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A bibliometric analysis of leachate publications by ASEAN authors

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Abstract. Leachates are the aqueous effluent produced from waste filtration of rainwater, biochemical activities in the waste cells, and the unavoidable water content of the waste itself. Leachate can travel into soil and subsoil, seriously affecting the land, surface water, and groundwater ecosystems. Leachates typically contain significant quantities of organic matter, ammonia-nitrogen (NH_3-N), toxic chemicals, and organic and inorganic chlorinated salts, which are detrimental to living and biodiversity. Based on the significant risk posed by leachate, many kinds of research have been conducted on these environmental concerns. Therefore, this paper aims to analyse and report leachate-related publications by ASEAN authors based on the data collected from the Scopus database. As of 24th April 2020, a total number of 1133 articles were retrieved and analysed. This study examined publication productivity by analysing descriptive publication patterns and visualising keywords co-occurrences. The results showed that there had been an increase in the literature on leachate growth rate from 1989 until 2020. However, the number of publications slightly dropped in 2011 and 2014. This study revealed the widespread scholarly communication techniques in leachate research, which will assist future researchers in identifying the fundamental parts of this body of knowledge. In conclusion, this study enables researchers to develop innovative solutions to the leachate environmental problem by assessing the bibliometric parameters that provide the study's crucial and noteworthy findings.

Keywords: leachate; landfill; municipal solid waste; bibliometrics; Scopus

INTRODUCTION

During these decades, a large generation of by-products had been produced owing to economic growth and lifestyle transition. Developing countries and activities will increase solid waste production (Mohd-Salleh et al., 2020). This phenomenon can be seen clearly in most developing countries, especially in the ASEAN region. According to Sharifah and Latifah (2013), middle-income countries produce solid waste at which the level was around 0.78 to 1.16 Kg/Capita/day. Various forms and contents of debris have been deposited in waste sites, including commercial, industrial, and agricultural waste spin-offs, over the years without the separation phase having to pass (Mohd-Salleh et al., 2020). Landfilling is the commonly accepted method of proper waste disposal globally, and there are many types of landfills, such as open dumping landfills, managed landfills, and sanitary landfills. It is high time to fix landfill issues, as this waste disposal system produces extremely toxic wastewater, termed leachate, resulting from the degradation of organic matter combined with rainwater. In developing Asian nations, much municipal solid waste is disposed of on land, which could have significant environmental consequences and deterioration of the environment (Bhalla et al., 2013). Since some landfills products are methane emissions and liquids leachate, thus many researchers have reported the hazardous potential of leachate towards the environment.

Leachate is a water pollutant derived from municipal solid waste produced by precipitating blackish fluid that is entered into a waste site. The scientific concept of leachate can be clarified by the very aqueous contaminated waste generated by the biochemical processes between percolated rainwater and waste material (Yusoff & Mohamad Zuki, 2015). There are many characteristics of leachate, and the nature of leachate may vary by landfill maturity level, landfill hydrology, waste disposal site size, temperature, moisture content, and waste composition. Leachate occurs due to many chemical and biological reactions within the site of solid waste (Abu-Daabes et al., 2013). It includes different harmful contaminants, including high ammonia levels and heavy metals, organic loads, and reduced physical properties such as stink odour and dark colour (Mohd-Salleh et al., 2020). Singh et al. (2000) found that leachate poses a possible danger to the soil, groundwater, and surface water and is toxic to marine life in limited amounts of ammonia. Several kinds of research agree that leaching can pose a significant threat to the environment and the ecosystem because it can pollute groundwater and surface water following the dissipation of leachate through the soil (Ashraf et al., 2013, Naveen et al., 2017).

Leachate is mixed into groundwater by various processes, including chemical precipitation, microbial degradation, and sorption. According to Sharifah and Latifah (2013), leachate can contaminate the groundwater sources and surface water due to hydraulic relations under the surface because it is the natural way of polluting these kinds of water. Below the soil and landfill sites, groundwater sources can potentially migrate pollutants to remote areas once leachate is introduced to the underwater sources. Leachate will not only pollute water resources but also contaminate the soil. According to Azizan et al. (2020), leachate will increase the soil's toxicity, ultimately contributing to soil pollution. As leachate poses a significant environmental risk, thus many ways to reduce leachate risk and leachate treatment have been developed. Some of the ways that have been designed are Advanced Oxidation Process (AOP) with TiO2 photocatalysis, Ozone based process, chemical-based

ion-exchange system, activated sludge, and constructed wetland. Robinson (2017) says that a method used to extract harmful chemicals is the chemical ion-exchanging method used for the biological treatment of leachates. In order to enhance the biodegradation of micro-pollutants in wastewater leachate, increased activated sludge has also been used in accustomed bacterial sludge (Boonnorat et al., 2018). Finally, is the constructed wetland. Studies conducted by previous researchers (Akinbile et al., 2012; Ogata et al., 2015; Sawaittayothin & Polorasert, 2006) have established that built wetlands are a sustainable, low-cost leachate technology, especially in tropical/subtropical regions. Further studies (Stefanakis et al. 2014) have also shown that the developed wetlands can quickly degrade organic carbon and that constructed wetland can effectively extract NH_4-N from the slurry leachate.

Numerous studies have been carried out on analysing every aspect of leachate in various parts of the globe. Most of these findings have been published in publications and researched papers. Despite the increasing interest in leachate study, the information collected on a bibliometric review of leachate is woefully inadequate. Since leachate has indeed been analysed globally, the bibliometric analysis is necessary. Bibliometric analysis is a useful method of recognising research patterns and hot problems based on knowledge from past publications (Bi, 2013; Li et al., 2018). It can also be used as a framework for the assessment of research activities of institutions and researchers (Wang et al., 2010; Li et al., 2018). The primary purposes of this report are to carry out a regional review of the leachate research activities by ASEAN authors in the Scopus database by analysing the progression of publications using bibliometric review techniques.

METHOD

This paper aims to conduct a bibliometric analysis of leachate publications by ASEAN authors. In addition, the data collected is analysed using network visualisation mapping to comprehend the study of leachate research and predict the changing direction of the research interest.

Bibliometric Analysis

A bibliometric technique executes mathematics and statistical mechanisms pertinent to the books, articles, reports, and other communication media (Pritchard, 1969). In order to do bibliometric analysis, researchers must compile a collection of data sets or bibliometric data. A bibliometric data is a list of the sources of interest for research that provide a summary of the merit and demerit of the data related to any research topics that have been selected for analysing (Davin, 2008; Sofyan & Abdullah, 2022). The bibliometric evaluation includes identifying the author's research areas, the citation network, and the authors' keywords (Abdullah, 2022; Kar & Wray, 2016; Sofyan, 2022). Moreover, bibliometric data can be utilised to analyse any credible form of knowledge for a given bibliometric study (Abdullah, 2021)

Bibliometric analysis can be used to examine bibliometric data gathered from various databases, such as Scopus, Web of Science, Google Scholar, Microsoft Academics, or Dimensions (Abdullah et al., 2021). In addition, the analysis can be visualised using multiple tools, including VOSviewer, SciMAT, and ScientoPy (Abdullah & Sofyan, 2022). This study visualises the bibliometric network using VOSviewer. VOSviewer is a tool that facilitates the generation and viewing of bibliometric networks. This network can be constructed through

citation, bibliography, co-citation, or co-authorship of journals, scholars, or individual works (Abdullah & Othman, 2022).

Data Source and Data Collection

Scopus database is utilised to extract data sources with 1133 documents based on keyword leachate with a limitation to ten ASEAN countries: Malaysia, Thailand, Singapore, Indonesia, Laos, Cambodia, Myanmar, Vietnam, Brunei and Philippines. Considering that there are always new documents that might publish, this data source was taken on 24th April 2020 and exported into RIS and CSV format for further analysis. Microsoft excel, VOSviewer, and Harzing's Publish and Perish software were used to assist in reading and visualising the data extracted in RIS and CSV form.

RESULTS

Some of the general dataset statistics are presented to obtain a recapitulation of the leachate-related research study. The retrieval data were evaluated using descriptive publication patterns and visualising keywords co-occurrences as further explained in the following sub-topics.

Research Productivity

The first analysis concerns research productivity derived from the number of published documents per year. According to Gazali et al. (2021), the number of papers published and their publication year helps the researcher observe the pattern and popularity of the research subject over time. This study showed that the growth of publishing leachate research was slow until 2008. Also, there have been fluctuations in the number of publications. This study demonstrated that the highest number of publications on leachate was in 2018 (see Figure 1).

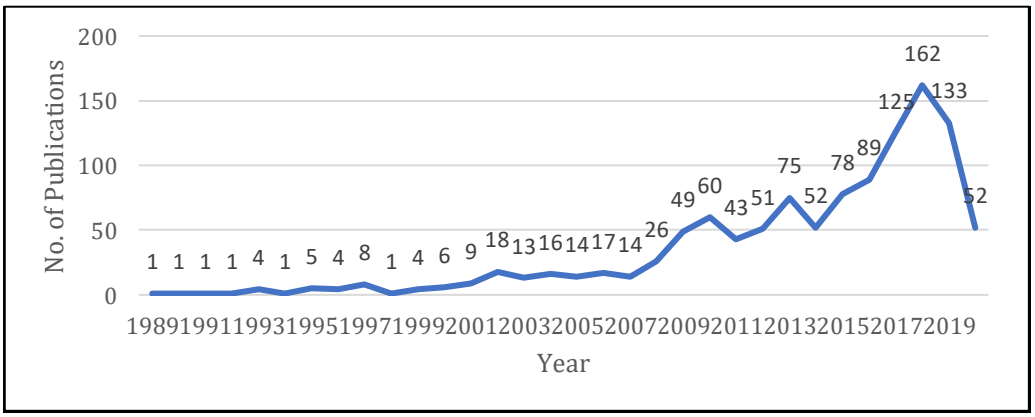

Figure1. Document per year

The Document Types, Source Type and Subject Areas

This study analysed the document type based on the types of published documents and the number of publications. According to Table 1, approximately 837 publications (73.87%) are articles, followed by 235 conference papers (20.74%). And the lowest publication rate for erratum-type papers is one, or 0.09%. Table 2 indicates the source type that was analysed, and the documents were classified into five different types. As shown in

Table 2, journal is highest in the percentage of source type with 858 publications (75.73%), followed by conference proceedings with 204 publications (18.01%) of total publications.

Meanwhile, trade publications are only one (0.09%), making it the smallest percentage of total publications. Since leachate is a pollutant to the environment, a large percentage of the subject area is related to Environmental Science. The second-largest rate, about 14.86%, is involved in the Engineering area to control environmental damage caused by leachate. Less than 10% of the document relates leachate to subjects like Materials Science, Agricultural Science, Chemistry, and Physics. The subject area in Veterinary, Health Professions, Economy, and Dentistry are related to leachate only in one document. Some documents relating leachate with more than one subject area.

Table 1. Document Type

Document Type	No. of Publications	Percentage (%)
Article	837	73.87
Conference Paper	235	20.74
Book Chapter	32	2.82
Review	24	2.12
Data Paper	2	0.18
Editorial	2	0.18
Erratum	1	0.09

Table 2. Source Type

Source Type	No. of Publications	Percentage (%)
Journals	858	75.73
Conference Proceedings	204	18.01
Book Series	49	4.32
Books	21	1.85
Trade Publications	1	0.09

Most Active Journals, Countries, and Institutions

This paper also featured at least 17 or more leachate publications in the most prominent journals (see Table 3). At the same time, the impact factor of each journal is listed in Table 3, and the AIP Conference Proceedings are the leading journals that contribute to publications of studies on leachate by the ASEAN authors.

Table 3. Most Active Journals

Journals	Number of Articles	Impact Factor (2020)
AIP Conference Proceedings	41	13.40
Water Science and Technology	40	13.07
IOP Conference Series Earth and Environmental Science	38	12.42
Waste Management	38	12.42
IOP Conference Series Materials Science and Engineering	30	9.80
Journal Of Hazardous Materials	26	8.50
Bio-resource Technology	21	6.86
Desalination And Water Treatment	20	6.54
Matec Web Of Conferences	18	5.88
Journal Of Environmental Management	17	5.56
Journal Of Physics Conference Series	17	5.56

Countries' contribution toward the study of leachate by the ASEAN authors has also been evaluated. Table 4 shows the top 10 most active countries. The highest percentage of total publications is from Malaysia, which is more than half of overall papers, about 53.49%. Thailand and Indonesia are in the second and third publications of study on leachate that are 19.15% and 14.12%, respectively. The other countries, besides ASEAN regions such as Japan, the United States, Australia, and China, also show interest in collaborative research with the ASEAN scholars.

Table 4. Top 10 Most Active Countries

Country	No. of Publications	Percentage (%)
Malaysia	606	53.49
Thailand	217	19.15
Indonesia	160	14.12
Singapore	90	7.94
Japan	73	6.44
United States	65	5.74
Australia	64	5.65
Viet Nam	53	4.68
China	37	3.27
Philippines	36	3.18

Table 5 shows that the top 10 institutions are involved in publishing the article related to leachate. The institution is primarily a university in Malaysia, where Universiti Sains Malaysia is leading with 171 papers. Kasetsart University in Thailand and Nanyang Technological University in Singapore are also in the top 10.

Table 5. Top 10 Most Active Institutions

Institution	No. of Publications	Percentage (%)
Universiti Sains Malaysia	171	10.16
Universiti Kebangsaan Malaysia	90	5.35
University of Malaya	85	5.05
Universiti Putra Malaysia	65	3.86
Universiti Tun Hussein Onn Malaysia	60	3.57
Kasetsart University	54	3.21
Nanyang Technological University	50	2.97
Universiti Teknologi Malaysia	46	2.73
Universiti Teknologi MARA	44	2.61
Universiti Teknologi Petronas	38	2.26

Authorship Analysis

The most active authors in this study have been displayed in Table 6, with a minimum of 20 publications. Based on this Table 6, Aziz, H.A. has the highest paper, about 94 (8.56%) published documents compared to the other authors, followed by Chemchaisri, C. and Yusoff, M.S. that both authors had published 44 papers (3.88%).

Table 6. Top 10 Most Active Institutions

Author Name	No. of Publications	Percentage (%)
Aziz, H.A.	97	8.56
Chiemchaisri, C.	44	3.88
Yusoff, M.S.	44	3.88
Bashir, M.J.K.	38	3.35
Chiemchaisri, W.	38	3.35
Adlan, M.N.	25	2.21
Agamuthu, P.	22	1.94
Hung, Y.T.	21	1.85

Keyword Analysis

Apart from the core keyword, leachate, common keywords such as leachate treatment, landfill, leaching, article, landfill leachate, and chemical oxygen demand are found by previous authors to be used to study leachate (see Table 7).

Table 7. Top 20 Keywords

Author Keywords	Total	Percentage (%)
Leachate	420	4.53
Leachate Treatment	409	4.41
Landfill	294	3.17
Leaching	286	3.09
Article	280	3.02
Landfill Leachate	256	2.76
Chemical Oxygen Demand	176	1.90
Leachates	175	1.89
Heavy Metals	148	1.60
Land Fill	142	1.53
Water Pollutants, Chemical	139	1.50
Landfill Leachates	132	1.42
Refuse Disposal	115	1.24
Municipal Solid Waste	114	1.23
Waste Treatment	112	1.21
Priority Journal	108	1.17
Waste Disposal	106	1.14
PH	103	1.11
Controlled Study	96	1.04
Adsorption	94	1.01

Using the VOSviewer, author keywords have been mapped in Figure 2. Figure 2 displayed a network visualisation map of the author keyword based on a different cluster in colour. Six significant clusters are in colour, yellow, blue, purple, red, orange, and green. The two most significant clusters are in blue and yellow with the keywords of leachate and landfill leachate. Meanwhile, keywords related to the blue cluster are landfill, up-flow anaerobic sludge blanket (uasb), biogas, methane, and anaerobic while, whereas keywords on the yellow cluster such as pH, electrode, and electrochemical.

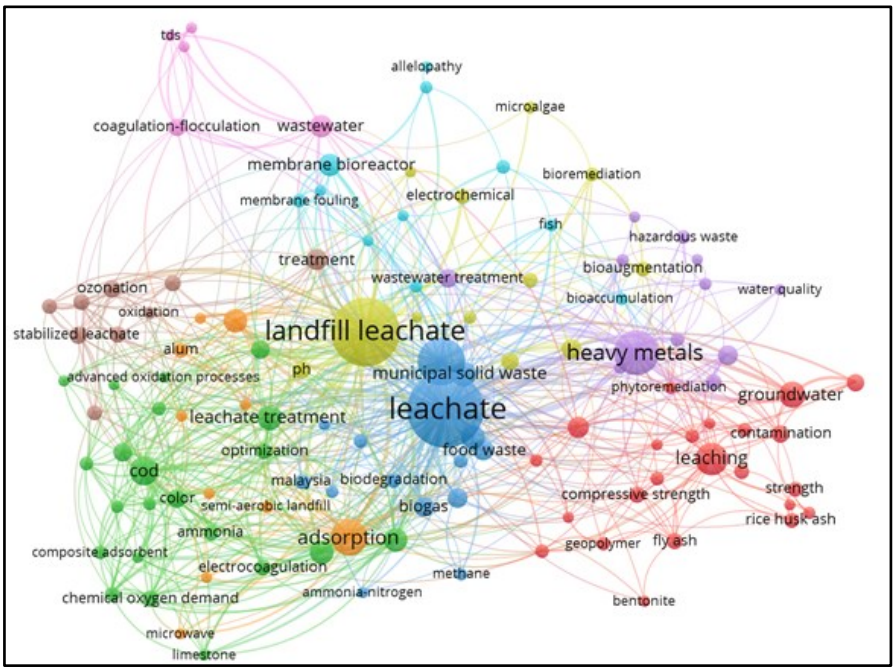

Figure2. Network visualisation map of the author keyword

Analysis of Citations

The standard quotation for the fetched papers as of 24th April 2020 is summarised in Table 8. As specified, a total of 14791 citations had been recorded in 31 years (1989 - 2020) of leachate publications. This citation metric has generated by Harzing's Publish and Perish software by importing RIS formatted files from the Scopus database to the said software to present the raw citation metrics. In addition, Table 9 shows the top 10 relevant cited papers based on the Scopus database. According to the database of Scopus, Teuten et al. (2009) document entitled "Transport and discharge of chemical products from plastics into the environment and wildlife" has a large number of citations with 914, equivalent to an average of 83.09 annual citations.

Table 8. Top 10 Most Active Institutions

Metrics	Data
Date of reference	24/04/2020 2:46:30
Publication years	1989-2020
Citation years	31 (1989-2020)
Papers	1133
Citations	14791
Citations/year	477.13
Citations/paper	13.05
Citations/author	4179.23
Papers/author	328.19
Authors/paper	4.14
Age-weighed citation rate	2088.77, 540.66/author
h-index	51
g-index	90
hI, norm	26
hI, annual	0.84

Table 9. Top 10 Cited Articles

Authors	Title	Source	Cites	Cites/Year
E.L. Teuten, J.M. Saquing, D.R.U. Knappe, M.A. Barlaz, S. Jonsson, A. BjÃ¶rn, S.J. Rowland, R.C. Thompson, T.S. Galloway, R. Yamashita, D. Ochi, Y. Watanuki, C. Moore, P.H. Viet, T.S. Tana, M. Prudente, R. Boonyatumanond, M.P. Zakaria, K. Akkhavong, Y. Ogata, H. Hirai, S. Iwasa, K. Mizukawa, Y. Hagino, A. Imamura, M. Saha, H. Takada	Transport and release of chemicals from plastics to the environment and wildlife	Philosophical Transactions of the Royal Society B: Biological Sciences	914	83.09
U. Rattanasak, P. Chindaprasirt	Influence of NaOH solution on the synthesis of fly ash geopolymer	Minerals Engineering	392	35.64
S. Ghafari, H.A. Aziz, M.H. Isa, A.A. Zinatizadeh	Application of response surface methodology (R.S. M) to optimise coagulation-flocculation treatment of leachate using poly-aluminium chloride (PAC) and alum	Journal of Hazardous Materials	319	29
K.Y. Foo, B.H. Hameed	An overview of landfill leachate treatment via activated carbon adsorption process	Journal of Hazardous Materials	311	28.27
M. Umar, H.A. Aziz, M.S. Yusoff	Trends in the use of Fenton, electro-Fenton, and photo-Fenton for the treatment of landfill leachate	Waste Management	255	25.5
W.T. Tan, S.T. Ooi, C.K. Lee	Removal of chromium (Vi) from solution by coconut husk and palm pressed fibres	Environmental Technology (United Kingdom)	218	8.07
M.J.K. Bashir, H.A. Aziz, M.S. Yusoff, Mohd.N. Adlan	Application of response surface methodology (R.S. M) for optimisation of ammoniacal nitrogen removal from semi-aerobic landfill leachate using ion-exchange resin	Desalination	198	19.8
H.A. Aziz, S. Alias, Mohd.N. Adlan, Faridah, A.H. Asaari, Mohd.S. Zahari	Colour removal from landfill leachate by coagulation and flocculation processes	Bioresource Technology	183	14.08
S. Netpradit, P. Thiravetyan, S. Towprayoon	Adsorption of three azo reactive dyes by metal hydroxide sludge: Effect of temperature, pH, and electrolytes	Journal of Colloid and Interface Science	180	11.25
S. Mohajeri, H.A. Aziz, M.H. Isa, M.A. Zahed, Mohd.N. Adlan	Statistical optimisation of process parameters for landfill leachate treatment using the electro-Fenton technique	Journal of Hazardous Materials	172	17.2

DISCUSSION AND CONCLUSION

In this paper, the Scopus database has been used to attain the objective of this study analysis. This had led to understanding the interpretation of leachate and predicting the changing direction of research

The Scopus database found 1133 documents based on the keyword of leachate on 24th April 2020. The title "Organic leachate effects on the permeability of compacted kaolinite" became the first-ever journal that published on the study of leachate in ASEAN region that is in the year 1989 initiated by Hamidon H.A., and Ali F.H. Meanwhile, Aziz, H.A. is the most active author who is published nearly 100 documents. Later, year by year, it shows an uptrend of study on leachate, with the highest publication being 162 in the year 2018 but falls afterwards in 2019 with 133 publications. Even though there is a slight decline in the study, it is believed their research will always be produced on leachate as in one-third of the year 2020, about 58 documents are published.

Journal type of documents is the highest in percentage compared to other documents. More than half of the study's publication comes from Malaysia compared to 65 other countries and is primarily written in English. Environmental Science and engineering are the top two subject areas related to the research of leachate, but veterinary, health professions, economics, econometrics and finance, and also dentistry is also in the subject area, although the percentage is small. Aside from the base study of leachate, the study of heavy metal, chemical oxygen demand (COD), leachate treatment, and waste disposal are also in a range of the study that is based on the keyword of the survey.

The citation metric on this paper shows the research's effect on leachate publication. Approximately 1133 articles with a total of 14791 citations were written in the years from 1989 until 2020. Overall, there are about 477.13 citations per year, 13.05 citations per article, and 4179.23 citations per author obtained based on this analysis in Scopus databases.

Given the essential nature of the bibliometric analysis, the study also has shortcomings that need to be addressed to provide readers with a better understanding and enhance future studies. Some of the limitations that should be addressed are writing related to leachate from external sources of the Scopus database are excluded. Some relevant articles related to leachate might have been excluded as articles, reports, documents, or citations outside the Scopus database. Scopus-certified documents are excluded and not evaluated in this study. Analysis derived from other databases such as Science Direct, Google scholar, and WoS would be worthwhile in further studies to verify this report's results.

Besides, many leachate-related papers have been explored, most of which was about how to treat landfill leachate via activated carbon. On the other hand, some of the papers explored are not entirely related to leachate. For instance, "Removal of chromium (Vi) from solution by coconut husk and palm pressed fibres" that was published on Environmental Technology was mainly about how heavy metal was removed via agricultural residue from industrial effluent. Manually filtering these non-related documents required a load of work and a lot of time. This can be overcome with text mining tools. In order to be effective in mining texts, text mining tools have been tested, and data from documents extracted, as this would increase competence in incoming research. Given these limitations, this review has amounted to the knowledge by presenting the latest research trend on leachate.

The third limitation found is bibliometric analysis focus on abstracts, titles, author keywords, and co-authors only. Thus, this analysis only reviews the surface of the article without looking deeper into the topic. Even though it intends to overcome bias review, bibliography analysis cannot replace extensive reading and excellent content analysis. As an example, a comparison of how significant effect of leachate between the country in ASEAN. These methods ultimately limit themselves by assuming that a document is crucial if citations for the transfer of knowledge or the academic contribution to later works are considered. Nevertheless, the study cannot consider certain motives that might guide writers in referencing prior documents.

Notwithstanding these limitations, this study has contributed to the knowledge by presenting the current research trends on leachate by ASEAN authors. The report on leachate work by the ASEAN authors was completed, and the current pattern of the subject was presented. The overview of the article also extends the previous finding on writing about leachate by using visual mapping and other bibliographic techniques to provide meaningful knowledge about leachate studies through the decade from 1989-2020.

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