plant (Wang et al., 2010)	202	Elsevier
6	Science Of The Total Environment	41 (2.0)	1067	13.7	Treatment of landfill leachate using an aerated, horizontal subsurface-flow constructed wetland (Nivala et al., 2007)	177	Elsevier
7	Waste Management And Research	39 (1.9)	365	5.7	A novel process using enhanced acidification and a UASB reactor for biomethanation of vegetable market waste (Rajeshwari et al., 2001)	37	SAGE
8	Chemosphere	38 (1.9)	1338	11.4	Completely autotrophic nitrogen-removal over nitrite in lab-scale constructed wetlands: Evidence from a mass balance study (Sun and Austin, 2007)	102	Elsevier
9	Environmental Technology United Kingdom	37 (1.8)	416	5.2	A cooperative microbial fuel cell system for waste treatment and energy recovery (Zhang and He, 2013)	28	Taylor & Francis
10	Huanjing Kexue Environmental Science	34 (1.7)	115	3.0	Landfill leachate treatment by anaerobic process and electrochemical oxidation (Wang et al., 2001)	22	Science Press

Kingdom, Germany, Italy, Japan, and France. Meanwhile, 2 out of 10 (China and India) are considered to be the leading countries with emerging economies. Therefore, this suggests that economic growth and technological advancement have played a significant role in the academic standards of a country, thus affecting the number of scientific research articles the country could publish.

3.2. Analysis of journals

According to Scopus online data, a total of 2013 articles were published in 160 different journals. However, most of these journals (81.3%) published fewer than ten articles related to leachate biological treatment. The top 10 most productive journals in this area of research, along with the highly cited articles from the respective journals, are presented in Table 2. The Waste Management journal ranked first among all journals with a total of 130 (6.5%) articles published. It was followed by Bioresource Technology and Water Research with a total of 122 (6.1%) and 69 (3.4%) published articles, respectively. However, based on the total citations count, Bioresource Technology received the highest number of citations with a total of 4264 citations, despite ranking second in productivity. It was closely followed by Waste Management, with 4056 total citations. Furthermore, the top 10 journals were published by five different publishers. Elsevier secured the top spot with six journals. Meanwhile, four other publishers, such as IWA Publishing, SAGE, Taylor & Francis, and Science Press, had one journal each.

As reported in the latest report of Scopus' CiteScore, 6 out of the 10 most productive journals had a CiteScore of more than 10. These journals include Waste Management, Bioresource Technology, Water Research, Journal of Hazardous Materials, Science of The Total Environment, and Chemosphere, with CiteScore values of 13.1, 16.9, 17.6, 14.4, 13.7, and 11.4, respectively. Interestingly, the Water Research journal had the highest CiteScore in 2021, although it only had 69 articles published. Meanwhile, the lowest CiteScore in 2021 was by Huanjing Kexue Environmental Science, with a CiteScore value of 3.0. Generally speaking, higher CiteScore is often associated with a journals' impact. However, it must be noted that CiteScore should be used solely to determine the impact of publications within the same subject fields, as differences in behavior within subject fields might also affect the CiteScore's relevance (Colledge et al., 2017).

3.3. Analysis of subject area

The publications on leachate biological treatment were associated with 25 different subject areas. The top 5 most explored subject areas were Environmental Science (1532), Chemical Engineering (326), Engineering (258), Agricultural and Biological Science (213), and Chemistry (201). Meanwhile, when all subject areas were sorted by decades, a shift in the research profile of leachate biological treatment can be observed (Fig. 3). In the 1970s, the publications were dominated by Engineering, Environmental Science, and Chemical Engineering subjects with total percentages of 38.1%, 14.3%, and 9.5%, respectively. These subject areas remained representative until the present, regardless of changes in the order of dominance. Environmental Science has been in the lead since the 1980s (>40%), and it was distantly followed by other subject areas. New subject areas such as Earth and Planetary Science as well as Biochemistry, Genetics, and Molecular Biology emerged in the 1980s. Meanwhile, as a consequence of global concern regarding the fossil fuel depletion and the need for alternative energy sources, the publications related to the Energy subject have grown steadily since the 1990s. This phenomenon could be linked to the high amount of methane gas (biogas) production that is known to be generated during the anaerobic treatment of leachate (Begum et al., 2018; Berrueta and Castrillón, 1992; Cirik and Gocer, 2020; Parawira et al., 2006). The increasing trend of Energy-related publications is expected to continue in the future as interest in the circular economy continues to grow. The circular economy not only addresses resource shortages effectively but also points toward the direction of sustainability (Smol et al., 2020).

3.4. Analysis of leading academic institutions

According to Scopus online data, 160 different institutions have contributed to publishing research articles regarding leachate biological treatment. Out of 160 institutions, 136 were academic institutions. Non-academic institutions such as National Research Centre, National Research Laboratory, Research Service, Organization, etc. were ruled

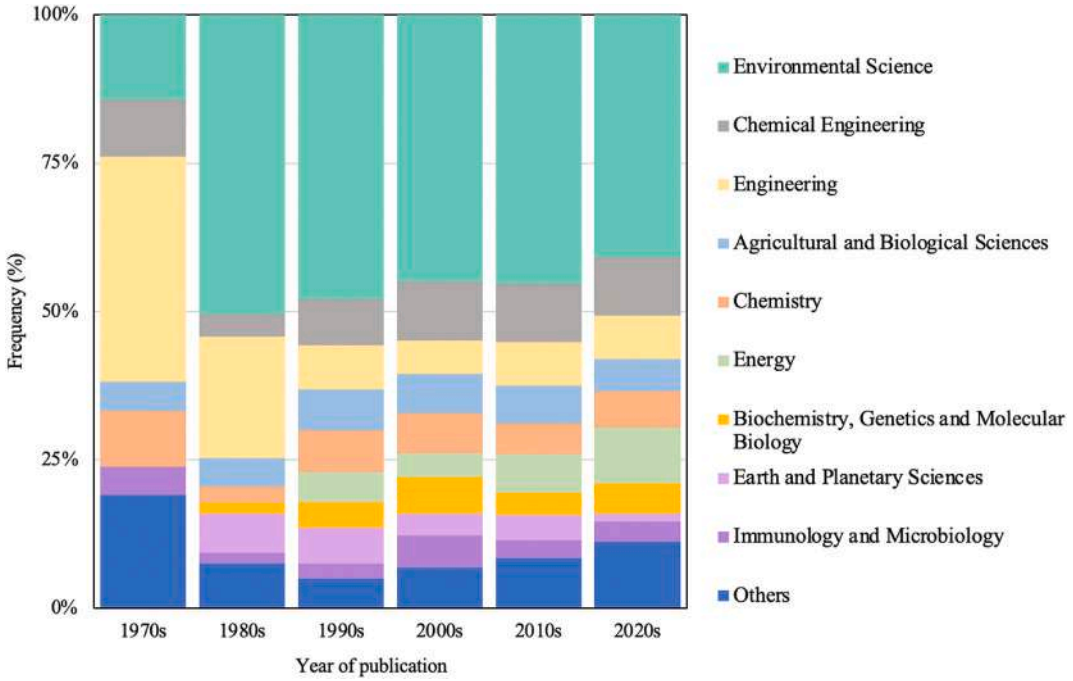

Fig. 3. Publications per subject area per decades.

out from the analysis. Therefore, the top 10 most productive academic institutions are listed in Table 3. As can be seen, each of the institutions listed in the table has published more than 15 articles. Of these, China led with six institutions while countries like Canada, Thailand, Australia, and Italy came next with one institution each. Beijing University of Technology (China) had the highest total publication number with 78 articles (3.87%), followed by Tongji University (China) with 44 publications (2.19%). The University of British Columbia (Canada) and Harbin Institute of Technology (China) came up next with the same publication number of 29 articles (1.44%) each. The only Thai (Kasetsart University) and Australian (The University of Queensland) institutions with a total publication of 17 articles contributed to 0.84% of the total publications. Meanwhile, the sole Italian institution (Università degli Studi di Padova) published 16 articles, accounting for 0.79% of the total publications. Aside from that, it is pertinent to mention that very few of the leading countries with a high number of publications (Fig. 2) have any of their institutions ranked among the top 10 most prolific academic institutions. This is most likely because research in these countries is not centralized.

By analyzing the average cited frequency per paper of each institution, The University of Queensland (Australia) had the highest average cited frequency with 57.4 citations/paper. This number was significantly higher than the 2nd highest average cited frequency, which is Tongji University (China), with 30.3 citations/paper. It was worth noting that the total number of publications from The University of Queensland was only 17, whereas Tongji University had 44 publications. It was discovered that seven articles from Tongji University were written in Chinese, which could explain the lower citation count. Besides, The University of British Columbia (Canada), Beijing Forestry University (China), and Università degli Studi di Padova (Italy) have received over 20 citations/per paper. On the other hand, although Beijing University of Technology had the highest number of publications, its average cited frequency (13.3 citations/paper) was considerably lower compared to the others. Similar to Tongji University, it was discovered that 46 of the 77 publications from Beijing University of Technology were published in Chinese regional journals. Given the immense productivity of Chinese institutions in leachate biological treatment research, greater attention should be paid to enhancing the quality of the research so that the articles can be published in international journals, exposing them to a wider audience and resulting in increased citation counts.

Table 3
The top 10 most productive institutions in leachate biological treatment research.

No	Affiliation	Country	Total publications	Contribution rate (%)	Average citation per paper
1	Beijing University of Technology	China	78	3.87	13.3
2	Tongji University	China	44	2.19	30.3
3	The University of British Columbia	Canada	29	1.44	26.3
4	Harbin Institute of Technology	China	29	1.44	11.3
5	Beijing Forestry University	China	22	1.09	23.5
6	Kasetsart University	Thailand	17	0.84	16.8
7	Tsinghua University	China	17	0.84	15.7
8	The University of Queensland	Australia	17	0.84	57.4
9	Università degli Studi di Padova	Italy	16	0.79	25.0
10	Chongqing University	China	16	0.79	6.9

3.5. Analysis of leading authors

Authors who have contributed substantially to leachate biological treatment research throughout the past 47 years have been acknowledged in this analysis. Consequently, the top 10 most productive authors in leachate biological treatment are listed in Table 4 along with the author's *h*-index, total citations, and current affiliation. With 52 (2.58%) research articles, an h-index of 73, and 663 total citations per 2021, Y. Peng from Beijing University of Technology, China, was on the top of the list. Peng was then followed by an author from the same affiliation, S. Wang, with a total of 25 (1.24%) publications, an *h*-index of 56, and 538 total citations. Meanwhile, two authors from Thailand, C. Chiemchaisri and W. Chiemchaisri, contributed by publishing 18 (0.89%) and 15 (0.75%) publications, respectively. It was intriguing that of all the authors included on the list, only one author was from a non-Asian country, D.S. Mavinic from Canada. This author has an *h*-index of 38 and has published 15 (0.75%) research articles with a total number of citations of 461.

It also can be observed that Chinese authors dominated with 7 of them ranking in the top 10. Thailand and Canada came in 2nd and 3rd with 2 and 1 author(s), respectively. Moreover, the fact that most of these authors are affiliated with the same university in their respective countries is an interesting revelation. There were four authors that were affiliated with the Beijing University of Technology, whereby this university was the leading institution in leachate biological treatment research (Table 3). Meanwhile, two other Chinese authors were affiliated with Beijing Forestry University, which was also in the top 10 most productive institutions (5th place). The Thai authors were both affiliated with the same university in Thailand (Kasetsart University), whereas the only one Canadian author was associated with The University of British Columbia, Canada. Overall, the results of the most productive authors analysis were in line with the results of the most productive countries and institutions.

3.6. Analysis of country co-authorship

Academic co-authorship across countries is critical for increasing knowledge distribution and academic interaction among experts (Chen et al., 2020). Therefore, Fig. 4 depicts the co-authorship network between countries. Larger circles represent a higher number of publications, while thicker lines portray stronger collaborative work. Additionally, a closer space between two countries also implies a stronger relationship between two respective countries. A total of 53 countries were incorporated in the bibliometric map; 18 were countries from Asia, 23 from Europe, six from America, four from Africa, and two from Oceania. Results showed that the USA was the most active country in initiating international affiliations in leachate biological treatment research, collaborating with 33 other countries in 102 collaborative works. It was also found that the USA mostly collaborated with China, publishing a total of 31 articles, followed by South Korea (8 articles), Canada (7 articles), Germany (6 articles), and Spain (5 articles). Meanwhile, the affiliations of the USA with the remaining countries had less than five publications each.

Germany, the country with the 2nd highest number of affiliations, had 47 collaborative works and was affiliated with 27 countries such as China, the USA, France, Italy, Netherlands, United Kingdom, France, etc. Although Germany collaborated mainly with European countries, the strongest collaborations made were with China and the USA, each of which had six publications. It was further discovered that Germany had made links with Southeast Asian countries such as the Philippines and

Table 4
The top 10 of most productive authors in leachate biological treatment research.

No	Author	Scopus author ID	Year of 1st publication	Total publications	Contribution rate (%)	H-index	Total citations	Current affiliation	Country
1	Peng, Yongzhen	7403418825	2007	31	1.54	73	663	Beijing University of Technology	China
2	Wang, Shuying	8835662900	2007	25	1.24	56	538	Beijing University of Technology	China
3	Chiemchaisri, Chart	8647489600	2009	18	0.89	29	340	Kasetsart University	Thailand
4	Dang, Yan	55625041500	2013	17	0.84	22	386	Beijing Forestry University	China
5	Sun, Dezhi	56273109000	2007	16	0.79	46	440	Beijing Forestry University	China
6	Chiemchaisri, Wilai	8647489000	2009	15	0.75	21	311	Kasetsart University	Thailand
7	Mavinic, Donald S	7006480391	1979	15	0.75	38	461	The University of British Columbia	Canada
8	Liu, Mu	55554577800	2010	14	0.70	4	58	Beijing University of Technology	China
9	Miao, Lei	57200712886	2012	13	0.65	15	385	Huazhong University of Science and Technology	China
10	Zhang, Shujun	50462904700	2006	13	0.65	20	69	Beijing University of Technology	China

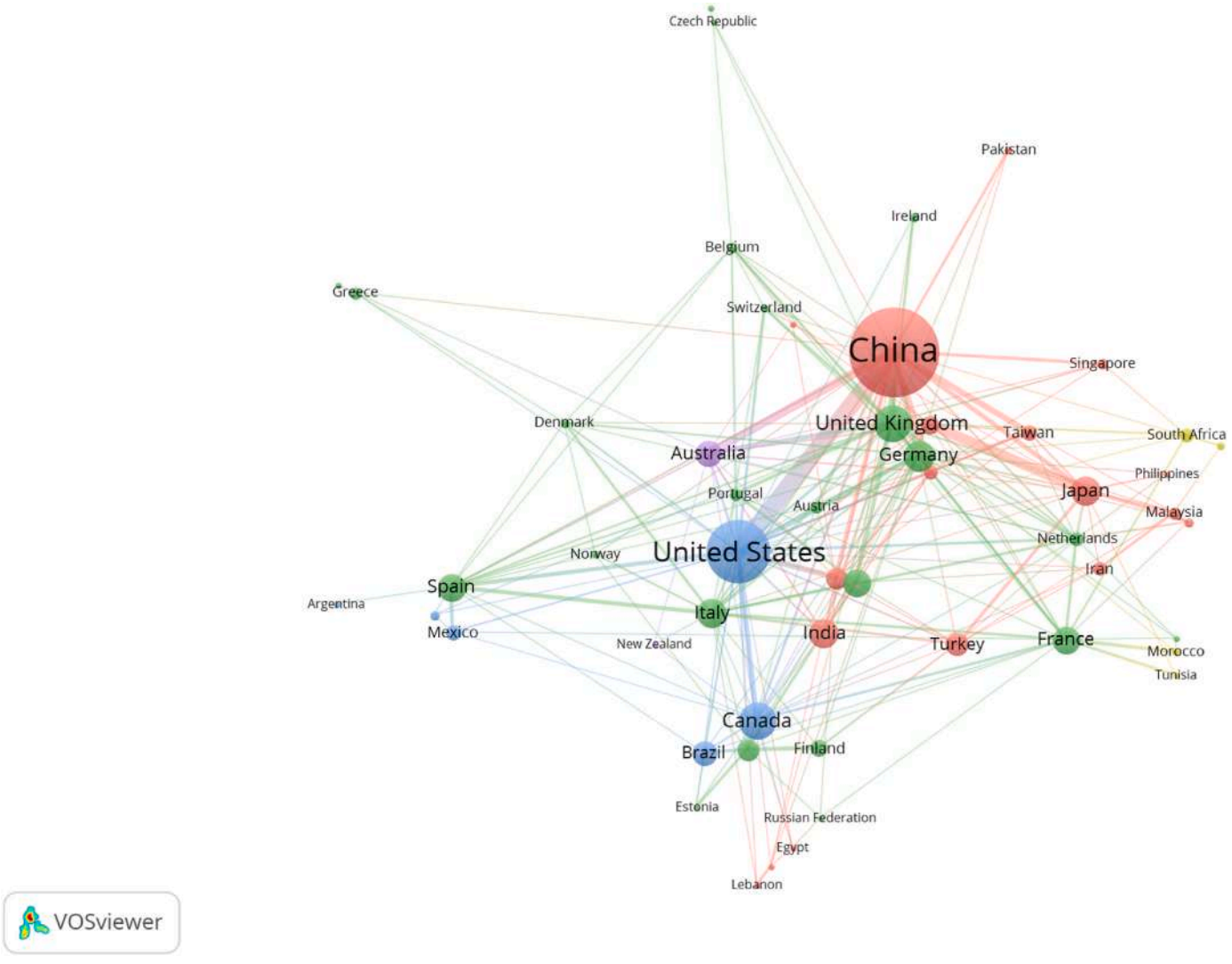

Fig. 4. A bibliometric map of country co-authorship based on network visualization mode (Bibliometric map can be accessed online through the following link https://tinyurl.com/y9thpnlz).

Indonesia, while the sole link with African countries was with South Africa. Meanwhile, China followed as the country with the 3rd highest number of international collaborations, collaborating with 25 countries in 118 collaborative works. These countries included Poland, Hongkong, Nigeria, Norway, India, etc. Moreover, China was primarily associated with the USA and has not established significant collaborations with the other countries, despite having the highest number of publications and collaborative works. Meanwhile, it was also discovered that there were strong collaborations between Thailand-Japan and Australia-China that had published 16 and 13 collaborative works, respectively. These results imply that there are still huge opportunities for improvement in terms of international academic collaborations between countries in the field of leachate biological treatment.

3.7. Author keywords

A total of 4496 author keywords were detected in 2013 publications from 1974 to 2021. Upon polishing the data by merging similar words and setting the minimum occurrences to 5 in VOSViewer, it was found that 220 keywords met the threshold. Fig. 5 depicts the bibliometric map of keyword co-occurrences; whereby larger circles indicate a more frequent keyword appearance while thicker lines indicated a stronger relationship between respective keywords. Moreover, the closer the two keywords are located on the bibliometric map, the stronger their ties are.

3.7.1. Analysis of keyword co-occurrences

The results showed that 'Leachate' was the most frequently occurring keyword, with 690 occurrences and 170 links to other keywords, thereby making this keyword the center of the bibliometric map. Other popular keywords with more than 100 occurrences were 'MSW' and 'Landfill' with 153 and 150 occurrences, respectively. These keywords were closely related to leachate because it is estimated that landfills receive most of the total MSW collected worldwide whereby the generation of leachate remains one of the main issues for landfills (Gao et al., 2014).

The term 'biological treatment' located at the center of the bibliometric map had total occurrence of 32 and was linked with 34 other keywords. Among related keywords were those regarding the targeted pollutants in biological leachate treatment, including 'nutrient removal', 'organic pollutants', 'ammonia', 'nitrification', 'denitrification', and 'free ammonia'. Considering their cost-effectivity, biological treatments are frequently employed to remove nutrients such as ammonia and organic compounds from leachate. Besides, biological nitrogen removal, such as nitrification/denitrification integrated into biological treatments, has exhibited high effectivity in removing nitrogen and ammonia from leachate (Mojiri et al., 2021). In addition, the term 'biological treatment' was also closely connected to 'biodegradability'. This finding further confirmed that biological treatment effectiveness highly depends on the level of leachate biodegradability, whereby the treatment is quite effective in removing organic and nitrogen from leachate with high biodegradability (BOD/COD >0.5) (Miao et al., 2019). Furthermore, its close relation with keywords such as 'design', 'kinetics', and 'modelling' indicated that the study of leachate biological treatment was intently related to the engineering field, as evidenced in Fig. 2. Simply put, kinetic parameters are required for addressing the design model and thus vital for the process design of the treatment (Goswami et al., 2017).

Meanwhile, the popular biological processes for leachate based on the keyword occurrences were 'anaerobic digestion' (70), 'constructed wetland' (57), 'MBR' (54), 'SBR' (47), 'UASB' (40), 'microbial fuel cell' or MFC (39), and 'activated sludge' (34). It was further revealed that most of these keywords were linked to each other. For instance,

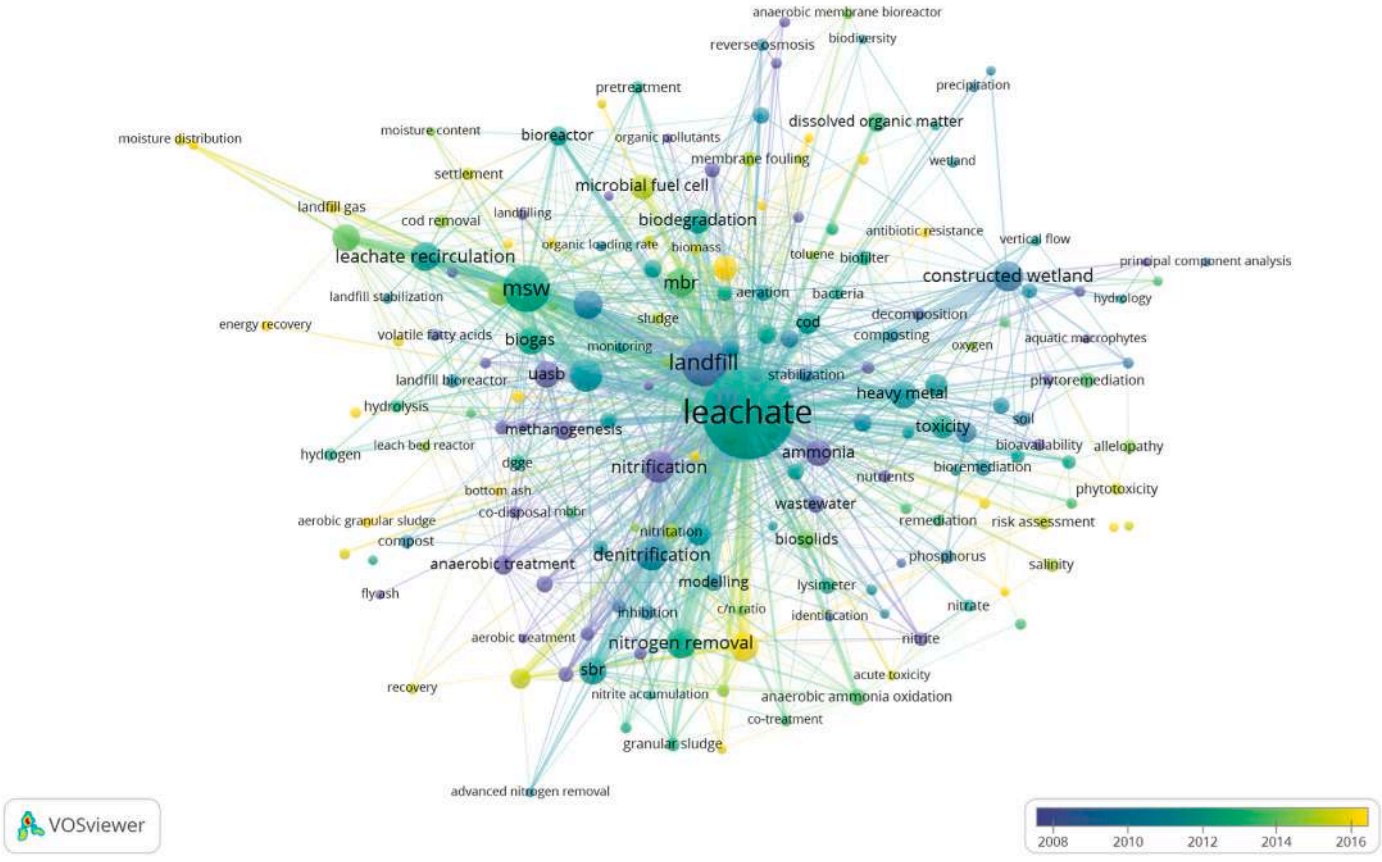

Fig. 5. Overlay visualization of author keywords co-occurrences from 1974 to 2021 (Bibliometric map can be accessed online through this following link https://tinyurl.com/y7prpwqw).

'anaerobic digestion' was linked with 'MFC' and 'UASB' while 'UASB' was linked with 'Anammox' and 'SBR'. The combination of two or more treatments that were used to remove targeted specific contaminants could be the cause of these treatments being linked together. This result was in accordance with previous studies that reported most leachate treatment was, in fact, combined with other treatments in order to achieve more satisfactory results while complying with the strict discharge standards (Song et al., 2020; Tulun, 2020; Wang et al., 2013).

'Anaerobic digestion' as the most frequently occurred (70 occurrences) treatment type with an average publication year in 2011, was linked to other 43 keywords, in which the strongest link was connected with 'biogas' (11 links). Moreover, 'anaerobic digestion' had the strongest relationship with 'methane' (9 links) and 'methanogenesis' (6 links), which indicated that this type of treatment was not only utilized for leachate treatment but also for biogas production, especially methane (Begum et al., 2018; Feng et al., 2019). 'Anaerobic digestion' also had a strong connection with 'leachate recirculation' (5 links), whereby leachate recirculation could help optimize biogas generation during the anaerobic digestion process (White et al., 2011). The keywords associated with the factors influencing the anaerobic digestion process were 'hydraulic retention time', 'pH', 'hydrolysis', and 'pretreatment'. The anaerobic digestion process is highly affected by hydraulic retention time (HRT) because HRT has a direct effect on the volatile solids (VS) conversion into biogas (Shi et al., 2017). Additionally, due to slow rates and incomplete degradation, hydrolysis in anaerobic digestion remains one of the major drawbacks (Menzel et al., 2020). Furthermore, the pH in an anaerobic digestion reactor should be in the range of 6.6–7.8 to maintain the anaerobic condition. Decreased pH (lower than 6.2) inhibits the methanogenic bacteria, allowing acid-forming bacteria to easily overgrow them (Kheradmand et al., 2010).

The second most frequently occurring treatment type was 'constructed wetland', which appeared 57 times and had connections to 47 other keywords. This keyword was mostly linked with 'willow' and 'ammonia', each with five links. Willow (*Salix* sp.), as the common natural wetland plant, has been extensively studied for leachate treatment and has shown outstanding results in terms of ammonia and total nitrogen (TN) removal (Białowiec et al., 2007, 2012). Besides, 'phragmites australis' (reed) was also found to have a strong connection, with a total of 4 links. Reed is known to have high resistance to toxic compounds found in leachate (Białowiec, 2015). Moreover, even if reed was mostly applied for nitrogen removal, De Feo et al. (2005) found that great COD removal was also achieved during the treatment of leachate utilizing reed. Another relevant keyword found with 4 links was 'vertical flow', which implied that this type of wetland was more explored than the others. Vertical flow wetlands have more benefits compared to horizontal subsurface flow (HSSF) wetlands and free water surface (FWS) wetlands. The advantages include less land demand, a better supply of oxygen which leads to a better nitrification rate, a simpler hydraulic system, and a higher pollutant removal rate (Gorgoglione and Torretta, 2018). In addition, 'constructed wetland' also had a strong connection with 'evapotranspiration' with a total of 3 links. Owing to the features such as abundant water supply, along with oasis and clothesline effects, evapotranspiration might be considerably boosted in wetlands (Frédette et al., 2019). Furthermore, the hydraulics of the wetland and its efficacy in removing pollutants are strongly impacted by the evapotranspiration rate (Beebe et al., 2014; Białowiec et al., 2014; Kadlec and Wallace, 2008).

On the other hand, keywords relating to nitrogen removal most frequently occurred in terms of pollutant types, accounting for 16 keywords in total. These keywords including 'nitrification', 'denitrification', 'anammox', 'partial nitrification','nitritation', 'shortcut nitrification', 'free ammonia', 'partial nitritation', 'advanced nitrogen removal', etc. It is challenging to remove nitrogen efficiently and effectively from leachate due to its complex and fluctuating characteristics. Therefore, nitrogen removal has been a major research focus in leachate treatment. More importantly, biological processes have been shown to be effective at removing nitrogen. Aside from the conventional nitrogen removal processes, such as nitrification-denitrification and anammox, several advanced nitrogen removal processes have been integrated into leachate biological treatments. Among the advanced nitrogen removal processes applied in leachate treatment were partial nitrification (PN) (Zhang et al., 2019), nitritation-denitritation (Sun et al., 2015), and shortcut nitrification (Zhang et al., 2015). Generally speaking, either conventional or advanced nitrogen removal methods have shown satisfactory results in removing nitrogen from leachate. However, in order to effectively remove nitrogen from leachate, careful consideration must be given to which methods are to be used due to the different properties of leachate that are highly influenced by its degradation phases (Miao et al., 2019). Moreover, some of these methods may be difficult to be implemented in real scale applications due to technical reasons. For instance, the anammox process requires a relatively longer start-up period due to the difficulties in anammox bacteria growth and enrichment (Jagaba et al., 2021). Thus, this process is usually coupled with a partial nitrification process which provides nitrites for the growth of anammox bacteria and thereby shortens the start-up period (Zhang et al., 2019). Moreover, a study have also shown that anammox start-up might be enhanced by the addition of hydrazine (Zekker et al., 2021a). In addition, there is a difficulty in achieving an optimum microbial community in the real-scale application of a simultaneous nitrification and denitrification (SND) process, and this affects the process' effectivity. Therefore, optimizing the operating parameters such as controlling the C/N ratio and the oxygen concentration might address the issue (Zhang et al., 2009, 2020; S. Zhang et al., 2020).

Another popular keyword related to pollutant types was 'heavy metal', which had 49 occurrences and was linked with 48 other keywords. With average publication year 2011, 'heavy metal' was closely related to terms such as 'constructed wetland' and 'bioremediation', indicating that heavy metal in leachate was mostly treated by these treatments. These treatments are preferred due to their low costs, ease of application, and high removal rate (Carvajal-Flórez and Santiago-Alonso Cardona-Gallo, 2019). Meanwhile, 'heavy metal' was also connected to 'toxicity', whereby heavy metals such as Cd, Cr (IV), As, Hg, and Pb are known to be the major contributors to leachate toxicity. These heavy metals can cause severe toxic effects on every form of life, even at low levels (Hussein et al., 2021). Moreover, 'heavy metal' was also found to have a link with 'bioassay' whose function is to address the effect of leachate toxicity on the environment (Luo et al., 2020). The bioassays that have been applied for leachate toxicity include plant bioassay (Kwasniewska et al., 2012; Sang et al., 2006), bacterial bioassay (da Costa et al., 2018; Fan et al., 2006), algae bioassay (Baun et al., 2004; Marttinen et al., 2002), invertebrate bioassay (Mavakala et al., 2016; Svensson et al., 2005), mammals bioassay (Alimba et al., 2016; Wang et al., 2016), and aquatic organisms bioassay (Ben Salem et al., 2014; Tsarpali and Dailianis, 2012).

3.7.2. *Analysis of keyword co-occurrences evolution and the future trends*

Observing the time periods of the keywords' initial and current occurrences is an alternative method to discern the trending topics in leachate biological treatment research. Therefore, the publications were grouped into four time periods (1974–2000, 2001–2010, 2011–2015, and 2016–2021) and analyzed based on the keywords co-occurrences. This analysis might also be used to predict the future trends in leachate biological treatment research by distinguishing the author keywords according to their most recent average publication year. Furthermore, by trying to link keywords that have not been associated before, it is also possible to anticipate the research gaps.

The year 1974–2000 was identified as the initial stage due to the limited number of research publications on leachate biological treatment. During this period, only a few treatment types were emphasized, such as 'anaerobic digestion' (10 occurrences), 'constructed wetland' (6 occurrences), 'UASB' (6 occurrences), 'activated sludge' (5

occurrences), and 'SBR' (5 occurrences). If the data were ordered from the most recent average publication year, the rising trend in this time frame was 'SBR' which had an average publication year in 1998. The increasing use of SBR to treat leachate was most probably attributed to its operating flexibility, tolerance to shock loads, and high biomass retention. Furthermore, SBR incorporates anaerobic and aerobic cycles to accomplish simultaneous nitrification, denitrification, organics removal, and phosphorous removal in a single tank, nullifying the need for additional clarifiers (Jagaba et al., 2021). It was also observed that even during the early studies, the focus of leachate biological treatment pointed to nitrogen removal, as evidenced by the occurrences of keywords such as 'nitrification' (15 occurrences), 'ammonia' (9 occurrences), and 'denitrification' (9 occurrences).

The research on leachate biological treatment has grown significantly in the 10 following years of the development stage (2001–2010), as demonstrated by the denser bibliometric map. In this stage, there were reappearances of almost all the keywords that occurred in the earlier period. This indicated that research in this stage was a continuation and development of research in the previous stage. Furthermore, it is possible to infer that the topics discussed in the previous period were still impactful. Meanwhile, a lot of significant new keywords related to leachate biological treatment have emerged. Treatments such as 'bioremediation', 'MBR', and 'phytoremediation', with average publication years of 2005, 2006, and 2008, were introduced in this stage. Moreover, a variety of improved biological nitrogen removal techniques, such as 'anammox', 'shortcut nitrification,' and 'partial nitrification,' also appeared. Besides, the studies related to 'heavy metal', 'methanogenesis', and 'toxicity' also started to be highlighted in this period, with the average publication years in 2005, 2005, and 2007, respectively. Other significant keywords that are worth noting were 'DGGE' (denaturing gradient gel electrophoresis) (5 occurrences) and 'FISH' (fluorescence in situ hybridization) (7 occurrences) which are related to the field of microbial community. Both of these keywords were connected to each other and strongly connected to the keywords related to ammonia removal. Microbial activity and diversity should also be assessed to successfully run the nitrification/denitrification processes at exceptionally high ammonia levels in leachate. Based on the assessment, some operating variables can be modified which can further enhance reactor performance (Calli et al., 2003). During this period, 'bioreactor landfill' has emerged as one of the alternatives for MSW disposal other than sanitary landfills. In bioreactor landfills, liquid and air are added to promote the microbial activities that facilitate the MSW degradation. Hence, a faster waste degradation and stabilization rate is achieved (Sughosh and Babu, 2021).

In 2011–2015, 'microbial fuel cell' was the most highlighted treatment with 17 occurrences and an average publication year in 2013. This keyword was linked with keywords such as 'nitrogen', 'organic matter', and 'dissolved organic matter', which are the commonly targeted pollutants in MFC (Sawasdee and Pisutpaisal, 2016). Meanwhile, research on 'biofilter' was also highlighted in this stage with 5 occurrences. Leachate biofilters have demonstrated stable organic matter and total organic carbon (TOC) removal from leachate in a long operational time (Shim et al., 2012). Besides, another emerging treatment in this period was 'granular sludge' with 5 occurrences and an average publication year in 2013. The granular sludge was mostly developed in anaerobic reactors such as EGSB (Liu et al., 2015; Luo et al., 2014) and internal circulation reactors (Luo et al., 2014). Among the above-mentioned reactors, EGSB was the most utilized reactor to cultivate anaerobic granular sludge due to its ability to effectively treat leachate even with a high organic loading rate of up to 44 kg COD/m^3d (Liu et al., 2012). Above all, an advanced nitrogen removal process, 'partial nitritation', was drawing attention during this stage. This keyword had 5 occurrences and 7 links with other terms such as 'SBR', 'granular sludge', 'anammox', etc. On top of that, it also made a link with 'temperature', whereby it further revealed that temperature played a key role in achieving a stable partial nitritation process in leachate treatment with a high load of ammonia (Gabarró et al., 2012).

The keywords that were featured in the exploration stage (2016–2021) have generally been displayed in the earlier stages. The 'anammox' process, with an average publication year in 2018 was still gaining popularity in this stage with 32 occurrences and 15 links despite its first appearance in the developed stage (2011–2010). Meanwhile, treatment types including 'anaerobic digestion', 'MBR', 'microbial fuel cell', 'activated sludge', 'constructed wetland', and 'SBR' were the most explored treatment types during this period. Moreover, the study on 'microbial community' received great attention among researchers with 27 occurrences. It was further revealed that 'microbial community' had the strongest connection with 'nitrification' (3 links), in which most of the reported studies involving these terms revealed that the presence of nitrifying bacteria during leachate treatment was highly influenced by aeration strategy (Hira et al., 2018; Hirakawa et al., 2019).

In addition to what has been discussed previously, an in-depth review of the overlay network enables us to determine the future research trends. As can be seen, the yellow-orange color in Fig. 6 represents current trending terms, whereas the purplish color represents more dated terms. Nitrogen removal processes, particularly 'partial nitrification', are driving future studies. Moreover, its strong connection with 'SBR' indicated that among the other treatment types, SBR would be the topic of interest in the following years to accomplish partial nitrification. Meanwhile, modeling-based studies will continue to be popular, as evidenced by the fact that the term 'modelling' has an average publication date of 2019 with 6 occurrences.

On the other hand, 'aerobic granular sludge' is gaining popularity, as illustrated in Fig. 6. It has been previously claimed that AGS is superior to activated sludge. This claim was based on the evidence that AGS has more advantages, such as a more compact and denser structure, faster settling time, and higher resistance to shock loadings (Adav et al., 2008; van Dijk et al., 2020). On top of that, the occurrence of simultaneous nitrification, denitrification, and phosphorus removal (SNDPR) within the granules makes AGS an excellent feasible option for leachate treatment (Ren et al., 2017, 2018). Nevertheless, the study of AGS for leachate treatment is still considered to be limited. For instance, previous studies solely applied AGS in SBRs for the removal of COD, nitrogen, and phosphorus (Bella and Torregrossa, 2014; Bueno et al., 2020), while the removal of other pollutants from leachate by AGS has not been reported. Hence, there is still room for improvement, such as exploring the application scope and applying different types of reactors. Furthermore, thorough research is needed to fully comprehend the underlying mechanism and the influence of operational parameters and other affecting parameters.

The study on 'energy recovery' is also expected to be highly explored, considering its latest average publication year in 2020. Wastewaters, including leachate, were recently recognized as a source of valuable compounds. Due to the high concentration of organic matter in leachate, it has a tremendous potential to be used in the manufacturing of bioenergy (Moujanni et al., 2020). Biohydrogen and biomethane are bioenergy in the form of biogases recovered from leachate (Barghash et al., 2021; Siciliano et al., 2019). Biohydrogen has long been considered to be a potential substitute for fossil fuels since it is a renewable source of energy with no emissions (Anwar et al., 2019). Among other biohydrogen production processes, light and dark hydrogen fermentation have been the focus of organic waste and leachate recycling (Watanabe and Yoshino, 2010). Moreover, biohydrogen production by combined light-dark fermentation offers numerous advantages over either process alone, including the complete degradation of organic matter and increasing production of biohydrogen. Its chemical equation is $C_6H_{12}O_6 + 6H_2O \rightarrow 12H_2 + 6CO_2$ (Zhang, 2021). Meanwhile, by comparing several methods, it is inferred that biomethane is the most desirable form of bioenergy to recover from leachate and that anaerobic digestion is the most viable method to do so (Gu et al., 2019). During the anaerobic digestion process, organic matter breaks down with the help of microbes, producing biogas in which a mixture of methane (CH_4) and

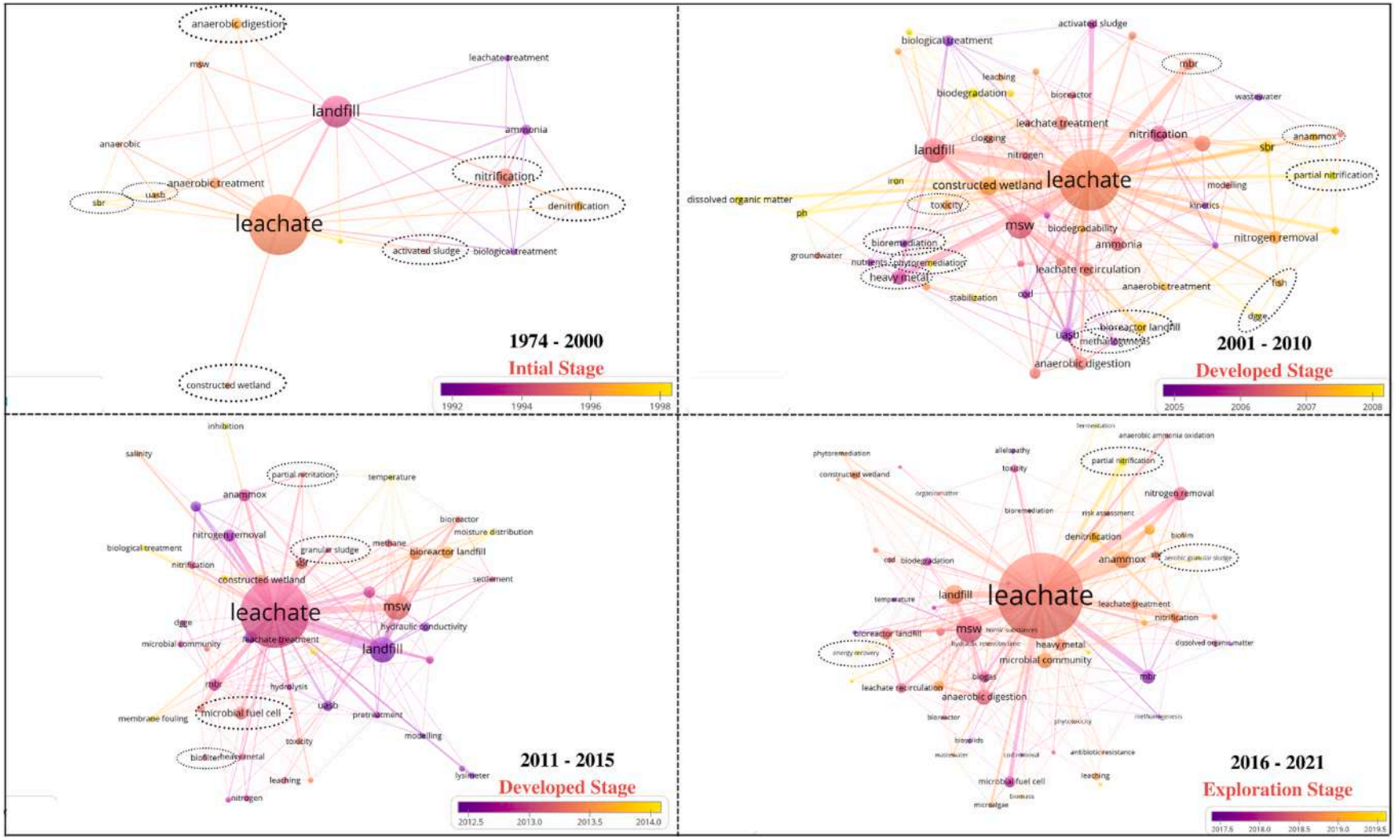

Fig. 6. Overlay visualization of the evolution of the author keywords co-occurrences.

carbon dioxide (CO_2) are generated. Biomethane is then produced when biogas is purified. During biomethane production, incompatible components are eliminated, leaving a high-caloric, purified gas (Siciliano et al., 2019). Nevertheless, implementation and sustainability of bioenergy production are hindered by issues such as financial viability and scale-up operations, which are the challenges to progress in the future studies.

The potential research gaps related to leachate biological treatment can be found by connecting terms that have not been associated in the bibliometric map. For example, connecting 'aerobic granular sludge' with 'microalgae' could result in a new treatment process, known as microalgae-bacteria AGS. This system has been applied to various types of wastewaters, including municipal wastewater (He et al., 2018; Huang et al., 2015), piggery wastewater (Lee and Han, 2016), and paper mill effluent (Van Den Hende et al., 2017). By either inoculating particular microalgae species or utilizing indigenous microalgae, the growth of microalgae in AGS can induce the granulation process, enhance nutrient and organic removal, lower the energy demand, and increase the potential for resource recovery (Meng et al., 2019; Y. Zhang et al., 2020). Moreover, microalgae can serve as a secondary habitat for bacteria, protecting them from extreme environmental conditions (Zhang et al., 2018), which is a promising feature for leachate treatment. However, despite its growing popularity, no research has been published on the application of microalgae-bacteria AGS for leachate treatment. Furthermore, various features of the microalgae-bacteria AGS application need to be investigated further.

4. Conclusion

A bibliometric study can provide insight into the current state and research gaps in leachate biological treatment. In this article, a bibliometric analysis of 2013 publications was performed on the subject of leachate biological treatment. Overall, the results of the most productive countries' analysis were in line with the results of the most productive authors and institutions, in which China and the USA showed their dominance. It was further revealed that there are still opportunities for improvement in terms of international academic collaborations between countries. Through the keyword co-occurrences analysis, it was revealed that anaerobic digestion and constructed wetlands have been the research hot spots in the field of leachate biological treatment. Meanwhile, the critical role of biological treatment in removing nitrogen from leachate was also illustrated. The optimization of nitrogen removal through partial nitrification is predicted to be a future research trend which can be further explored. Moreover, exploring research on AGS and microalgae-bacteria AGS for leachate treatment are encouraged in order to fully comprehend the underlying mechanism and the influence of operational parameters and other affecting parameters. Also, it is suggested that future studies should focus on the application of energy-efficient systems and extensively on energy recovery in the form of biogases.

Credit author statement

Dhaneswara Ilmasari: Conceptualization, Writing - Original Draft. Eri Sahabudin: Methodology, Writing - Review & Editing. Fatimah Azizah Riyadi: Validation, Writing - Review & Editing. Norhayati Abdullah: Writing - Review & Editing. Ali Yuzir: Supervision, Writing - Review & Editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors are sincerely grateful to the JICA technical ASEAN University Network/Southeast Asia Engineering Education Development Network (AUN/SEED-Net) for funding this study with research grant number 4B403 under the Collaborative Education Program for Sustainable Environmental Engineering Network (CEP-SEEN).

References

Abdelfattah, A., Hossain, M.I., Cheng, L., 2020. High-strength wastewater treatment using microbial biofilm reactor: a critical review. World J. Microbiol. Biotechnol. 36, 1–10. https://doi.org/10.1007/s11274-020-02853-y.

Abuabdou, S.M.A., Ahmad, W., Aun, N.C., Bashir, M.J.K., 2020. A review of anaerobic membrane bioreactors (AnMBR) for the treatment of highly contaminated landfill leachate and biogas production: effectiveness, limitations and future perspectives. J. Clean. Prod. 255, 120215 https://doi.org/10.1016/j.jclepro.2020.120215.

Adav, S.S., Lee, D.J., Show, K.Y., Tay, J.H., 2008. Aerobic granular sludge: recent advances. Biotechnol. Adv. 26, 411–423. https://doi.org/10.1016/j.biotechadv.2008.05.002.

Alimba, C.G., Gandhi, D., Sivanesan, S., Bhanarkar, M.D., Naoghare, P.K., Bakare, A.A., Krishnamurthi, K., 2016. Chemical characterization of simulated landfill soil leachates from Nigeria and India and their cytotoxicity and DNA damage inductions on three human cell lines. Chemosphere 164, 469–479. https://doi.org/10.1016/j.chemosphere.2016.08.093.

Anwar, M., Lou, S., Chen, L., Li, H., Hu, Z., 2019. Recent advancement and strategy on bio-hydrogen production from photosynthetic microalgae. Bioresour. Technol. 292, 121972 https://doi.org/10.1016/j.biortech.2019.121972.

Barghash, H., Okedu, K.E., Al Balushi, A., 2021. Bio-hydrogen production using landfill leachate considering different photo-fermentation processes. Front. Bioeng. Biotechnol. 9, 1–12. https://doi.org/10.3389/fbioe.2021.644065.

Baun, A., Ledin, A., Reitzel, L.A., Bjerg, P.L., Christensen, T.H., 2004. Xenobiotic organic compounds in leachates from ten Danish MSW landfills - chemical analysis and toxicity tests. Water Res. 38, 3845–3858. https://doi.org/10.1016/j.watres.2004.07.006.

Beebe, D.A., Castle, J.W., Molz, F.J., Rodgers, J.H., 2014. Effects of evapotranspiration on treatment performance in constructed wetlands: experimental studies and modeling. Ecol. Eng. 71, 394–400. https://doi.org/10.1016/j.ecoleng.2014.07.052.

Begum, S., Anupoju, G.R., Sridhar, S., Bhargava, S.K., Jegatheesan, V., Eshtiaghi, N., 2018. Evaluation of single and two stage anaerobic digestion of landfill leachate: effect of pH and initial organic loading rate on volatile fatty acid (VFA) and biogas production. Bioresour. Technol. 251, 364–373. https://doi.org/10.1016/j.biortech.2017.12.069.

Bella, G. Di, Torregrossa, M., 2014. Aerobic granular sludge for leachate treatment. Chem. Eng. Trans. 38, 493–498. https://doi.org/10.3303/CET1438083.

Ben Salem, Z., Capelli, N., Grisey, E., Baurand, P.E., Ayadi, H., Aleya, L., 2014. First evidence of fish genotoxicity induced by heavy metals from landfill leachates: the advantage of using the RAPD-PCR technique. Ecotoxicol. Environ. Saf. 101, 90–96. https://doi.org/10.1016/j.ecoenv.2013.12.014.

Berrueta, J., Castrillón, L., 1992. Anaerobic treatment of leachates in UASB reactors. J. Chem. Technol. Biotechnol. 54, 33–37. https://doi.org/10.1002/jctb.280540107.

Białowiec, A., 2015. Transpiration as landfill leachate phytotoxicity indicator. Waste Manag. 39, 189–196. https://doi.org/10.1016/j.wasman.2015.02.002.

Białowiec, A., Albuquerque, A., Randerson, P.F., 2014. The influence of evapotranspiration on vertical flow subsurface constructed wetland performance. Ecol. Eng. 67, 89–94. https://doi.org/10.1016/j.ecoleng.2014.03.032.

Białowiec, A., Davies, L., Albuquerque, A., Randerson, P.F., 2012. Nitrogen removal from landfill leachate in constructed wetlands with reed and willow: redox potential in the root zone. J. Environ. Manag. 97, 22–27. https://doi.org/10.1016/j.jenvman.2011.11.014.

Białowiec, A., Wojnowska-Baryła, I., Agopsowicz, M., 2007. The efficiency of evapotranspiration of landfill leachate in the soil-plant system with willow Salix amygdalina L. Ecol. Eng. 30, 356–361. https://doi.org/10.1016/j.ecoleng.2007.04.006.

Boonnorat, J., Kanyatrakul, A., Prakhongsak, A., Ketbubpha, K., Phattarapattamawong, S., Treesubsuntorn, C., Panichnumsin, P., 2021. Biotoxicity of landfill leachate effluent treated by two-stage acclimatized sludge AS system and antioxidant enzyme activity in Cyprinus carpio. Chemosphere 263, 128332. https://doi.org/10.1016/j.chemosphere.2020.128332.

Boyle, W.C., Ham, R.K., 1974. Biological treatability of landfill leachate. J. Water Pollut. Control Fed. 46, 860–872.

Bueno, R. de F., Faria, J.K., Uliana, D.P., Liduino, V.S., 2020. Simultaneous removal of organic matter and nitrogen compounds from landfill leachate by aerobic granular sludge. Environ. Technol. (United Kingdom) 0 1–30. https://doi.org/10.1080/09593330.2020.1740798.

Calli, B., Tas, N., Mertoglu, B., Inanc, B., Ozturk, I., 2003. Molecular analysis of microbial communities in nitrification and denitrification reactors treating high ammonia leachate. J. Environ. Sci. Heal. - Part A Toxic/Hazardous Subst. Environ. Eng. 38, 1997–2007. https://doi.org/10.1081/ESE-120023327.

Carvajal-Flórez, E., Cardona-Gallo, Santiago-Alonso, 2019. Technologies applicable to the removal of heavy metals from landfill leachate. Environ. Sci. Pollut. Res. 26, 15725–15753. https://doi.org/10.1007/s11356-019-04888-7.

Chen, H., Jiang, W., Yang, Y., Man, X., Tang, M., 2015. A bibliometric analysis of waste management research during the period 1997–2014. Scientometrics 105, 1005–1018. https://doi.org/10.1007/s11192-015-1714-3.
Chen, W., Geng, Y., Zhong, S., Zhuang, M., Pan, H., 2020. A bibliometric analysis of ecosystem services evaluation from 1997 to 2016. Environ. Sci. Pollut. Res. 27, 23503–23513. https://doi.org/10.1007/s11356-020-08760-x.
Chen, W., Zhang, A., Gu, Z., Li, Q., 2018. Enhanced degradation of refractory organics in concentrated landfill leachate by Fe0/H2O2 coupled with microwave irradiation. Chem. Eng. J. 354, 680–691. https://doi.org/10.1016/j.cej.2018.08.012.
Cirik, K., Gocer, S., 2020. Performance of anaerobic membrane bioreactor treating landfill leachate. J. Environ. Heal. Sci. Eng. 18, 383–393. https://doi.org/10.1007/s40201-019-00376-9.
Colledge, L., James, C., Azoulay, N., Meester, W., Plume, A., 2017. CiteScore metrics are suitable to address different situations – a case study. Eur. Sci. Ed. 43, 27–31. https://doi.org/10.20316/ESE.2017.43.003.
Contrera, R.C., da Cruz Silva, K.C., Morita, D.M., Domingues Rodrigues, J.A., Zaiat, M., Schalch, V., 2014. First-order kinetics of landfill leachate treatment in a pilot-scale anaerobic sequence batch biofilm reactor. J. Environ. Manag. 145, 385–393. https://doi.org/10.1016/j.jenvman.2014.07.013.
Coppini, E., Palli, L., Fibbi, D., Gori, R., 2018. Long-term performance of a full-scale membrane plant for landfill leachate pretreatment: a case study. Membranes 8, 4–13. https://doi.org/10.3390/membranes8030052.
Cuschieri, S., 2018. WASP: is open access publishing the way forward? A review of the different ways in which research papers can be published. Early Hum. Dev. 121, 54–57. https://doi.org/10.1016/j.earlhumdev.2018.02.017.
da Costa, F.M., Daflon, S.D.A., Bila, D.M., da Fonseca, F.V., Campos, J.C., 2018. Evaluation of the biodegradability and toxicity of landfill leachates after pretreatment using advanced oxidative processes. Waste Manag. 76, 606–613. https://doi.org/10.1016/j.wasman.2018.02.030.
Dai, Y., Song, Y., Gao, H., Wang, S., Yuan, Y., 2015. Bibliometric analysis of research progress in membrane water treatment technology from 1985 to 2013. Scientometrics 105, 577–591. https://doi.org/10.1007/s11192-015-1669-4.
De Feo, G., Lofrano, G., Belgiorno, V., 2005. Treatment of high strength wastewater with vertical flow constructed wetland filters. Water Sci. Technol. 51, 139–146. https://doi.org/10.2166/wst.2005.0360.
Del Moro, G., Prieto-Rodríguez, L., De Sanctis, M., Di Iaconi, C., Malato, S., Mascolo, G., 2016. Landfill leachate treatment: comparison of standalone electrochemical degradation and combined with a novel biofilter. Chem. Eng. J. 288, 87–98. https://doi.org/10.1016/j.cej.2015.11.069.
Egli, K., Fanger, U., Alvarez, P.J.J., Siegrist, H., Van der Meer, J.R., Zehnder, A.J.B., 2001. Enrichment and characterization of an anammox bacterium from a rotating biological contactor treating ammonium-rich leachate. Arch. Microbiol. 175, 198–207. https://doi.org/10.1007/s002030100255.
Fan, H. jung, Shu, H.Y., Yang, H.S., Chen, W.C., 2006. Characteristics of landfill leachates in central Taiwan. Sci. Total Environ. 361, 25–37. https://doi.org/10.1016/j.scitotenv.2005.09.033.
Fang, C., Mao, H., Jiang, L., Long, Y., 2020. Transformation of di-n-butyl phthalate in an anaerobic/anoxic/oxic leachate treatment process. J. Mater. Cycles Waste Manag. 22, 221–227. https://doi.org/10.1007/s10163-019-00930-5.
Feng, S., Hou, S., Huang, X., Fang, Z., Tong, Y., Yang, H., 2019. Insights into the microbial community structure of anaerobic digestion of municipal solid waste landfill leachate for methane production by adaptive thermophilic granular sludge. Electron. J. Biotechnol. 39, 98–106. https://doi.org/10.1016/j.ejbt.2019.04.001.
Frédette, C., Grebenshchykova, Z., Comeau, Y., Brisson, J., 2019. Evapotranspiration of a willow cultivar (Salix miyabeana SX67) grown in a full-scale treatment wetland. Ecol. Eng. 127, 254–262. https://doi.org/10.1016/j.ecoleng.2018.11.027.
Gabarró, J., Ganigué, R., Gich, F., Ruscalleda, M., Balaguer, M.D., Colprim, J., 2012. Effect of temperature on AOB activity of a partial nitritation SBR treating landfill leachate with extremely high nitrogen concentration. Bioresour. Technol. 126, 283–289. https://doi.org/10.1016/j.biortech.2012.09.011.
Gao, J., Oloibiri, V., Chys, M., Audenaert, W., Decostere, B., He, Y., Van Langenhove, H., Demeestere, K., Van Hulle, S.W.H., 2014. The present status of landfill leachate treatment and its development trend from a technological point of view. Rev. Environ. Sci. Biotechnol. 14, 93–122. https://doi.org/10.1007/s11157-014-9349-z.
Gorgoglione, A., Torretta, V., 2018. Sustainable management and successful application of constructed wetlands: a critical review. Sustain. Times 10, 1–19. https://doi.org/10.3390/su10113910.
Goswami, S., Sarkar, S., Mazumder, D., 2017. A new approach for development of kinetics of wastewater treatment in aerobic biofilm reactor. Appl. Water Sci. 7, 2187–2193. https://doi.org/10.1007/s13201-016-0389-0.
Gu, N., Liu, J., Ye, J., Chang, N., Li, Y.Y., 2019. Bioenergy, ammonia and humic substances recovery from municipal solid waste leachate: a review and process integration. Bioresour. Technol. 293, 122159 https://doi.org/10.1016/j.biortech.2019.122159.
He, Q., Chen, L., Zhang, S., Chen, R., Wang, H., Zhang, W., Song, J., 2018. Natural sunlight induced rapid formation of water-born algal-bacterial granules in an aerobic bacterial granular photo-sequencing batch reactor. J. Hazard Mater. 359, 222–230. https://doi.org/10.1016/j.jhazmat.2018.07.051.
Hira, D., Aiko, N., Yabuki, Y., Fujii, T., 2018. Impact of aerobic acclimation on the nitrification performance and microbial community of landfill leachate sludge. J. Environ. Manag. 209, 188–194. https://doi.org/10.1016/j.jenvman.2017.12.056.
Hirakawa, S., Koga, T., Shimizu, N., Hori, T., Kurokawa, Y., Toba, M., 2019. Nitrification-related factors involved in the biochemical oxygen demand of leachate from inert-waste landfill site. J. Mater. Cycles Waste Manag. 21, 1341–1349. https://doi.org/10.1007/s10163-019-00885-7.
Huang, W., Li, B., Zhang, C., Zhang, Z., Lei, Z., Lu, B., Zhou, B., 2015. Effect of algae growth on aerobic granulation and nutrients removal from synthetic wastewater by using sequencing batch reactors. Bioresour. Technol. 179, 187–192. https://doi.org/10.1016/j.biortech.2014.12.024.
Hussein, M., Yoneda, K., Mohd-Zaki, Z., Amir, A., Othman, N., 2021. Heavy metals in leachate, impacted soils and natural soils of different landfills in Malaysia: an alarming threat. Chemosphere 267. https://doi.org/10.1016/j.chemosphere.2020.128874.
Ittisupornrat, S., Phetrak, A., Theepharaksapan, S., Mhuantong, W., Tobino, T., 2021. Effect of prolonged sludge retention times on the performance of membrane bioreactor and microbial community for leachate treatment under restricted aeration. Chemosphere 284, 131153. https://doi.org/10.1016/j.chemosphere.2021.131153.
Jagaba, A.H., Kutty, S.R.M., Lawal, I.M., Abubakar, S., Hassan, I., Zubairu, I., Umaru, I., Abdurrasheed, A.S., Adam, A.A., Ghaleb, A.A.S., Almahbashi, N.M.Y., Al-dhawi, B.N. S., Noor, A., 2021. Sequencing batch reactor technology for landfill leachate treatment: a state-of-the-art review. J. Environ. Manag. 282, 111946 https://doi.org/10.1016/j.jenvman.2021.111946.
Jokela, J.P.Y., Kettunen, R.H., Sormunen, K.M., Rintala, J.A., 2002. Biological nitrogen removal from municipal landfill leachate: low-cost nitrification in biofilters and laboratory scale in-situ denitrification. Water Res. 36, 4079–4087. https://doi.org/10.1016/S0043-1354(02)00129-X.
Kadlec, R.H., Wallace, S., 2008. Treatment Wetlands, second ed. Taylor & Francis, Boca Raton. https://doi.org/10.1201/9781420012514.
Kheradmand, S., Karimi-Jashni, A., Sartaj, M., 2010. Treatment of municipal landfill leachate using a combined anaerobic digester and activated sludge system. Waste Manag. 30, 1025–1031. https://doi.org/10.1016/j.wasman.2010.01.021.
Kurniawan, T.A., Lo, W., Chan, G., Sillanpää, M.E.T., 2010. Biological processes for treatment of landfill leachate. J. Environ. Monit. 12, 2032–2047. https://doi.org/10.1039/c0em00076k.
Kwasniewska, J., Nałecz-Jawecki, G., Skrzypczak, A., Płaza, G.A., Matejczyk, M., 2012. An assessment of the genotoxic effects of landfill leachates using bacterial and plant tests. Ecotoxicol. Environ. Saf. 75, 55–62. https://doi.org/10.1016/j.ecoenv.2011.08.020.
Lebron, Y.A.R., Moreira, V.R., Brasil, Y.L., Silva, A.F.R., Santos, L.V. de S., Lange, L.C., Amaral, M.C.S., 2021. A survey on experiences in leachate treatment: common practices, differences worldwide and future perspectives. J. Environ. Manag. 288 https://doi.org/10.1016/j.jenvman.2021.112475.
Lee, Y.S., Han, G.B., 2016. Complete reduction of highly concentrated contaminants in piggery waste by a novel process scheme with an algal-bacterial symbiotic photobioreactor. J. Environ. Manag. 177, 202–212. https://doi.org/10.1016/j.jenvman.2016.04.025.
Li, Y., Tang, F., Xu, D., Xie, B., 2021. Advances in biological nitrogen removal of landfill leachate. Sustain. Times 13, 1–18. https://doi.org/10.3390/su13116236.
Liu, H., Hong, R., Xiang, C., Lv, C., Li, H., 2020. Visualization and analysis of mapping knowledge domains for spontaneous combustion studies. Fuel 262, 116598. https://doi.org/10.1016/J.FUEL.2019.116598.
Liu, J., Luo, J., Zhou, J., Liu, Q., Qian, G., Xu, Z.P., 2012. Inhibitory effect of high-strength ammonia nitrogen on bio-treatment of landfill leachate using EGSB reactor under mesophilic and atmospheric conditions. Bioresour. Technol. 113, 239–243. https://doi.org/10.1016/j.biortech.2011.11.114.
Liu, Z., Dang, Y., Li, C., Sun, D., 2015. Inhibitory effect of high NH + 4 – N concentration on anaerobic biotreatment of fresh leachate from a municipal solid waste incineration plant. Waste Manag. 43, 188–195. https://doi.org/10.1016/j.wasman.2015.06.031.
Luo, H., Zeng, Y., Cheng, Y., He, D., Pan, X., 2020. Recent advances in municipal landfill leachate: a review focusing on its characteristics, treatment, and toxicity assessment. Sci. Total Environ. 703, 135468 https://doi.org/10.1016/j.scitotenv.2019.135468.
Luo, J., Lu, X., Liu, J., Qian, G., Lu, Y., 2014a. Biogas recirculation for simultaneous calcium removal and biogas purification within an expanded granular sludge bed system treating leachate. Bioresour. Technol. 173, 317–323. https://doi.org/10.1016/j.biortech.2014.09.128.
Luo, J., Zhou, J., Qian, G., Liu, J., 2014b. Effective anaerobic biodegradation of municipal solid waste fresh leachate using a novel pilot-scale reactor : comparison under different seeding granular sludge. Bioresour. Technol. 165, 152–157. https://doi.org/10.1016/j.biortech.2014.03.141.
Mæhlum, T., 1995. Treatment of landfill leachate in on-site lagoons and constructed wetlands. Water Sci. Technol. 32, 129–135. https://doi.org/10.1016/0273-1223(95)00613-3.
Marttinen, S.K., Kettunen, R.H., Sormunen, K.M., Soimasuo, R.M., Rintala, J.A., 2002. Screening of physical-chemical methods for removal of organic material, nitrogen and toxicity from low strength landfill leachates. Chemosphere 46, 851–858. https://doi.org/10.1016/S0045-6535(01)00150-3.
Mavakala, B.K., Le Faucheur, S., Mulaji, C.K., Laffite, A., Devarajan, N., Biey, E.M., Giuliani, G., Otamonga, J.P., Kabatusuila, P., Mpiana, P.T., Poté, J., 2016. Leachates draining from controlled municipal solid waste landfill: detailed geochemical characterization and toxicity tests. Waste Manag. 55, 238–248. https://doi.org/10.1016/j.wasman.2016.04.028.
Meng, F., Xi, L., Liu, D., Huang, Weiwei, Lei, Z., Zhang, Z., Huang, Wenli, 2019. Effects of light intensity on oxygen distribution, lipid production and biological community of algal-bacterial granules in photo-sequencing batch reactors. Bioresour. Technol. 272, 473–481. https://doi.org/10.1016/j.biortech.2018.10.059.
Menzel, T., Neubauer, P., Junne, S., 2020. Role of microbial hydrolysis in anaerobic digestion. Energies 13. https://doi.org/10.3390/en13215555.

Miao, L., Yang, G., Tao, T., Peng, Y., 2019. Recent advances in nitrogen removal from landfill leachate using biological treatments – a review. J. Environ. Manag. 235, 178–185. https://doi.org/10.1016/j.jenvman.2019.01.057.
Michalska, J., Piński, A., Zur, J., Mrozik, A., 2020. Analysis of the bioaugmentation potential of Pseudomonas putida OR45a and Pseudomonas putida KB3 in the sequencing batch reactors fed with the phenolic landfill leachate. Water (Switzerland) 12. https://doi.org/10.3390/w12030906.
Mojiri, A., Zhou, J.L., Ratnaweera, H., Ohashi, A., Ozaki, N., Kindaichi, T., Asakura, H., 2021. Treatment of landfill leachate with different techniques: an overview. J. Water Reuse Desalin. 11, 66–96. https://doi.org/10.2166/wrd.2020.079.
Moujanni, A., Qarraey, I., Ouatmane, A., 2020. Biogas recovery from fresh landfill leachates by using a coupled air stripping-up follow anaerobic sludge blanket (UASB) process. Environ. Eng. Res. 27, 200470 https://doi.org/10.4491/eer.2020.470. –0.
Neczaj, E., Kacprzak, M., Kamizela, T., Lach, J., Okoniewska, E., 2008. Sequencing batch reactor system for the co-treatment of landfill leachate and dairy wastewater. Desalination 222, 404–409. https://doi.org/10.1016/J.DESAL.2007.01.133.
Nivala, J., Hoos, M.B., Cross, C., Wallace, S., Parkin, G., 2007. Treatment of landfill leachate using an aerated, horizontal subsurface-flow constructed wetland. Sci. Total Environ. 380, 19–27. https://doi.org/10.1016/j.scitotenv.2006.12.030.
Parawira, W., Murto, M., Zvauya, R., Mattiasson, B., 2006. Comparative performance of a UASB reactor and an anaerobic packed-bed reactor when treating potato waste leachate. Renew. Energy 31, 893–903. https://doi.org/10.1016/j.renene.2005.05.013.
Payandeh, P.E., Mehrdadi, N., Dadgar, P., 2017. Study of biological methods in landfill leachate treatment. Open J. Ecol. 7, 568–580. https://doi.org/10.4236/oje.2017.79038.
Qiu, S., Hu, Y., Liu, R., Sheng, X., Chen, L., Wu, G., Hu, H., Zhan, X., 2019. Start up of partial nitritation-anammox process using intermittently aerated sequencing batch reactor: performance and microbial community dynamics. Sci. Total Environ. 647, 1188–1198. https://doi.org/10.1016/j.scitotenv.2018.08.098.
Rajeshwari, K.V., Lata, K., Pant, D.C., Kishore, V.V.N., 2001. A novel process using enhanced acidification and a UASB reactor for biomethanation of vegetable market waste. Waste Manag. Res. 19, 292–300. https://doi.org/10.1177/0734242X0101900405.
Ren, Y., Ferraz, F., Kang, A.J., Yuan, Q., 2017. Treatment of old landfill leachate with high ammonium content using aerobic granular sludge. J. Biol. Eng. 11, 1–8. https://doi.org/10.1186/s13036-017-0085-0.
Ren, Y., Ferraz, F.M., Yuan, Q., 2018. Biological leachate treatment using anaerobic/aerobic process: suspended growth-activated sludge versus aerobic granular sludge. Int. J. Environ. Sci. Technol. 15, 2295–2302. https://doi.org/10.1007/s13762-017-1633-3.
Reshadi, M.A.M., Soleymani Hasani, S., Nazaripour, M., McKay, G., Bazargan, A., 2021. The evolving trends of landfill leachate treatment research over the past 45 years. Environ. Sci. Pollut. Res. 28, 66556–66574. https://doi.org/10.1007/s11356-021-14274-x.
Saidulu, D., Majumder, A., Gupta, A.K., 2021. A systematic review of moving bed biofilm reactor, membrane bioreactor, and moving bed membrane bioreactor for wastewater treatment: comparison of research trends, removal mechanisms, and performance. J. Environ. Chem. Eng. 9, 106112 https://doi.org/10.1016/j.jece.2021.106112.
Sang, N., Li, G., Xin, X., 2006. Municipal landfill leachate induces cytogenetic damage in root tips of Hordeum vulgare. Ecotoxicol. Environ. Saf. 63, 469–473. https://doi.org/10.1016/j.ecoenv.2005.02.009.
Sawasdee, V., Pisutpaisal, N., 2016. Simultaneous pollution treatment and electricity generation of tannery wastewater in air-cathode single chamber MFC. Int. J. Hydrogen Energy 41, 15632–15637. https://doi.org/10.1016/j.ijhydene.2016.04.179.
Selvam, S.B., Chelliapan, S., Din, M.F.M., Nasri, N.S., Abdullah, N., Yuzir, A., 2017. Performance of an up-flow anaerobic sludge bed (UASB) reactor for treating landfill leachate containing heavy metals and formaldehyde. Desalination Water Treat. 86, 51–58. https://doi.org/10.5004/dwt.2017.21406.
Shi, X.S., Dong, J.J., Yu, J.H., Yin, H., Hu, S.M., Huang, S.X., Yuan, X.Z., 2017. Effect of hydraulic retention time on anaerobic digestion of wheat straw in the semicontinuous continuous stirred-tank reactors. BioMed Res. Int. 2017 https://doi.org/10.1155/2017/2457805.
Shim, W.G., Abdul, J.M., Mohammad, T., Vigneswaran, S., Ngo, H.H., Kandasamy, J., 2012. Biofilter in leachate treatment processes. Desalination Water Treat. 41, 249–257. https://doi.org/10.1080/19443994.2012.664722.
Show, P.L., Pal, P., Leong, H.Y., Juan, J.C., Ling, T.C., 2019. A review on the advanced leachate treatment technologies and their performance comparison: an opportunity to keep the environment safe. Environ. Monit. Assess. 191 https://doi.org/10.1007/s10661-019-7380-9.
Siciliano, A., Limonti, C., Curcio, G.M., Calabrò, V., 2019. Biogas generation through anaerobic digestion of compost leachate in semi-continuous completely stirred tank reactors. Processes 7. https://doi.org/10.3390/pr7090635.
Smol, M., Adam, C., Preisner, M., 2020. Circular economy model framework in the European water and wastewater sector. J. Mater. Cycles Waste Manag. 22, 682–697. https://doi.org/10.1007/s10163-019-00960-z.
Song, J., Zhang, W., Gao, J., Hu, X., Zhang, C., He, Q., Yang, F., Wang, H., Wang, X., Zhan, X., 2020. A pilot-scale study on the treatment of landfill leachate by a composite biological system under low dissolved oxygen conditions: performance and microbial community. Bioresour. Technol. 296, 122344 https://doi.org/10.1016/j.biortech.2019.122344.
Sughosh, P., Babu, G.L.S., 2021. The role of bioreactor landfill concept in waste management in India REVIEW. J. Indian Inst. Sci. xxx 1. https://doi.org/10.1007/s41745-021-00248-y. –25.
Sun, G., Austin, D., 2007. Completely autotrophic nitrogen-removal over nitrite in lab-scale constructed wetlands: evidence from a mass balance study. Chemosphere 68, 1120–1128. https://doi.org/10.1016/j.chemosphere.2007.01.060.
Sun, H., Zhao, H., Bai, B., Chen, Y., Yang, Q., Peng, Y., 2015. Advanced removal of organic and nitrogen from ammonium-rich landfill leachate using an anaerobic-aerobic system. Chin. J. Chem. Eng. 23, 1047–1051. https://doi.org/10.1016/j.cjche.2014.03.007.
Svensson, B.M., Mathiasson, L., Mårtensson, L., Bergström, S., 2005. Artemia salina as test organism for assessment of acute toxicity of leachate water from landfills. Environ. Monit. Assess. 102, 309–321. https://doi.org/10.1007/s10661-005-6029-z.
Tan, H., Li, Jialing, He, M., Li, Jiayu, Zhi, D., Qin, F., Zhang, C., 2021. Global evolution of research on green energy and environmental technologies:A bibliometric study. J. Environ. Manag. 297, 113382 https://doi.org/10.1016/j.jenvman.2021.113382.
Tsarpali, V., Dailianis, S., 2012. Investigation of landfill leachate toxic potency: an integrated approach with the use of stress indices in tissues of mussels. Aquat. Toxicol. 124–125, 58–65. https://doi.org/10.1016/j.aquatox.2012.07.008.
Tulun, A., 2020. Treatment of leachate using up-flow anaerobic sludge blanket reactors/vertical flow subsurface constructed wetlands. Ecol. Chem. Eng. S 27, 129–137. https://doi.org/10.2478/eces-2020-0008.
Turk, O., Mavinic, D.S., 1989. Maintaining nitrite build-up in a system acclimated to free ammonia. Water Res. 23, 1383–1388. https://doi.org/10.1016/0043-1354(89)90077-8.
Van Den Hende, S., Rodrigues, A., Hamaekers, H., Sonnenholzner, S., Vervaeren, H., Boon, N., 2017. Microalgal bacterial flocs treating paper mill effluent: a sunlight-based approach for removing carbon, nitrogen, phosphorus, and calcium. Nat. Biotechnol. 39, 1–10. https://doi.org/10.1016/j.nbt.2017.03.004.
van Dijk, E.J.H., Pronk, M., van Loosdrecht, M.C.M., 2020. A settling model for full-scale aerobic granular sludge. Water Res. 186, 116135 https://doi.org/10.1016/j.watres.2020.116135.
Wang, C.C., Lee, P.H., Kumar, M., Huang, Y.T., Sung, S., Lin, J.G., 2010. Simultaneous partial nitrification, anaerobic ammonium oxidation and denitrification (SNAD) in a full-scale landfill-leachate treatment plant. J. Hazard Mater. 175, 622–628. https://doi.org/10.1016/j.jhazmat.2009.10.052.
Wang, G., Lu, G., Yin, P., Zhao, L., Jimmy Yu, Q., 2016. Genotoxicity assessment of membrane concentrates of landfill leachate treated with Fenton reagent and UV-Fenton reagent using human hepatoma cell line. J. Hazard Mater. 307, 154–162. https://doi.org/10.1016/j.jhazmat.2015.12.069.
Wang, K., Li, L., Tan, F., Wu, D., 2018. Treatment of landfill leachate using activated sludge technology: a review. Archaea 2018. https://doi.org/10.1155/2018/1039453.
Wang, K., Wang, S., Zhu, R., Miao, L., Peng, Y., 2013. Advanced nitrogen removal from landfill leachate without addition of external carbon using a novel system coupling ASBR and modified SBR. Bioresour. Technol. 134, 212–218. https://doi.org/10.1016/j.biortech.2013.02.017.
Wang, P., Lau, I., Fang, H., 2001. Landfill leachate treatment by anaerobic process and electrochemical oxidation. Huanjing Kexue 22, 70–73.
Watanabe, H., Yoshino, H., 2010. Biohydrogen using leachate from an industrial waste landfill as inoculum. Renew. Energy 35, 921–924. https://doi.org/10.1016/J.RENENE.2009.10.033.
White, J.K., Beaven, R.P., Powrie, W., Knox, K., 2011. Leachate recirculation in a landfill: some insights obtained from the development of a simple 1-D model. Waste Manag. 31, 1210–1221. https://doi.org/10.1016/j.wasman.2010.10.022.
Xie, Z., Wang, Z., Wang, Q., Zhu, C., Wu, Z., 2014. An anaerobic dynamic membrane bioreactor (AnDMBR) for landfill leachate treatment: performance and microbial community identification. Bioresour. Technol. 161, 29–39. https://doi.org/10.1016/j.biortech.2014.03.014.
Zekker, I., Artemchuk, O., Rikmann, E., Ohimai, K., Bhowmick, G.D., Ghangrekar, M.M., Burlakovs, J., Tenno, T., 2021a. Start-up of anammox SBR from non-specific inoculum and process acceleration methods by hydrazine. Water (Switzerland) 13, 350. https://doi.org/10.3390/w13030350.
Zekker, I., Bhowmick, G.D., Priks, H., Nath, D., Rikmann, E., Jaagura, M., Tenno, T., Tämm, K., Ghangrekar, M.M., 2020. ANAMMOX-denitrification biomass in microbial fuel cell to enhance the electricity generation and nitrogen removal efficiency. Biodegradation 31, 249–264. https://doi.org/10.1007/s10532-020-09907-w.
Zekker, I., Mandel, A., Rikmann, E., Jaagura, M., Salmar, S., Ghangrekar, M.M., Tenno, T., 2021b. Ameliorating effect of nitrate on nitrite inhibition for denitrifying P-accumulating organisms. Sci. Total Environ. 797, 149133 https://doi.org/10.1016/J.SCITOTENV.2021.149133.
Zhang, B., Lens, P.N.L., Shi, W., Zhang, R., Zhang, Z., Guo, Y., Bao, X., Cui, F., 2018. Enhancement of aerobic granulation and nutrient removal by an algal–bacterial consortium in a lab-scale photobioreactor. Chem. Eng. J. 334, 2373–2382. https://doi.org/10.1016/j.cej.2017.11.151.
Zhang, C., Zhang, S., Zhang, L., Rong, H., Zhang, K., 2015. Effects of constant pH and unsteady pH at different free ammonia concentrations on shortcut nitrification for landfill leachate treatment. Appl. Microbiol. Biotechnol. 99, 3707–3713. https://doi.org/10.1007/s00253-014-6340-0.
Zhang, F., He, Z., 2013. A cooperative microbial fuel cell system for waste treatment and energy recovery. Environ. Technol. 34, 1905–1913. https://doi.org/10.1080/09593330.2013.770540.
Zhang, L., Fan, J., Nguyen, H.N., Li, S., Rodrigues, D.F., 2019. Effect of cadmium on the performance of partial nitrification using sequencing batch reactor. Chemosphere 222, 913–922. https://doi.org/10.1016/j.chemosphere.2019.02.006.
Zhang, L., Wei, C., Zhang, K., Zhang, C., Fang, Q., Li, S., 2009. Effects of temperature on simultaneous nitrification and denitrification via nitrite in a sequencing batch

biofilm reactor. Bioproc. Biosyst. Eng. 32, 175–182. https://doi.org/10.1007/s00449-008-0235-3.

Zhang, Q., 2021. Waste to biohydrogen: progress, challenges, and prospects. Waste to Renew. Biohydrogen Adv. Theory Exp. 1, 55–70. https://doi.org/10.1016/B978-0-12-821659-0.00002-2.

Zhang, S., Jiang, X., Li, M., Zhang, Q., Yuan, J., Guo, W., 2020. Effects of deoxygenation pretreatment and dissolved oxygen adjustment on performance of double-layer-packed sequencing biofilm batch reactor treating secondary effluent under low temperature. J. Clean. Prod. 258, 120650 https://doi.org/10.1016/J.JCLEPRO.2020.120650.

Zhang, Y., Dong, X., Liu, S., Lei, Z., Shimizu, K., Zhang, Z., Adachi, Y., Lee, D.J., 2020. Rapid establishment and stable performance of a new algal-bacterial granule system from conventional bacterial aerobic granular sludge and preliminary analysis of mechanisms involved. J. Water Proc. Eng. 34, 101073 https://doi.org/10.1016/j.jwpe.2019.101073.