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Artificial Intelligence and Air Pollution : A Bibliometric Analysis from 2012 to 2022

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Abstract

The application of artificial intelligence (AI) is becoming increasingly important to coping with air pollution. AI is effective in coping with it in various ways including air pollution forecasting, monitoring, and control, which is attracting a lot of attention. This attention has created high need for analyzing studies on AI and air pollution. To contribute for satisfying it, this study performed bibliometric analyses on the studies on AI and air pollution from 2012 to 2022 using the Web of Science database. This study analyzed them in various aspects such as the trend in the number of articles, the trend in the number of citations, the top 10 countries of origin, the top 10 research organizations, the top 10 research funding agencies, the top 10 journals, the top 10 articles in terms of total citations, and the distribution by languages. This study not only reports the bibliometric analysis results but also reveals the eight distinct features in the research steam in studies on AI and air pollution, identified from the bibliometric analysis results. They are expected to make a useful contribution for understanding the research stream in AI and air pollution.

Keywords: *Air Pollution; AI; Artificial Intelligence; Machine Learning; Deep Learning*

1. Introduction

It is critical to find out effective ways of coping with air pollution as various issues resulting from it are becoming more and more serious across the world. The application of artificial intelligence (AI) is becoming increasingly important to coping with air pollution [1]. AI is playing the significant role in coping with it in various ways including air pollution forecasting [2, 3], air pollution monitoring [4, 5], and air pollution control [6], which is attracting a lot of attention. This attention has generated high need for analyzing studies about AI and air pollution. Aiming at contributing for meeting it, this study poses the following eight research questions (RQs):

RQ 1: What is the trend in articles published in AI and air pollution?

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RQ 2: What is the trend in article citations in AI and air pollution?

RQ 3: What are the leading countries in studies on AI and air pollution?

RQ 4: What are the leading research organizations in studies on AI and air pollution?

RQ 5: What are the active research funding agencies in studies on AI and air pollution?

RQ 6: What are the active journals in studies on AI and air pollution?

RQ 7: What are the important articles, in terms of total citations, in AI and air pollution?

RQ 8: What is the distribution by language in the articles on AI and air pollution?

In order to effectively answer the eight research questions, this study carried out bibliometric analyses on the studies on AI and air pollution in various aspects such as the trend in the number of articles, the trend in the number of citations, the top 10 countries of origin, the top 10 research organizations, the top 10 research funding agencies, the top 10 journals, the top 10 articles in terms of total citations, and the distribution by languages.

2. Research Methods

The study performed a bibliometric analysis using the Web of Science (WOS) which is a widely used database across the world for various bibliometric analyses. This study searched the WOS for articles published in AI and air pollution from 2012 to 2022. Articles on AI and air pollution were observed to be published in various journals from diverse domains including environment, engineering, information technology, mathematics, and national policy. Therefore, this study used the bibliometric data extracted from the WOS, considering the extensive coverage of it with various journals in AI and air pollution.

To conduct a rigorous bibliometric analysis, this study took three steps, including identifying potential research, filtering out irrelevant research, and analyzing selected research.

In the first step for identifying potential research in AI and air pollution, this study made a search of the WOS for studies containing key phrases, such as ""artificial intelligence", "AI", "machine learning", "deep learning", "artificial neural network", or "artificial neural networks" combined with "air pollut~" in their keywords, titles, and abstracts. The period for this search was from 2012 to 2022. This step resulted in a total number of 1,980 studies.

In the second step for filtering out irrelevant research, the potential 1,980 studies resulting from the first step were filtered into a total number of 1,558 studies that matched the article in the type of documents categorized by the WOS, filtering out retracted publications.

In the third step for analyzing the selected research, this study looked into the 1,558 articles in term of their trend in yearly publications, the top 10 countries of origin, the top 10 research organizations, the top 10 research funding agency, the top 10 journals, the top 10 articles in total citations, and the distribution by language. Furthermore, this study analyzed the trend in the number of yearly citations in AI and air pollution.

3. Results

3.1. The Trend in the Number of Articles Published in AI and Air pollution

The bibliometric analysis revealed the drastically increasing trend in the number of articles published in AI and air pollution since 2018, as illustrated in Figure 1. The total number of 1,558 articles were published in AI and air pollution from 2012 to 2022. The 163 articles were published from 2012 to 2017, representing the 10.5% of the 1,558 articles published in AI and air pollution but the 1,395 articles were published from 2018 to 2022, accounting for the 89.5% of them. These results reveal the rapidly increasing interest in AI and air pollution since 2018.

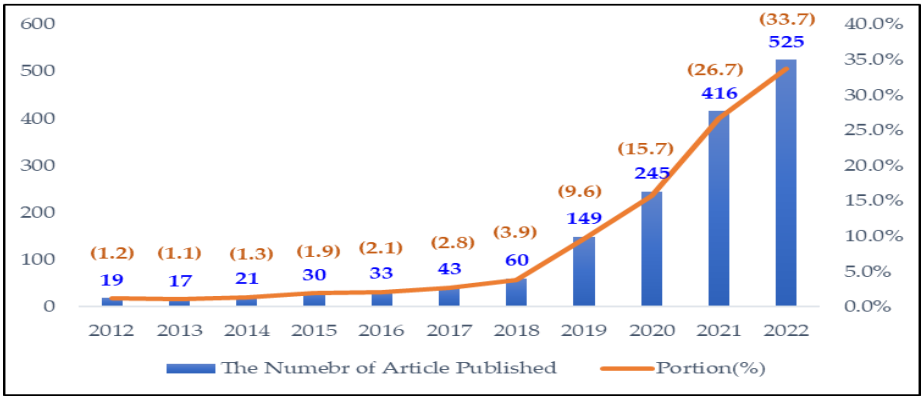

Figure 1. The Trend in the Number of Articles Published in AI and Air Pollution

3.2. The Trend in the Number of Citations in AI and Air Pollution

The number of citations in AI and air pollution was found out to show an exponential growth in its trend from 2012 to 2022, as illustrated in Figure 2. The number of citations was 14 in 2012, but it drastically increased to 9,298 in 2022, showing the rapid growth with the compound annual growth rate of 91.5%. These results confirm that AI and air pollution is a very crucial research domain with an exponential growth in its trend in terms of citations.

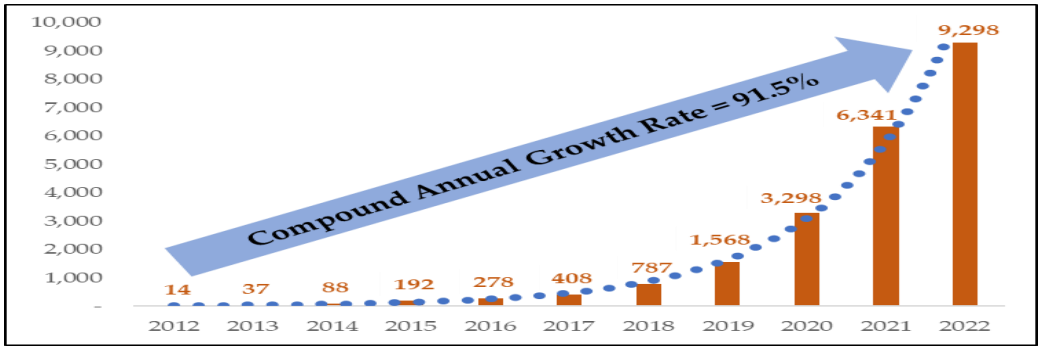

Figure 2. The Trend in the Number of Citations in AI and Air Pollution[1]

[1] The blue dotted line indicates the trend line fitted for the number of yearly citations; the red figures above

3.3. The Top 10 Countries of Origin

China, USA, India, England, South Korea, Iran, Spain, Italy, Taiwan, and Germany were the top 10 countries of origin of the 1,558 articles published in AI and air pollution, as illustrated in Figure 3. China is the salient country of origin. A total of 522 articles originated from China (33.5%), 287 from USA (18.4%), 136 from India (8.7%), 123 from England (7.9%), 83 from South Korea (5.3%), 77 from Iran (4.9%), 75 from Spain (4.8%), 71 from Italy (4.6%), 63 from Taiwan (4%), and 58 from Germany (3.7%).

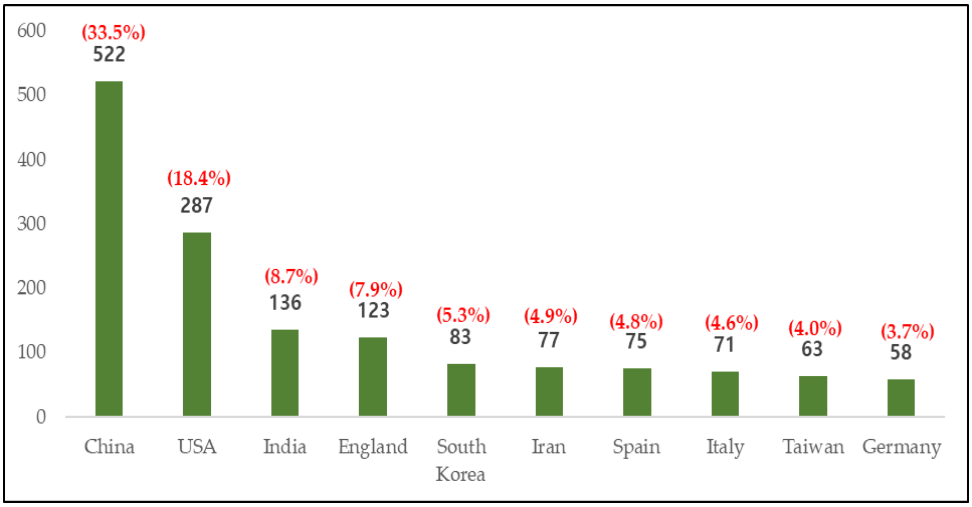

Figure 3. The top 10 countries of origin

3.4. The Top 10 Research Organizations

Chinese Academy of Sciences, Peking University, University of Chinese Academy of Sciences, Tshinghua University, Harvard University, University of California System, Wuhan University, Nanjing University of Information Science Technology, National Aeronautics Space Administration, and Zhejiang University are the top ten research organizations in terms of their portion of the authors' affiliation in the 1,558 articles published in AI and air pollution. A total number of 82 articles could be traced to Chinese Academy of Sciences (5.26%), 40 to Peking University (2.57%), 30 to University of Chinese Academy of Sciences (1.93%), 29 to Tshinghua University (1.86%), 28 to Harvard University (1.80%), 28 to University of California System (1.80%), 27 to Wuhan University (1.73%), 26 to Nanjing University of Information Science Technology (1.67%), 24 to National Aeronautics Space Administration (1.54%), 24 to Zhejiang University (1.54%). Table 1 summarizes the top ten research organizations.

Table 1. The top 10 research organizations

Rank	Research Organization	Frequency	Portion(%)
1	Chinese Academy of Sciences	82	5.26
2	Peking University	40	2.57
3	University of Chinese Academy of Sciences	30	1.93
4	Tshinghua University	29	1.86

each year indicate the number of yearly citations in AI and air pollution.

5	Harvard University	28	1.80
5	University of California System	28	1.80
7	Wuhan University	27	1.73
8	Nanjing University of Information Science Technology	26	1.67
9	National Aeronautics Space Administration	24	1.54
9	Zhejiang University	24	1.54

3.5. The Top 10 Research Funding Agency

National Natural Science Foundation of China, National Key Research and Development Program of China, United States Department of Health Human Services, National Institutes of Health, UK Research Innovation, European Union, Spanish Government, Fundamental Research Funds for the Central Universities, National Key R&D Program of China, and National Research Foundation of Korea are the top 10 research funding agencies with regard to their portion of research funders in the 1,558 articles published in AI and air pollution. A total number of 294 articles were funded by National Natural Science Foundation of China (18.87%), 45 by National Key Research and Development Program of China (2.89%), 41 by United States Department of Health Human Services (2.63%), 40 by National Institutes of Health (2.57%), 37 by UK Research Innovation (2.38%), 32 by European Union (2.05%), 31 by Spanish Government (1.995), 25 by Fundamental Research Funds for the Central Universities (1,61%), 24 by National Key R&D Program of China (1.54%), and 24 by National Research Foundation of Korea (1.54%). Table 2 reports the top 10 research funding agencies.

Table 2. The top 10 research funding agencies

Rank	Funding Agency	Frequency	Portion(%)
1	National Natural Science Foundation of China	294	18.87
2	National Key Research and Development Program of China	45	2.89
3	United States Department of Health Human Services	41	2.63
4	National Institutes of Health	40	2.57
5	UK Research Innovation	37	2.38
6	European Union	32	2.05
7	Spanish Government	31	1.99
8	Fundamental Research Funds for the Central Universities	25	1.61
9	National Key R&D Program of China	24	1.54
9	National Research Foundation of Korea	24	1.54

3.6. The Top 10 Journals

Science of the Total Environment, Atmospheric Environment, Atmosphere, Environmental Pollution, Sustainability, Journal of Cleaner Production, IEEE Access, Environmental Science and Pollution Research, Remote Sensing, and Atmospheric Pollution Research are the top 10 journals in terms of publication of the 1,558 articles AI and air pollution. A total number of 69 articles were published in Science of the Total Environment (4.43%), 55 in Atmospheric Environment (3.53%), 51 in Atmosphere (3.27%), 47 in Environmental Pollution (3.02%), 41 in Sustainability (2.63%), 38 in Journal of Cleaner Production (2.44%), 37 in IEEE Access (2.38%), 35 in Environmental Science and Pollution Research (2.25%), 35 in Remote Sensing (2.25%), and 33 in Atmospheric Pollution Research (2.12%). Table 3 summarizes the top 10 journals.

Table 3. The top 10 journals

Rank	Journal	Frequency	Portion(%)
1	*Science of the Total Environment*	69	4.43
2	*Atmospheric Environment*	55	3.53
3	*Atmosphere*	51	3.27
4	*Environmental Pollution*	47	3.02
5	*Sustainability*	41	2.63
6	*Journal of Cleaner Production*	38	2.44
7	*IEEE Access*	37	2.38
8	*Environmental Science and Pollution Research*	35	2.25
8	*Remote Sensing*	35	2.25
10	*Atmospheric Pollution Research*	33	2.12

3.7. The Top 10 Articles in Terms of Total Citations

As illustrated in Figure 4, the 1,558 articles in AI and air pollution show an L-shaped distribution, arranged by their ranks in the total citations. The maximum and minimum values of the L-shaped distribution 370 and 0, respectively.

He et al. [7], Feng et al. [8], Huang et al. [9], Li et al. [10], Li et al. [11], Zimmerman et al. [12], Qi et al. [13], Stafoggia et al. [14], Zhao et al. [15], and Joharestani et al. [16] are the top 10 articles in AI and air pollution in terms of their total citations.

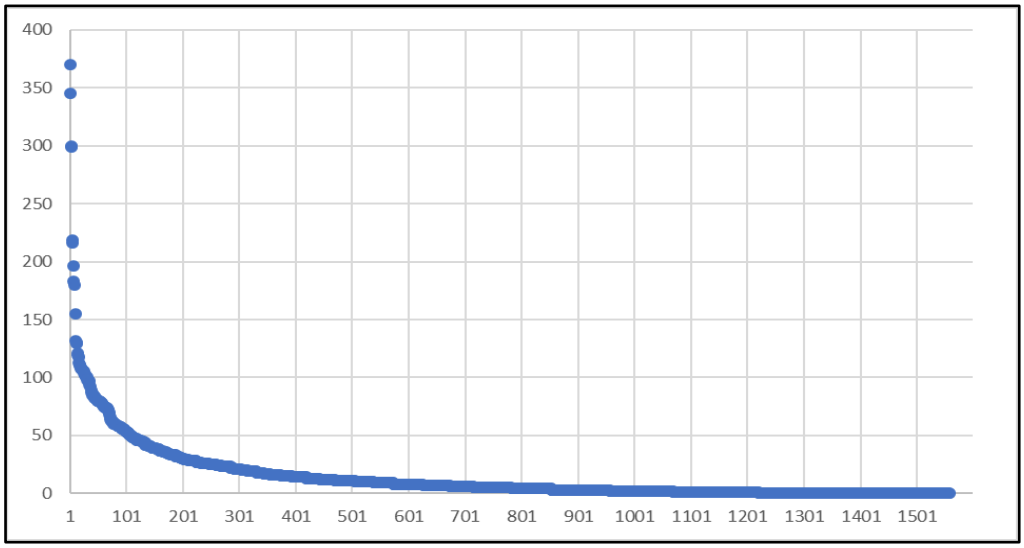

Figure 4. The distribution of total citations of each article[2]

He et al. [7] were cited 370 times, Feng et al. [8] 345 times, Huang et al. [9] 300 times, Li et al. [10] 299

[2] The blue dots represent each of the 1,558 articles; X-axis indicates the rank of the 1,558 articles by the total citations; Y-axis represents their total citations.

times, Li et al. [11] 219 times, Zimmerman et al. [12] 216 times, , Qi et al. [13] 196 times, Stafoggia et al. [14] 183 times, Zhao et al. [15] 180 times, and Joharestani et al. [16] 155 times. Table 4 summarizes the top 10 articles.

Table 4. The top 10 articles in total citations

Rank	Article	Total Citations
1	[7]	370
2	[8]	345
3	[9]	300
4	[10]	299
5	[11]	219
6	[12]	216
7	[13]	196
8	[14]	183
9	[15]	180
9	[16]	155

3.8. The Distribution by languages

English is the dominant languages which was used across the 1,558 articles published in AI and air pollution. English, Korean, Chinese, Malay, and Russian were used in the 1,588 articles published in AI and air pollution. A total number of 1,551 articles were written in English (99.55%), 3 in Korean (0.19%), 2 in Chinese (0.13%), 1 in Malay (0.06%), and 1 in Russian (0.06%). Table 5 reports the distribution of the 1,588 articles by language.

Table 5. Distribution of the articles in AI and air pollution by languages

Rank	Language	Frequency	Portion(%)
1	English	1,551	99.55
2	Korean	3	0.19
3	Chinese	2	0.13
4	Malay	1	0.06
4	Russian	1	0.06

4. Conclusion

The results from this study provide the following eight major findings in the research stream in AI and air pollution, answering the eight research questions (RQs) 1 through 8.

First, the number of research on AI and air pollution has gained momentum since 2018. Answering the RQ 1, this study revealed that 163 articles were published from 2012 to 2017 but 1,395 articles were published from 2018 to 2022. Their portions were 10.5% and 89.5%, respectively, in the 1,558 articles published in AI and air pollution from 2012 to 2022. Moreover, their compound annual growth rates were 17.7% and 72%, respectively. Therefore, the research on AI and air pollution has been found out to rapidly increase since 2018.

Second, the number of citations in AI and air pollution has been revealed to show an exponential growth from 2012 to 2022. The number of citations was 14 in 2012 but 9,298 in 2022, resulting in the compounding annual growth rate of 91.5%. Answering the RQ 2, this rapid growth confirms that AI and air pollution is a very important and promising research domain which has attracted a lot of increasing attention.

Third, China, USA and India have been found out to be the leading countries in terms of the country of origin of the 1,558 articles published in AI and air pollution, answering RQ 3. The analysis on the top 10 countries of origin showed that the portion of China USA and India is 60.6%, which is larger than that of the other seven countries such as England, South Korea, Iran, Spain, Italy, Taiwan, and Germany.

Fourth, answering RQ 4, Chinese research organizations have been revealed to be salient with regard to the research organizations of the 1,558 articles published in AI and air pollution. The analysis on the top 10 research organization revealed that seven organizations, except Harvard University, University of California System, and National Aeronautics Space Administration, are Chinese organizations. Especially, Chinese Academy of Sciences, Peking University, and University of Chinese Academy of Sciences are the top 3 research organization. The other four Chinese research organizations are Tshinghua University, Wuhan University, Nanjing University of Information Science Technology, and Zhejiang University.

Fifth, answering RQ 5, this study shows that National Natural Science Foundation of China plays the most active role in funding the 1,558 articles published in AI and air pollution. The analysis on the top 10 research funding agencies indicated that the number of articles funded by National Natural Science Foundation of China is much more than that of the other research funding agencies. A total number of 294 articles were funded by National Natural Science Foundation of China but the number of articles funded by each of the other nine research funding agencies has been found out to be 45 at maximum.

Sixth, this study reveals that Science of the Total Environment is the journal which published the most of the 1,558 articles in AI and air pollution, answering RQ 6. The analysis on the top 10 journals indicated that a total number of 69 articles were published in it. The number of articles published by each of the other nine journals was revealed to be 55 at most.

Seventh, answering RQ 7, this study shows that He et al. [7], Feng et al. [8], Huang et al. [9], Li et al. [10], Li et al. [11], are the top 5 articles in terms of total citations. The analysis on the top 10 articles in terms of total citations revealed that total citations of the top 5 articles, respectively, are more than 218 but those of the other five articles, respectively, are less than it.

Eighth, this study reveals that English is the most dominant language in the 1,558 articles published in AI and air pollution, answering RQ 8. The analysis on the distribution of them by language showed that a total number of 1,551 articles were written in English, composing the 99.55% of the 1,558 articles in AI and air pollution.

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