atmosphere

Article

Unveiling Trends and Hotspots in Air Pollution Control: A Bibliometric Analysis

Jing Chen [1,*], Qinghai Chen [1], Lin Hu [1], Tingting Yang [2], Chuangjian Yi [1,*] and Yingtang Zhou [3]

[1] School of Economics and Management, Zhejiang Ocean University, Zhoushan 316000, China; chenqinghai@zjou.edu.cn (Q.C.)
[2] CNPC Xibu Drilling Engineering Limited Company, Urumqi 830011, China; yangtingt@cnpc.com.cn
[3] Institute of Innovation & Application, National Engineering Research Center for Marine Aquaculture, Zhejiang Ocean University, Zhoushan 316021, China; zhouyingtang@zjou.edu.cn
* Correspondence: chenjing@zjou.edu.cn (J.C.); cjyi@zjou.edu.cn (C.Y.); Tel.: +86-0580-226-2630 (J.C.)

Abstract: With the continuous acceleration of urbanization, air pollution has become an increasingly serious threat to public health. Strengthening the detection and control of pollutants has become a focal point in current society. In light of the increasing amount of literature in the field of air pollution control with every passing year, numerous reviews have been compiled; however, only a limited number employ bibliometric methods to comprehensively review and summarize research trends in this field. Herein, this study utilizes two bibliometric analysis tools, namely, CiteSpace (6.1.R6) and VOSviewer (1.6.20), to conduct a visual and comprehensive analysis of air pollution literature spanning 2000 to 2023. By doing so, it establishes a knowledge framework for research on air pollution control. Simultaneously, collaborative network analysis, reference co-citation network analysis, keyword co-occurrence network analysis, and keyword prominence are employed to undertake an exhaustive and profound visual examination within this domain. Results indicate that, over time, the number of relevant papers has exponentially increased, while interdisciplinary cooperation trends have gradually formed. Additionally, this study describes key areas of current research, including air pollution control residue treatment, regional joint air pollution control, and air pollution control mechanism analysis. Finally, challenges faced by researchers in this field and their different perspectives are discussed. To better integrate research findings on air pollution control, we explore the correlations among data and systematically present their developmental trends. This confirms the interdisciplinary nature of air pollution control research, in the hope of its guiding air pollution control in the future.

Keywords: bibliometrics; CiteSpace; VOSviewer; air pollution control

Citation: Chen, J.; Chen, Q.; Hu, L.; Yang, T.; Yi, C.; Zhou, Y. Unveiling Trends and Hotspots in Air Pollution Control: A Bibliometric Analysis. *Atmosphere* **2024**, *15*, 630. https://doi.org/10.3390/atmos15060630

Academic Editor: Tao Zhu

Received: 15 April 2024
Revised: 9 May 2024
Accepted: 20 May 2024
Published: 24 May 2024

1. Introduction

With the continuous development of the economy, there is a constant improvement in people's living standards. Currently, humanity is experiencing an era of rapid development where daily life increasingly relies on high-tech and intelligent systems. However, this ongoing progress inevitably escalates the demand for energy and other resources, leading to environmental pollution issues, such as nitrogen oxides (NOx) [1,2], volatile organic compounds (VOCs) [3], sulfur dioxide (SO_2) [4], and heavy metal contamination in both air and water [5]. Research indicates that individuals residing in low socioeconomic areas face higher concentrations of air pollutants [6]. According to a report released by the World Health Organization, over 6000 cities across 117 countries are presently monitoring air quality while accumulating substantial evidence regarding the detrimental impact of air pollution on human health. It has been demonstrated that even minimal levels can cause severe harm [7].

To address this critical challenge, each nation has implemented policies, enacted law, and developed strategies aimed at controlling emissions from their sources of pollution as fundamental advantages for preventing and mitigating air pollution. Enhancing air quality becomes imperative to avoid adverse health consequences. The Clean Air Act in America underwent significant amendments in 1990 to strengthen its authority; in 1997, atmospheric $PM_{2.5}$ standards were established; in 2000, China's National People's Congress passed the Law of the People's Republic of China on Prevention and Control of Air Pollution; and finally, in 2013, the United States issued a Presidential Action Plan to tackle changing weather conditions. Several international initiatives, such as the implementation of the Clean Power Plan in 2015 and active participation in the signing of the Paris Agreement, aim to provide guidance for countries to undertake corresponding measures. Specifically, these measures are aimed at limiting global warming to below 2 °C and effectively mitigating potential risks [8–10].

In China, the Action Plan for Air Pollution Prevention and Control was promulgated in 2013, followed by the release of the Three-year Action Plan for Winning the Battle for Blue Skies in 2018. These comprehensive strategies encompass establishing air quality standards and emission limits, promoting clean energy and production technologies, strengthening control over industrial and transportation emissions, as well as enhancing monitoring and supervision of atmospheric environmental quality. Through these measures mentioned above, it is possible to significantly reduce air pollutant concentrations while minimizing adverse impacts on public health and alleviating associated medical burdens. Furthermore, these actions contribute towards safeguarding ecological systems [11].

The European Union (EU) has issued guidelines concerning air pollutant values, along with agreements related to reducing specific air pollutants, under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) [12]. In the context of local preventive measures against air pollution, the predominant approach often involves prohibiting the use of solid fuels in residential areas and low emission zones (LEZs), as well as implementing vehicle exhaust catalysts (VECs) [13].

Scientific publications within disciplines like atmospheric chemistry typically assume a certain level of expertise from readers, while expert reviews in these fields primarily concentrate on air pollution itself and provide comprehensive policy discussions from a national standpoint [14]. Environmental governance and legal literature generally address environmental regulation holistically, with limited separate discussions on air pollution control policies [15]. Environmental economics studies predominantly offer descriptive background information before delving into individual policy analyses [16]. Air pollution modeling serves as a valuable technique for authorities to enhance planning, decision-making, and strategy development aimed at reducing harmful emissions at local, regional, or even global levels. This modeling primarily employs emissions and meteorological data to estimate and predict pollutant concentrations in the atmosphere, thereby evaluating the effectiveness of air pollution control strategies [17]. The US Environmental Protection Agency (EPA) has developed model compliance testing software—Community Edition (SMAT—CE) along with the Environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP—CE) to assess both health and economic impacts resulting from improved air quality [18].

The number of annual articles and citations related to air pollution control research is an important indicator for understanding the development trends in this field [19]. As depicted in Figure 1, there has been a sharp increase in the number of articles on air pollution control over the past twenty years. It is worth noting that, since 2018, there has been a significant and rapid increase in the number of articles, indicating a continuous increase in academic participation in air pollution control. Webster and Watson argue that reviewing and analyzing previous research projects are considered valuable activities by the academic community because the theoretical and experiential contributions from individual research are crucial for the growth of knowledge and assumptions in the academic field. A literature review is an unbiased summary of accumulated evidence on a specific topic, resulting in strong and broad conclusions. It involves critical and comprehensive evaluation by identifying relationships, contradictions, gaps, and inconsistencies in one or more articles and exploring their causes. Grace et al. conducted a systematic review of air pollution monitoring systems and discussed their advantages and disadvantages [20].

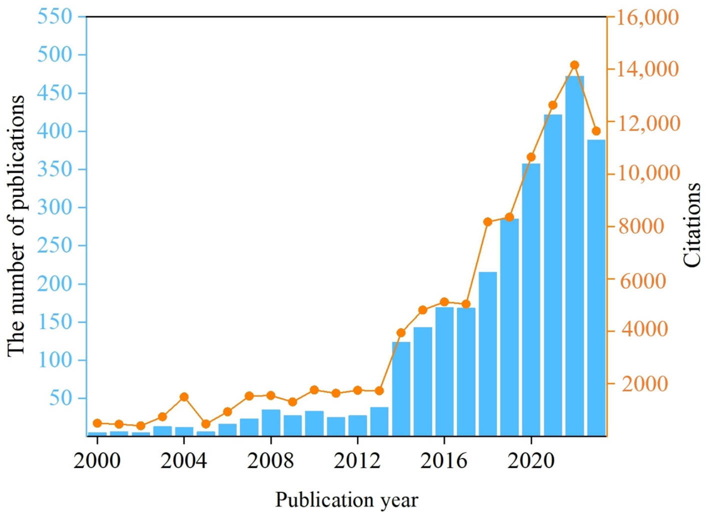


Figure 1. The annual number of publications on air pollution control.

Gulia et al. conducted a systematic review starting from scientific and technological literature on removing pollutants from the surrounding environment [21]. Bibliometrics is a quantitative analysis method that uses mathematical and statistical methods to describe, evaluate, and predict the current status and trends of a certain aspect of research, with the main feature being the outputting of quantifiable information content. Bibliometric analysis helps understand the development trends of air pollution control in the research field, identifies research hotspots and frontiers, and guides selection of future research direction and planning. By analyzing the number of literature citations, journal impact factors, and other relevant indicators, different research qualities and impacts can be evaluated, helping researchers understand the contributions of different research to the academic field [22].

A large number of reviews from multiple perspectives, from technical energy efficiency and system design optimization to policymaking, provide important references for this field [23–26]. Through searching for bibliometric articles, it is found that the discipline in which bibliometric analysis is most applied is medicine, and bibliometrics and citation analysis are popular forms of analyzing medical literature. Zhang Li et al. conducted a visual analysis of artificial blood vessel research based on bibliometrics [27]. In terms of environmental governance, Sharifi et al. used bibliometric analysis to analyze the interaction between climate change and conflict and peace events over the past thirty years [28]. Wu et al. analyzed publications on environmental impact assessment using social network analysis [29]. Although the use of bibliometric analysis to analyze research on environmental pollution control has been increasing year by year, the topic of environmental pollution is vast and broad, and air pollution is one of its main aspects. However, there are currently few reports using bibliometric methods to explore the current trends, topics, and frontier issues in the field of air pollution control.

Bibliometrics is a branch of informatics that involves the quantitative analysis of scientific literature patterns with the aim of understanding new trends and the knowledge base of specific research areas. The use of bibliometric tools allows us to explore the expansion of this field, key contributors, and the interrelationships among various subtopics in an intuitive and analytical manner. Moreover, it emphasizes the evolution of research topics over time, providing deep insights into the development and diversification of the field. In this study, we comprehensively reviewed articles related to air pollution control published on the Web of Science (WOS) from 2000 to 2023 using the scientific metrics methods based on CiteSpace (6.1.R6) and VOSviewer (1.6.20).

The use of CiteSpace and VOSviewer for visual analysis has become an important step in the summary of research hotspots and research frontier analysis, and there are currently 3856 articles using CiteSpace for visual analysis and 3622 articles using VOSviewer for visual analysis through WOS query. It can be seen from the number of published papers that the use of visualization software for bibliometric analysis of different disciplines is very reliable and convenient.

In 2022, an article titled "The Hot Topics, Frontiers and Trends about Research on the Relationship between Air Pollution and Public Health Visual Analysis Based on Knowledge Map" was published in ATMOSPHERE, in which CiteSpace software was used to visually analyze the hot topics, frontiers, and trends of research on the relationship between air pollution and public health. Visual data support is provided for the study of the relationship between air pollution and public health.

Before the bibliometric analysis of air pollution control research, the research question and research objectives were clarified. In order to ensure that the data used were up-to-date and complete, the Web of Science Core Collection was selected as the database for the study, and the data were cleaned to remove duplicates and select the optimal data. According to the research objectives, the method using CiteSpace + VOSviewer was selected for visual analysis. CiteSpace excels at temporal analysis and exploring the evolution of subject areas, while VOSviewer is better suited for constructing co-citation and co-word networks. During the analysis with visualization software, parameters such as time slices, thresholds, etc., were set appropriately to reduce noise and focus on the most important trends and topics. Keyword filtering, author filtering, institutional filtering, etc., were applied appropriately to narrow down the scope of the study. Data from different perspectives (country, publications, etc.) were examined to gain a more complete understanding, and multiple bibliometric metrics (co-citation frequency, centrality, etc.) were considered to increase the depth and breadth of the analysis.

The main research content is divided into four main aspects: (1) categorizing existing literature on air pollution control to determine the research directions and content of the field; (2) understanding the interdisciplinary characteristics of air pollution control; (3) using visual graphs to describe the key knowledge clusters in this field and their evolution over the past twenty years; (4) identifying research hotspots in the field of air pollution control and predicting its development trends. Through the use of bibliometrics to visually analyze research on air pollution control, researchers can gain a concise and clear understanding of the research hotspots and trends in this field.

(1) Visual analysis of the literature can show the contribution of universities and institutions to the sum of human knowledge and help us understand which research institutions' research results are outstanding and widely cited and recognized. Thus, sharing the research of the academic community on a global scale expands the boundaries of human understanding of air pollution control technologies. (2) Bibliometric analysis provides an average field-weighted citation impact (FWCI) score for each institution, which indicates how the number of citations received by the institution's research compares to the average number of citations of all other similar studies, which is helpful in assessing the quality and resonance of the study. (3) Bibliometric analysis can help us understand which studies on air pollution control technologies have been accepted and established by other scholars to guide subsequent research and policy formulation from the same city.

2. Materials and Methods

2.1. CiteSpace

Bibliometrics is a widely employed quantitative analysis method for scientific literature [30]. CiteSpace, an automated science-based software developed by Professor Chen Chaomei, utilizes mathematical and statistical techniques to describe, evaluate, and predict the current state and future trends of science and technology. It facilitates comprehensive analysis of extensive literature collections [31]. The knowledge graph generated by CiteSpace offers a more lucid and intuitive interpretation of the analysis results, thereby greatly assisting researchers in accomplishing diverse objectives [32]. In this study, we utilized CiteSpace to import the collected literature data and conducted keyword cluster analysis to identify prominent research topics while unveiling research focus through keyword network co-occurrence maps. Timeline analysis was employed to track the evolution of research hotspots, whereas word burst analysis enabled tracking of cutting-edge ongoing research.

2.2. VOSviewer

VOSviewer is a software tool designed for constructing and visualizing bibliometric networks, with a primary focus on analyzing and displaying the relationships among literature data, particularly knowledge units. It facilitates the mapping of scientific knowledge by showcasing the interplay between network data, thereby revealing structural correlations, evolutionary patterns, and collaborative efforts within the domain of knowledge. Additionally, VOSviewer offers a comprehensive word filter that computes relevance scores for each noun. This feature enables users to exclude generic terms lacking valuable research significance and conduct co-occurrence analyses solely on words with specific meanings [33].

2.3. Research Process

The research process is illustrated in Figure 2. In the first phase, the data required for the study were collected and the retrieval strategy was determined. In this study, the data from the bibliometric study were extracted from Web of Science Core Collection database. Searches were conducted using the title "air pollution control" for the timeframe from 1 January 2000 to 31 December 2023. According to the requirements of the visualization software CiteSpace and VOSviewer and to ensure the accuracy of the visualization results, the search data were filtered to include only articles, not books, conference papers, or other file types. After eliminating duplicate records in WOS and completing the filtering in the recording process, a total of 3165 relevant documents were obtained. Finally, a bibliometric analysis was performed. The full record of a WOS entry includes author, document type, Web of Science category, keywords, year of publication, publisher, affiliation, country, and index for each article.

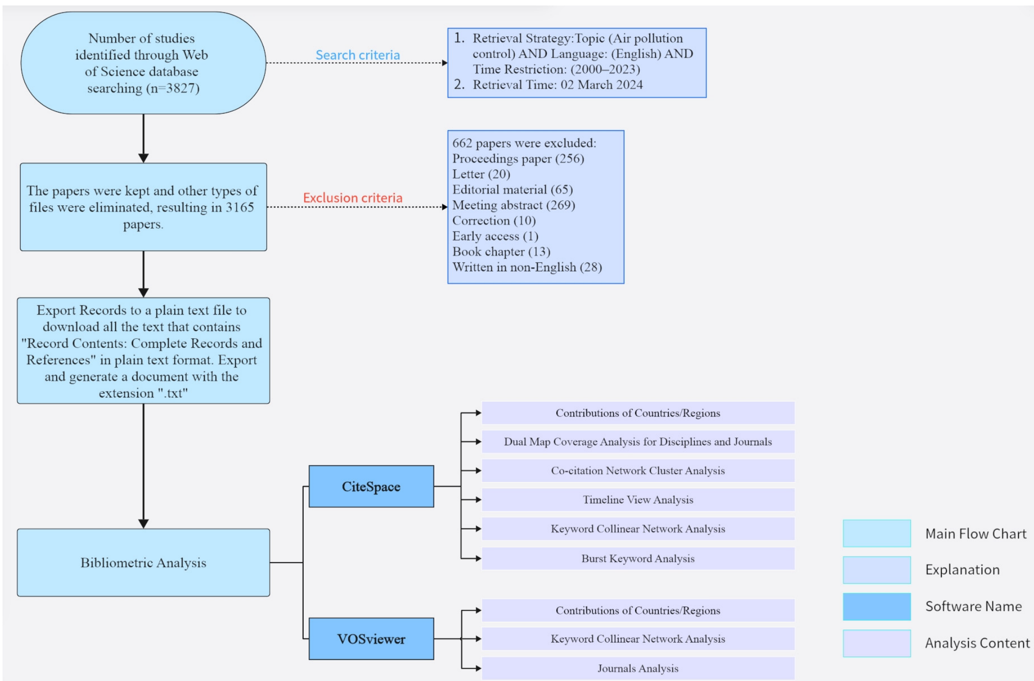


Figure 2. Schematic diagram of research process.

In the second phase, the 3165 articles obtained first underwent "Export Records to Plain Text Files", and all texts containing "Record Contents: Full Records and Cited References" were downloaded in plain text format. Since the number of documents created at a time was $\leq$500, 7 different documents with the extension ".txt" were generated. Then, two different pieces of software were used to generate, visualize, and analyze the bibliometric network.

2.4. Parameter Design and Key Indicator Description

The CiteSpace software and VOSviewer software were employed in this study to visually analyze scientific publications, following the analysis guidelines provided by CiteSpace. In terms of node type selection, we meticulously chose nodes that accurately depicted the network's actual state and aligned with our research objectives. Parameter adjustment plays a crucial role in ensuring result reliability, and the user-friendly interface of CiteSpace facilitates this process. To comprehend the evolution and trends of research topics over time, we adopted the time slice method to chronologically segment the literature into 24 slices spanning January 2000 to December 2023. Regarding node selection, "Top N per slice" is a commonly utilized criterion, where "N" represents items with the highest citations or occurrences selected for each slice to construct the network; only papers meeting threshold requirements are included in the final network.

The network's general structural characteristics can be analyzed through three key indicators. Modularity Q is a community module algorithm that quantifies the extent to which article authors or author organizations are assigned to multiple independent modules and regrouped together [34,35]. Q values range from 0 to 1, with values above 0.3 indicating significant and cohesive network community structures. The contour index is commonly used as an evaluation metric for cluster analysis quality [36], where a value close to 1 indicates good clustering effectiveness, while values exceeding 0.5 suggest reasonable clustering results. Segment centrality measures the importance of a node in connecting other nodes through the shortest paths [32,37]. Nodes with higher centrality play crucial roles in facilitating connections between other nodes within the network's shortest paths. Additionally, CiteSpace employs burst detection techniques to identify sudden changes in subject matter, document citations, author citations, and journal citations. Burst detection is often utilized to identify articles experiencing peak reference counts within a short timeframe or to detect the presence/absence of important links. A rapid increase in paper citations signifies its contribution towards solving major problems within the academic field.

VOSviewer offers three visualization views, namely, network visualization, overlay visualization, and density visualization. In the network visualization view, elements are depicted as circles with labels, where their size is determined by factors such as node strength, link strength, and citation count. The color of elements represents their cluster affiliation; different colors indicate distinct clusters. This view facilitates the examination of individual clusters, the identification of structural distributions of research hotspots through topic co-occurrence analysis, the discovery of research subgroups through author collaboration networks, and the exploration of similarities and differences among scholars' perspectives on research topics via author coupling networks. On the other hand, overlay visualization differs from network visualization in that users can color nodes in the map file using score or color (red, green, blue) fields, depending on their research needs.

By default, average keyword year values are used for color mapping. VOSviewer takes the score value according to the average year of the keyword and the meaning of color mapping, which reflects the degree to which the data of the current month deviate from the mean value of historical data. Specifically, the Z-Score is calculated as follows: relative position = (xt − x)/sdx, where x is the mean of variable x over the last 60 months and sdx is the standard deviation of x over the same period. This indicator is used to measure the degree of deviation between the current month's data and the historical mean so as to display the average year score of different keywords in VOSviewer through color mapping.

Density visualization relies on element density around a point to determine color fill; higher densities appear closer to red, while lower densities tend towards blue. The density is influenced by both the number and importance of surrounding elements. Through the density view option, researchers can swiftly observe significant fields along with knowledge intensity and research activity within specific domains [38,39].

3. Results

3.1. Classification of Literature in the Field of Air Pollution Control

For the classification of literature on air pollution control, we retrieved 3165 documents from the WOS database on the selected keywords in Section 2.3. After categorization, as depicted in Figure 3a, it was observed that the largest number of articles focused on the disposal of air pollution control residues, totaling 1425 articles. This was followed by articles related to regional joint air pollution control, with a total count of 862, while there were also 476 articles analyzing the mechanism of air pollution control. These findings indicate a significant research interest in addressing the disposal of air pollution control residues. In terms of studying air pollution control (Figure 3b), keyword cluster analysis revealed that most papers concentrated on issues associated with incineration of byproducts such as municipal solid waste, bottom ash, heavy metals, and dioxins. These concerns currently represent key areas within air pollution control research.

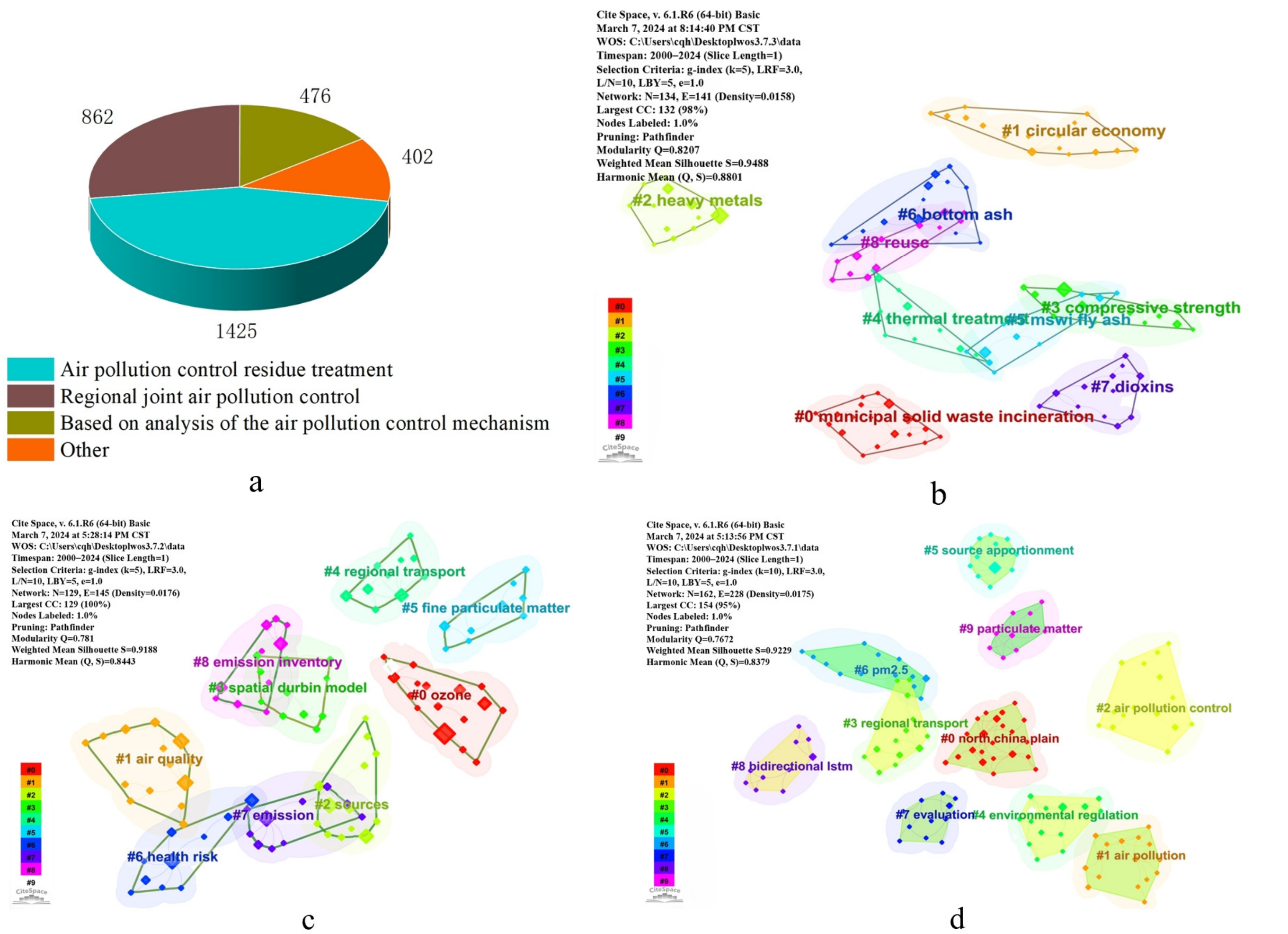


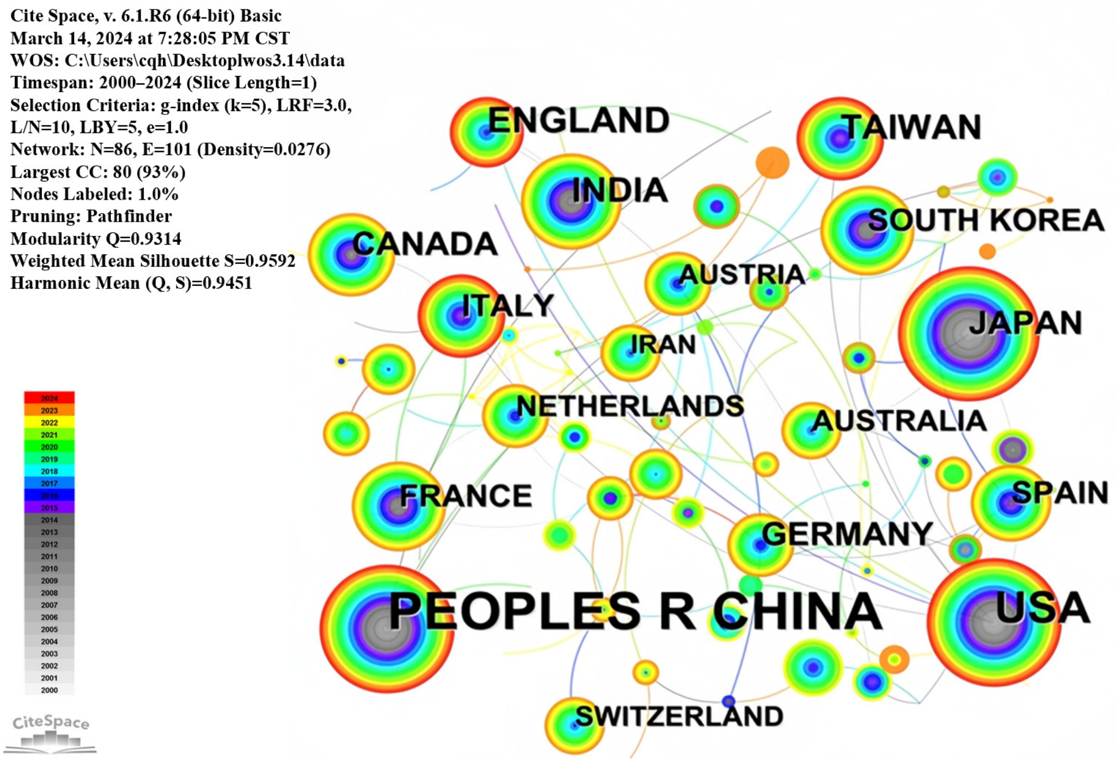
Figure 3. (**a**) Literature classification in the field of air pollution control. (**b**) Clustering analysis of keywords based on residual treatment of air pollution control. (**c**) Clustering analysis of keywords based on regional joint air pollution control. (**d**) Clustering analysis of keywords based on mechanisms of air pollution control.

The situation regarding regional joint air pollution control is illustrated in Figure 3c. According to the visualization map, the keywords "regional transport" and "spatial Durbin model" appear more often. From the summary of the relevant literature, it is found that although the air pollution prevention and control policies and measures in a single place are effectively implemented, the air pollution prevention and control effect is not as expected. By inductive analysis of the literature, the traditional use of sample data models to test the environmental Kuznets curve (ECK) hypothesis is to treat the samples as independent individuals with no interaction, but traditional EKC studies have failed to capture the spillover effects of air pollution, especially for provincial and municipal studies. Later, some scholars began to incorporate spatial effects into EKC studies. The Spatial Durbin model was used to analyze the spatial spillover effect of fine particulate matter concentration in the spatial agglomeration area of air-pollution-intensive industries, and the environmental Kuznets curve (EKC) was verified. Currently, non-cooperative emission reduction models remain dominant but are ineffective and costly due to cross-boundary transport caused by wind propagation effects. To address this issue, experts have proposed a cooperative reduction model aimed at minimizing adverse health effects at minimum cost through encouraging neighboring regions' participation in controlling emissions.

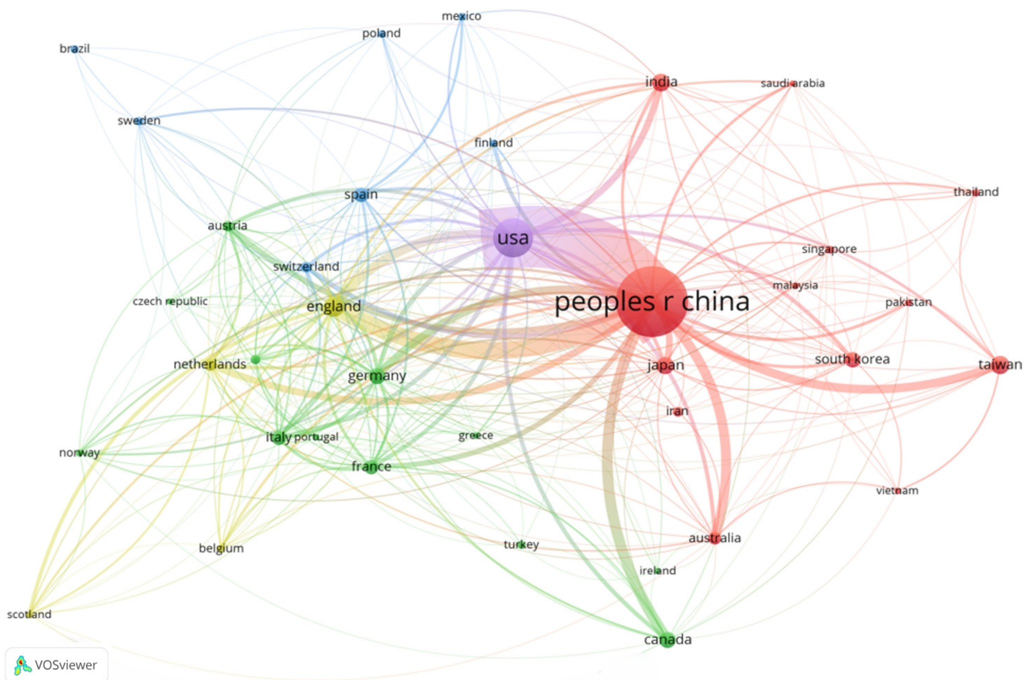
An analysis focusing on the mechanism for recovering clean air is presented in Figure 3d. The air pollution control mechanism refers to the formulation and implementation of a series of measures and policies in response to the problem of air pollution. The keyword "source apportionment" is a technique used to determine the source of air pollutants and the extent to which each source contaminates the quality of the environment. This technology can help policymakers and government agencies develop effective air quality management policies and measures. The keyword "bidirectional lstm" refers to the BiLSTM model, which can be used for air quality prediction, trend analysis, and early warning. This model can more accurately capture the complex relationships in time series data, helping decision-makers better understand the changes in pollutant concentrations and formulate more effective management and remediation strategies. The keyword "environmental regulation" refers to the role of environmental regulation in air pollution control research, which is crucial, through a variety of means, such as regulation formulation, monitoring and evaluation, source control, risk assessment, policy formulation and social participation, in helping manage air quality, maintain the ecological environment, and protect public health. Regarding the keyword "evaluation", assessment is an indispensable part of air pollution control research, which, through the evaluation of data and research results, can guide the formulation of effective air quality management policies and measures and promote environmental protection and human health. The keyword "regional transport" relates to the role of regional transport in air pollution control research, which includes promoting cross-border pollution control, carrying out source analysis and contribution assessment, supporting air quality simulation and prediction, and guiding policy formulation and inter-regional coordination, which is of great significance for effectively responding to regional air pollution. The comprehensive application of these methods and technologies enables the air pollution control mechanism to deal with air quality problems more comprehensively and scientifically, protect public health and the ecological environment, help improve the efficiency and effectiveness of air pollution, and promote continuous improvement of air quality.

3.2. Network Analysis of Common Countries or Regions

According to the CiteSpace analysis, the network of collaborating countries or regions in air pollution control research from 2000 to 2023 comprises 86 nodes and 101 links (refer to Figure 4a). In the VOSviewer analysis, we examined each country individually and set a keyword occurrence threshold of five. The findings revealed that among the total of 90 countries minimum occurrences were observed in 59 (see Figure 4b). Based on the CiteSpace and VOSviewer analyses of country and regional collaboration networks, it can be inferred that China and the United States are leading contributors with significant cooperation between them. Consequently, Table 1 presents the top ten countries and regions contributing most significantly to overall output. In terms of the number of publications, the leading countries and regions are China, the United States, the United Kingdom, Taiwan, India, Japan, Canada, Germany, South Korea, and Spain. China was the leading contributor, with 1880 papers published, well ahead of the second-placed United States (586).



(a)



(b)

Figure 4. (**a**) Visualization of network analysis of country and regional cooperation. (**b**) Co-occurrence network analysis of key control keywords by country and region.

Table 1. Top 10 countries and regions listed by frequency.

Country	Frequency	BC	Country	Frequency	BC
China	1880	0.32	Japan	106	0.13
USA	586	0.30	Canada	105	0.24
England	157	0.19	Germany	93	0.15
Taiwan	124	0.08	South Korea	90	0.11
India	121	0.09	Spain	81	0.12

Between Centrality (BC) is employed to gauge the extent to which a country or region functions as a pivotal bridge or connector within an intricate network of international cooperation. By analyzing the citation relationship network between literatures, the intermediary centrality index can be used to identify the literature or research fields that play an important intermediary role in the academic field so as to help understand the patterns and trends of academic communication and cooperation.

A higher BC value signifies a more prominent role in facilitating connections between diverse countries or regions. As shown in Table 1, the analysis of BC shows that China (0.32), the United States (0.30), the United Kingdom (0.19) and Canada (0.24) have significant cooperation with other countries in air pollution control research and highlights their key role. In addition, in terms of study years in each country, research in China, the United States, the United Kingdom, and Taiwan developed rapidly around 2015.

3.3. Dual-Map Overlay of Disciplines and Journals in Air Pollution Control Research

The dual- map overlay is a bibliometric visualization technique employed to unveil the interconnections among various scientific fields or disciplines [40]. As depicted in Figure 5, the findings demonstrate the interdisciplinary nature of air pollution control research. The left diagram illustrates the clustering of cited journals representing cutting-edge knowledge, while the right diagram showcases clusters of journals associated with fundamental research. Journal clusters from diverse disciplines are distinguished by different colors and clustered using CiteSpace's LLR algorithm [41]. For instance, in the left diagram, physics and materials chemistry form a cluster encompassing physics, materials, and chemistry-related journals. The undulating line depicts the changing trend in the degree of close correlation between air pollution control research topics across multiple disciplines within the dual-map superposition. The thickness of the line indicates the proximity of the connection. As depicted in Figure 5, eight primary reference lines, comprising two pink lines, five yellow lines, and one blue line, visually illustrate the interdisciplinary connections among various disciplines within air pollution control research. Evidently, Subject 3 (ecology, Earth, ocean), Subject 5 (physics, materials, chemistry), and Subject 7 (veterinary, animal science) emerge as dominant areas in the cited journals. This is attributed to the fact that literature pertaining to air pollution control is predominantly published in journals focusing on ecology, earth sciences, chemistry, and general science. The cited journals are primarily distributed across Discipline 2 (Environmental Sciences; Toxicology and Nutrition), Discipline 4 (Chemistry; Materials; Physics), Discipline 7 (Psychology; Education; Sociology), and Discipline 8 (Molecular Biology; Dynamics). This signifies that publications within this field frequently cite physics-oriented literature along with chemistry-related studies encompassing materials science aspects. Furthermore, the inclusion of environmental science research articles highlights a comprehensive approach towards air pollution control.

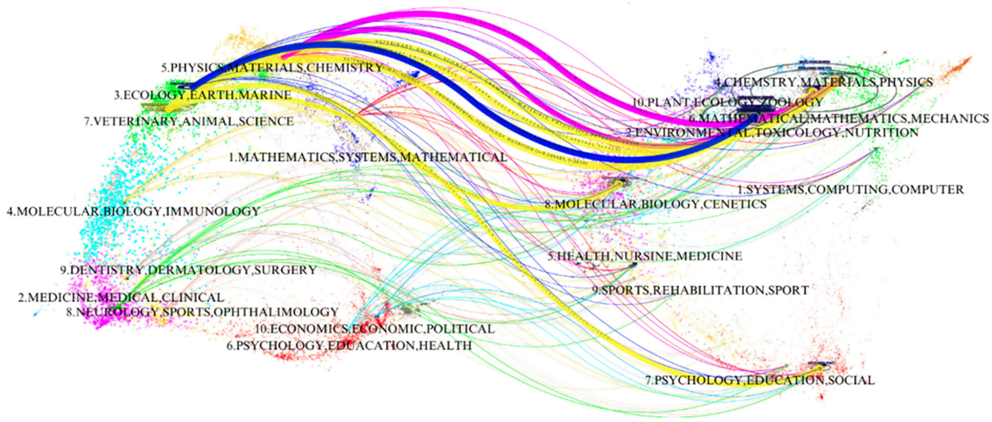


Figure 5. Dual-map overlay of disciplines and journals in air pollution control research.

3.4. Journals

According to the VOSviewer analysis, journal publication status is illustrated in Figure 6. As depicted in Table 2, the top 10 journals accounted for 46.504% of the total literature pertaining to air pollution control research. SCIENCE OF THE TOTAL ENVIRONMENT ranked first with 368 articles, representing 11.627%. This was followed by JOURNAL OF CLEANER PRODUCTION and ATMOSPHERIC ENVIRONMENT with 236 and 221 publications, respectively, accounting for 7.456% and 6.982%. In fourth and fifth positions were ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH and ATMOSPHERIC CHEMISTRY AND PHYSICS, contributing 151 and 138 articles, respectively, corresponding to proportions of 4.77% and 4.36%. Additionally, each journal ranked between sixth and tenth published over sixty articles, including ENVIRONMENTAL POLLUTION, INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH, SUSTAINABILITY, ENVIRONMENTAL SCIENCE & TECHNOLOGY, and ATMOSPHERE. According to the ranking results, the journals that publish more papers in the field of air pollution control are mainly concentrated in environmental science, engineering, atmospheric science, and chemistry, which aligns well with the discipline analysis findings.

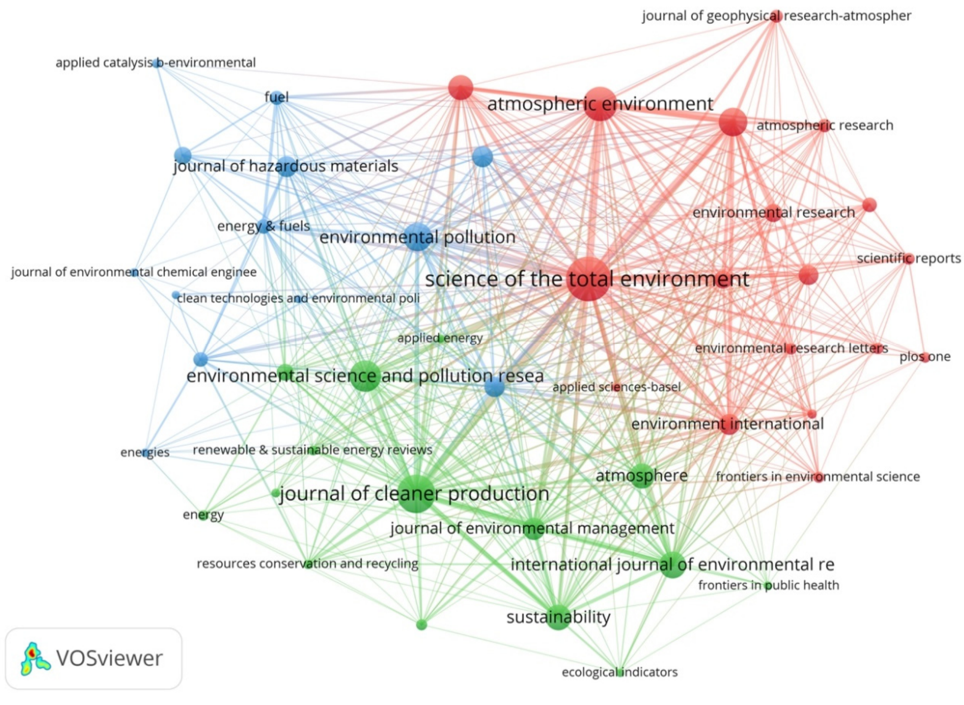


Figure 6. Analysis of journal publication status.

Table 2. Top ten journals with the most publications related to air pollution control.

Journals	Publication Numbers	Rate%
Science of the Total Environment	368	11.627%
Journal of Cleaner Production	236	7.456%
Atmospheric Environment	221	6.982%
Environmental Science and Pollution Research	151	4.770%
Atmospheric Chemistry and Physics	138	4.360%
Environmental Pollution	92	2.906%
International Journal of Environmental Research and Public Health	71	2.243%
Sustainability	66	2.085%
Environmental Science & Technology	65	2.053%
Atmosphere	64	2.022%

3.5. Co-Citation Network Analysis of References

Reference co-citation involves the simultaneous citation of multiple studies in a single paper to demonstrate the correlation and interconnectedness between these works [42]. In co-citation clustering analysis, CiteSpace uses the spectral clustering method to cluster keywords, clustering closely related keywords together to form different clusters. Each cluster represents a research topic or direction. By analyzing the number and size of clusters, we can understand research hotspots and trends in subject areas.

This analytical approach aids in uncovering underlying knowledge structures and emerging trends within the academic domain. CiteSpace utilizes threshold levels to filter data and identify the most significant networks within each time slice. Figure 7 illustrates the results of visual pruning using "Pathfinder" and "Pruning networks", with "reference" selected as the node type, a one-year time slice, and dg-index (k = 5). A noun phrase is extracted from the article keyword list (k) as a clustering label based on log-likelihood ratio (LLR) function. Table 3 presents cluster characteristics, while Figure 6 displays the clustering view of the co-citation network. Notably, this figure exhibits a modularity value of 0.8674, surpassing the set threshold of 0.3, indicating a strong fit. Furthermore, the top 10 clusters identified in the study on air pollution control encompassed various aspects, such as clean air (#0), $PM_{2.5}$ concentration (#1), diesel emissions (#2), an air quality prediction model system (#3), mercury salt (#4), IMED model (#5), argon–oxygen decarbonization (#6), health benefits (#7), Global Land actual EvAPOtranspiration dataset (#8), and meteorological conditions (#9). Specifically, Cluster 3 (air quality prediction model system), Cluster 5 (IMED model), and Cluster 8 (Global Land EvAPOtranspiration dataset) were found to be closely associated with the analysis of mechanisms for controlling air pollution [43–45]. In terms of regional integrated air pollution control strategies, Cluster 0 (clean air), Cluster 1 ($PM_{2.5}$ concentration), and Cluster 9 (meteorological conditions) were considered [46–50]. For the treatment of residues from air pollution control measures, involvement was observed in Cluster 2 (diesel emissions), Cluster 4 (mercury salts), and Cluster 6 (argon–oxygen decarbonization) [51–55].

The keyword timeline depicted in Figure 8 is utilized to depict the primary research content of a specific research topic over time, showcasing the research trend within a given timeframe. In the timeline view, by showing keywords and clusters at different points in time, you can reveal research trends in subject areas. By analyzing the timeline view, we can observe the evolution of research topics as well as the emergence and disappearance of emerging topics.

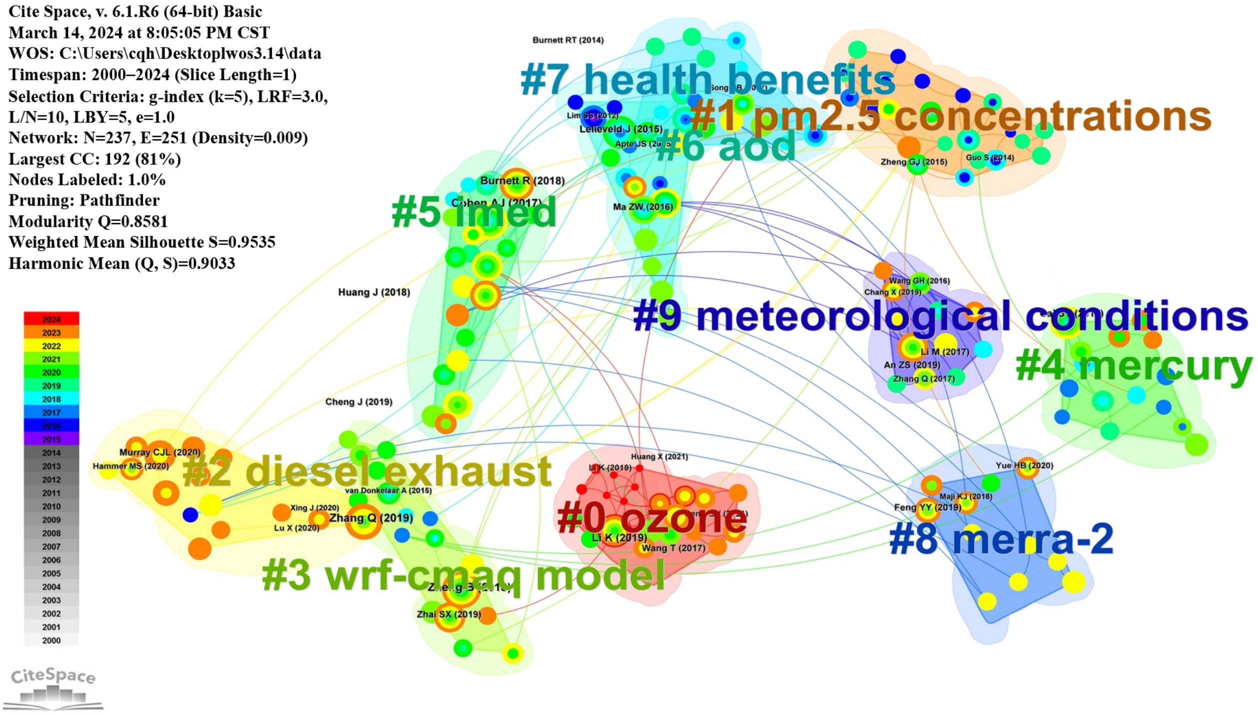


Figure 7. Cluster view of co-citation network analysis in air pollution control research.

Table 3. Cluster information for co-citation network analysis of literature related to air pollution control.

Cluster No.	Size	Silhouette	Mean (Year)	Cluster LLR
#0	38	0.964	2019	Ozone
#1	35	0.95	2013	$PM_{2.5}$ concentrations
#2	32	0.973	2020	Diesel exhaust
#3	28	0.983	2017	Wrf–cmaq model
#4	25	0.956	2014	Mercury
#5	22	0.938	2015	Imed
#6	18	0.879	2017	Aod
#7	16	0.94	2015	Health benefits
#8	15	0.96	2018	Merra-2
#9	13	0.976	2017	Meteorological conditions

The timeline view exhibits a strong correlation with both the keyword cluster graph and keyword emergence graph. The labels on the keyword timeline diagram represent the main names of each keyword cluster, while the keywords corresponding to each period are arranged chronologically to the left of their respective label names. CiteSpace software is employed to generate annual time slices for constructing these keyword timeline graphs. From a temporal perspective, during the initial stages of air pollution control, emphasis was placed on $PM_{2.5}$ research; however, as time progressed, scholars began shifting their focus towards trans-regional joint air pollution control [56–58]. Furthermore, various system models, such as air quality prediction model systems, IMED models, and Global Land actual EvAPOtranspiration datasets have been extensively applied in economic, energy, environmental, and climate policy analyses. These models provide scientific support for relevant decision-making processes [59].As urbanization accelerates, municipal solid waste continues to increase. Incineration represents one common method for disposing of municipal solid waste; nevertheless, concerns arise regarding air pollution control residues generated from incineration practices. Consequently, addressing these residues has become an important issue that experts and scholars aim to explore further [60–62].

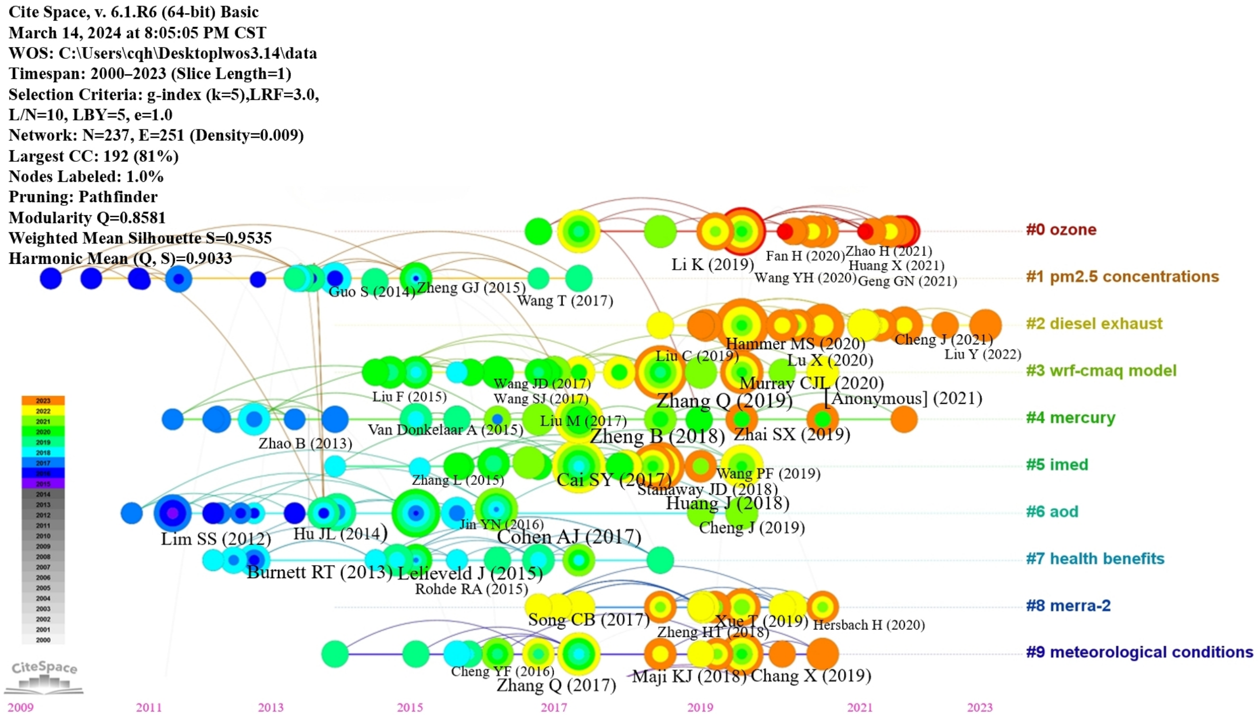


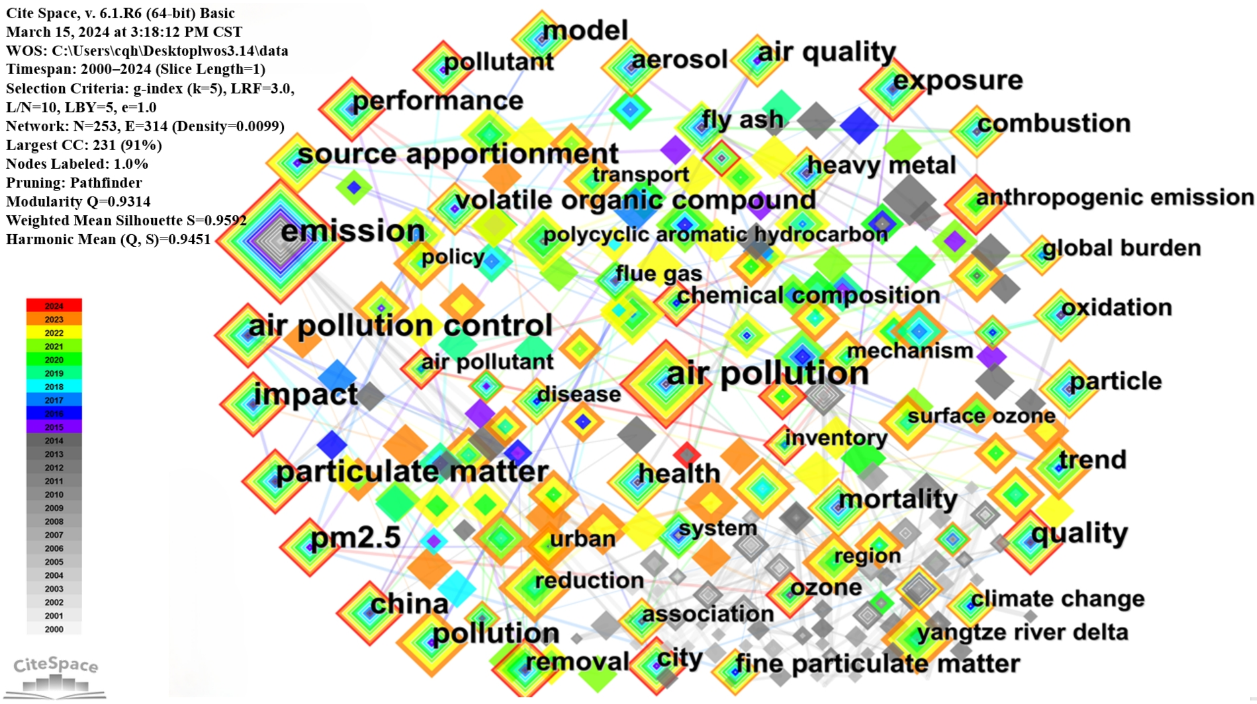
Figure 8. Timeline of co-citation reference clusters (2000–2023).

3.6. Keyword Co-Occurrence Network Analysis

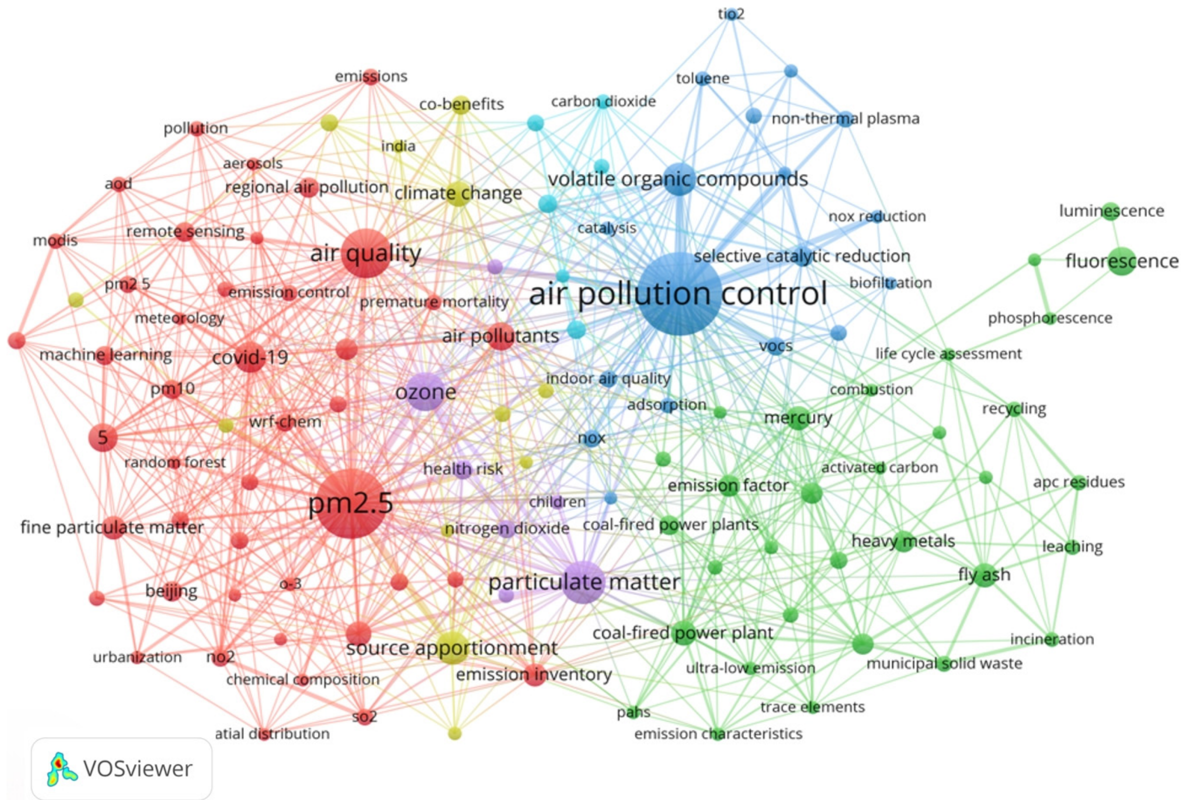
3.6.1. Analysis of Keyword Co-Occurrence Frequencies

The visualizations presented in Figure 9a,b, generated by CiteSpace and VOSviewer, demonstrate the interdependence of keyword research. Through keyword co-occurrence analysis, by counting the frequency of co-occurrence of keywords in the literature, the degree of association between different keywords can be revealed. When two keywords appear frequently in the same literature, it indicates that there is a strong correlation between them, which may represent a research topic or direction. This analysis method can help us quickly identify research hotspots in subject areas.

In CiteSpace, we selected "Keyword" as the node type and described nodes as keywords with lines representing their symbiotic relationship. The size of the year ring node is proportional to the frequency of keyword occurrence. The color gradient of nodes from center to edge represents changes in study keywords over time, where each time slice equals one year and g index (k) is set at five. Conversely, in VOSviewer, we chose "Co-occurrence" analysis for "Author Keywords". We set a minimum frequency threshold at seven; out of 8322 keywords analyzed, only 190 met this criterion (see Table 4 for details of the top ten high-frequency keywords). Among them, "air pollution", which appears a total of 860 times as the core theme of this study, was most frequent. Other prominent terms include "emission", "air pollution control", "impact", "particulate matter", "$PM_{2.5}$", "quality", "source apportionment", "pollution", and "model". Regarding centrality among mapping structures, "air pollution control" has highest centrality (0.29), followed by $PM_{2.5}$ (0.23), "air quality" (0.18), "particulate matter" (0.17), "ozone" (0.11), and "model" (0.11). These keywords play significant roles within relevant nodes. Through timeline and keyword analyses, it can be concluded that current research on air pollution control primarily focuses on controlling pollutant emissions at their sources while using system models to quantitatively analyze economic, energy, environmental, and climate policies to provide scientific support for relevant decisions.



(**a**)



(**b**)

Figure 9. (**a**) Co-occurrence network analysis of keywords related to air pollution control. (**b**) Layout of keyword co-occurrence research hotspots.

Table 4. Top ten high-frequency keywords in air pollution control research.

NO	Keywords	Frequency	Centrality
1	air pollution	860	0.13
2	emission	373	0.11
3	air pollution control	343	0.29
4	impact	330	0.11
5	particulate matter	325	0.17
6	$PM_{2.5}$	270	0.23
7	air quality	239	0.18
8	ozone	236	0.11
9	source apportionment	211	0.13
10	model	185	0.11

3.6.2. Analysis of Burst Keywords

Utilization of CiteSpace to conduct a burst analysis of keywords in the field of air pollution control research unveils emerging trends, prominent topics, and significant events or research subjects within specific academic domains. The burst detection feature is used to identify research topics that have received sudden attention in a short period of time. Burst detection can help us catch unexpected events or important developments in a subject area. The extent of the red portion represents the duration of the burst.

In the forefront of air pollution control research, we have identified 10 significant keywords, as presented in Table 5. These encompass "emissions", "chemistry", "spatial and temporal patterns", "dielectric barrier discharge", "fly ash", "dibenzo-p-dioxins", "non-thermal plasma", "gaseous ammonia", "environmental regulation", and "anthropogenic emissions". The terms "emissions" and "chemistry" exhibited substantial bursts between 2003 and 2015. Since Professor Tang Xiaoyan first introduced the concept of the "air pollution complex" in 1997, atmospheric chemistry research in China has experienced remarkable progress and thrived over the past 25 years [63–65].

Table 5. Top 10 keywords with the strongest citation bursts in air pollution control research.

Keywords	Year	Strength	Begin	End	2000–2023
Emission	2003	12.16	2003	2015	
Chemistry	2003	9.31	2003	2015	
Speciation	2014	7.94	2014	2019	
Dielectric barrier discharge	2014	6.89	2014	2019	
Fly ash	2013	14.52	2013	2018	
Dibenzo-p-dioxin	2014	6.55	2014	2019	
Nonthermal plasma	2015	6.63	2015	2019	
NH_3	2022	7.57	2022	2023	
Environmental regulation	2022	7.33	2022	2023	
Anthropogenic emission	2019	8.4	2022	2023	

The keywords "fly ash", "dibenzo-p-dioxins", and "non-thermal plasma" have exhibited significant exponential growth between 2014 and 2020. Emissions resulting from the incomplete combustion of fossil fuels have severely contaminated the environment. As an industrial waste, fly ash can give rise to various environmental issues if released into the atmosphere. However, extensive research conducted by experts and scholars has revealed that due to its unique characteristics, such as high porosity and large specific surface area [50,66], fly ash can serve as a cost-effective and efficient adsorbent for treating environmental pollutants. Moreover, some scholars have utilized nanofiber technology to fabricate multifunctional composite materials incorporating fly ash in order to mitigate air and water pollution, demonstrating promising future prospects [67]. The presence of volatile organic compounds (VOCs), specifically polychlorinated dibenzo-p-dioxins, in solid waste incineration facilities poses hazards to both human health and the environment. To eliminate these organic compounds, non-thermal plasma (NTP) has emerged as a successful technology choice capable of effectively converting VOCs even at low concentrations. Experimental results indicate that combining NTP with a catalytic system for VOC conversion represents a truly sustainable approach with considerable potential for the future [68].

Between 2014 and 2019, studies on air pollution control have highlighted the significance of understanding the spatiotemporal patterns of outbreaks for comprehending their transmission mechanisms and formulating effective environmental policies. By quantifying spatial patterns and movements of air pollution at annual, daily, and hourly scales, it becomes possible to gain a better insight into potential driving factors [69–71].

The phenomenon of dielectric barrier discharge emerged between 2014 and 2019, while the combustion process accounts for approximately 80% of the energy utilized in our daily lives and industrial production. However, conventional combustion technologies suffer from low-efficiency issues, resulting in energy wastage and severe environmental pollution. To address this challenge and enhance combustion efficiency, experts and scholars have proposed a non-equilibrium plasma-assisted combustion method based on dielectric barrier discharge [24,72].

The significance of gaseous ammonia production, along with $PM_{2.5}$ and its combination with acidic gases to form ammonium salts, in contributing to regional and global air pollution has only been acknowledged since 2020. Several studies have demonstrated that controlling gaseous ammonia emissions can effectively enhance urban air quality. However, due to variations in techniques and detection methods, uncertainties exist in the observation results. Therefore, accurately and comprehensively evaluating the temporal and spatial characteristics of gaseous ammonia has become a highly prioritized topic within the field of ecological environment [73–75].

Air pollution is a critical bottleneck that hampers economic and social development, with man-made emissions persisting since 2022. Addressing this pollution issue through effective environmental regulations has become a pivotal research topic of interest to both academia and government circles [76–78].

4. Conclusions

Based on CiteSpace and VOSviewer knowledge graph tools, we conducted a comprehensive analysis of air pollution control research and built a comprehensive knowledge framework for the field. This analysis draws several important conclusions: (1) Air pollution control research is mainly concentrated in China, the United States, Taiwan, Canada, and European countries. It is worth noting that China is at the forefront of global progress in this field, with its rich research output and excellent research institutions. (2) From the perspective of disciplinary distribution, air pollution control has become an interdisciplinary study, mainly involving six fields: chemistry, physics, environmental science, materials science, toxicology, and sociology. Its interdisciplinary nature enables it to achieve multiple uses and significant advances in multiple directions. (3) Cluster analysis of keywords used in literature references and publications shows that there are different stages in the field of air pollution control, from how to solve emissions problems to using system models to quantitatively analyze economic, energy, environmental, and climate policies to support relevant decisions. Keyword co-occurrence network analysis visualizes the research focus of air pollution control, which mainly includes source control of emissions, reduction of harmful emissions, and use of system models to forecast air pollution in order to take effective control measures.

According to the identified research hotspots and trends, (1) CiteSpace and VOSviewer provide a comprehensive analysis and visualization of academic literature, and researchers can quickly understand the latest research trends and research priorities through functions such as hotspot analysis and citation network. This helps researchers better position their research areas and find partners within the field, discover new research questions, and increase their academic impact. (2) By analyzing the research hotspots and trends in the field of air pollution control, policymakers can better understand the development direction and key issues in the field so as to formulate more scientific and reasonable policies and measures to deal with air pollution. They can guide the formulation and implementation of policies based on the conclusions and recommendations of academic research and promote environmental protection and improvement. (3) For practitioners involved in air pollution control, the analysis results of CiteSpace and VOSviewer can help them understand the latest technologies and methods and grasp the cutting-edge knowledge and development trends of the industry. This helps them improve their professional skills, improve their working methods, better respond to air pollution, and protect the environment and human health.

5. Perspectives

In recent years, there has been an exponential increase in research on air pollution control globally, reflecting a growing concern for addressing air quality issues. This trend is not only a response to the increasingly severe environmental conditions but also the result of continued efforts by governments and organizations worldwide to formulate and implement air quality management measures. With rapid urbanization and industrialization, the impact of air pollution on human health and the environment has become more severe, making monitoring and controlling air quality increasingly important. This trend not only reflects the urgent need for clean air among the public but also promotes global research cooperation and exchange on air pollution control, laying a foundation for future environmental protection and sustainable development. Although aspects of air pollution control are current research hotspots, there are still some challenges to overcome.

Firstly, the need to strengthen interdisciplinary cooperation: research on air pollution control is increasingly involving multiple disciplines such as chemistry, environmental science, and engineering. This interdisciplinary collaboration promotes innovation and the development of diverse solutions. Collaboration among experts and researchers from different disciplines has driven continuous advancements in air pollution control technology. The interdisciplinary collaboration in fields such as chemistry, environmental science, and engineering provides diverse perspectives and methods for research, helping to address complex air pollution problems. This collaboration not only promotes the development of the research field but also provides new ideas and directions for future environmental protection and sustainable development.

Secondly, development of research methods: through bibliometric analysis, several research hotspots in the field of air pollution control have been identified, including new pollution control technologies, air quality monitoring and evaluation methods, and others. These research hotspots provide important references for future research directions. Research and application of new pollution control technologies can improve air quality and reduce environmental pollution. The continuous improvement of air quality monitoring and evaluation methods can provide a more accurate understanding of the sources and distribution of air pollution, providing a scientific basis for the formulation of effective air quality management policies. The development of these research hotspots will drive progress in the field of air pollution control and provide new ideas and methods for solving air quality problems.

Thirdly, enhancing the research mechanism on atmospheric oxidation and aerosol formation for pollution control: it is imperative to enhance research on the mechanisms underlying atmospheric strong oxidation, the formation and growth of secondary aerosols, as well as the interaction between cross-regional pollutant transport and weather/climate phenomena. Emphasis should be placed on collaborative measures for $PM_{2.5}$ and NH_3 control, breakthroughs in quantitatively characterizing atmospheric oxidation processes driving air pollution formation, and the establishment of a high-resolution emission inventory database capable of accommodating global, regional, and urban multi-scale coupling.

Despite significant progress, air pollution control still faces many challenges, such as technological costs, policy formulation, and implementation. Future research needs to focus on these challenges and propose innovative solutions. Technological costs are an important challenge for air pollution control, so it is necessary to continuously improve the efficiency of technology and reduce costs, and promote clean energy and environmental protection technologies. In summary, the field of global research on air pollution control is currently witnessing exponential growth, which reflects the increasing concerns regarding air quality management. This emerging trend is fostering interdisciplinary collaboration, driving the development of diverse solutions, and highlighting crucial areas for future exploration in research.

Author Contributions: Conceptualization, C.Y.; Methodology, Q.C., L.H., T.Y. and C.Y.; Software, Q.C., L.H. and T.Y.; Validation, J.C. and C.Y.; Formal analysis, Q.C., L.H. and T.Y.; Investigation, Q.C., L.H. and T.Y.; Data curation, Q.C., L.H. and T.Y.; Writing—original draft, J.C. and C.Y.; Writing—review & editing, J.C. and Y.Z.; Supervision, J.C., C.Y. and Y.Z.; Project administration, C.Y.; Funding acquisition, Y.Z. All authors have read and agreed to the published version of the manuscript.

Funding: Zhejiang Province Basic Research Project of Provincial Colleges and Universities: 2021R004.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data will offer by email to correspondence author.

Conflicts of Interest: Tingting Yang is employee of CNPC Xibu Drilling Engineering Limited Company, Xinjiang Province, China. The company had no roles in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, or in the decision to publish the articles. The paper reflects the views of the scientists and not the company.

References

1. Chen, M.; Zhang, H.; Li, H.; Zhao, Z.; Wang, K.; Zhou, Y.; Zhao, X.; Dubal, D.P. CxNy-based materials as gas sensors: Structure, performance, mechanism and perspective. *Coord. Chem. Rev.* **2024**, *503*, 215653. [CrossRef]
2. Zhang, H.; Wang, H.; Cao, X.; Chen, M.; Liu, Y.; Zhou, Y.; Huang, M.; Xia, L.; Wang, Y.; Li, T.; et al. Unveiling Cutting-Edge Developments in Electrocatalytic Nitrate-to-Ammonia Conversion. *Adv. Mater.* **2024**, *36*, e2312746. [CrossRef]
3. Sun, M.; Chen, M.; Cui, X.; Zhao, Z.; Wang, J.; Liang, L.; Zhou, Y. Unveiling the gas sensing potential of CxNy monolayer through ab initio screening. *Surf. Interfaces* **2023**, *42*, 103313. [CrossRef]
4. Giles, L.V.; Koehle, M.S. The Health Effects of Exercising in Air Pollution. *Sports Med.* **2014**, *44*, 223–249. [CrossRef] [PubMed]
5. Chen, M.S.; Wang, H.J.; Wang, J.H.; Sun, M.Y.Z.; Hu, Y.X.; Zhao, X.; Zhou, Y.T. Efficient degradation of formaldehyde based on DFT-screened metal-doped C_3N_6 monolayer photocatalysts: Performance evaluation and mechanistic insights. *Phys. Chem. Chem. Phys.* **2023**, *25*, 25353–25360. [CrossRef] [PubMed]
6. Chi, G.C.; Hajat, A.; Bird, C.E.; Cullen, M.R.; Griffin, B.A.; Miller, K.A.; Shih, R.A.; Stefanick, M.L.; Vedal, S.; Whitsel, E.A.; et al. Individual and Neighborhood Socioeconomic Status and the Association between Air Pollution and Cardiovascular Disease. *Environ. Health Perspect.* **2016**, *124*, 1840–1847. [CrossRef]
7. Li, S.J.; Hu, S.W.; Jiang, W.; Liu, Y.; Liu, Y.P.; Zhou, Y.T.; Mo, L.Y.; Liu, J.S. Ag_3VO_4 Nanoparticles Decorated $Bi_2O_2CO_3$ Micro-Flowers: An Efficient Visible-Light-Driven Photocatalyst for the Removal of Toxic Contaminants. *Front. Chem.* **2018**, *6*, 255. [CrossRef] [PubMed]
8. Rogelj, J.; den Elzen, M.; Höhne, N.; Fransen, T.; Fekete, H.; Winkler, H.; Chaeffer, R.S.; Ha, F.; Riahi, K.; Meinshausen, M. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature* **2016**, *534*, 631–639. [CrossRef]
9. Arcos-Vargas, A. After the Paris Agreement. *Dyna* **2017**, *92*, 12–14. [CrossRef]
10. Chen, J.; Gui, P.F.; Ding, T.; Na, S.Y.; Zhou, Y.T. Optimization of Transportation Routing Problem for Fresh Food by Improved Ant Colony Algorithm Based on Tabu Search. *Sustainability* **2019**, *11*, 6584. [CrossRef]
11. Feng, Y.Y.; Ning, M.; Lei, Y.; Sun, Y.M.; Liu, W.; Wang, J.N. Defending blue sky in China: Effectiveness of the "Air Pollution Prevention and Control Action Plan" on air quality improvements from 2013 to 2017. *J. Environ. Manag.* **2019**, *252*, 109603. [CrossRef] [PubMed]
12. Davuliene, L.; Jasineviciene, D.; Garbariene, I.; Andriejauskiene, J.; Ulevicius, V.; Bycenkiene, S. Long-term air pollution trend analysis in the South-eastern Baltic region, 1981–2017. *Atmos. Res.* **2021**, *247*, 105191. [CrossRef]
13. Hamer, P.D.; Walker, S.E.; Sousa-Santos, G.; Vogt, M.; Vo-Thanh, D.; Lopez-Aparicio, S.; Schneider, P.; Ramacher, M.O.P.; Karl, M. The urban dispersion model EPISODE v10.0-Part 1: An Eulerian and sub-grid-scale air quality model and its application in Nordic winter conditions. *Geosci. Model Dev.* **2020**, *13*, 4323–4353. [CrossRef]
14. Liu, W.L.; Xu, Z.P.; Yang, T.N. Health Effects of Air Pollution in China. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1471. [CrossRef]

15. Young, O.R.; Guttman, D.; Qi, Y.; Bachus, K.; Belis, D.; Cheng, H.G.; Lin, A.; Schreifels, J.; Van Eynde, S.; Wang, Y.H.; et al. Institutionalized governance processes Comparing environmental problem solving in China and the United States. *Glob. Environ. Chang. Hum. Policy Dimens.* **2015**, *31*, 163–173. [CrossRef]
16. Mao, X.Q.; Zhou, J.; Corsetti, G. How Well Have China's Recent Five-Year Plans Been Implemented for Energy Conservation and Air Pollution Control? *Environ. Sci. Technol.* **2014**, *48*, 10036–10044. [CrossRef]
17. Jeldes, N.; Ibacache-Pulgar, G.; Marchant, C.; López-Gonzales, J.L. Modeling Air Pollution Using Partially Varying Coefficient Models with Heavy Tails. *Mathematics* **2022**, *10*, 3677. [CrossRef]
18. Qiu, X.Z.; Zhu, Y.; Jang, C.; Lin, C.J.; Wang, S.X.; Fu, J.; Xie, J.P.; Wang, J.D.; Ding, D.A.; Long, S.C. Development of an integrated policy making tool for assessing air quality and human health benefits of air pollution control. *Front. Environ. Sci. Eng.* **2015**, *9*, 1056–1065. [CrossRef]
19. Luo, X.Z.; Abazari, R.; Tahir, M.; Fan, W.K.; Kumar, A.; Kalhorizadeh, T.; Kirillov, A.M.; Amani-Ghadim, A.R.; Chen, J.; Zhou, Y.T. Trimetallic metal-organic frameworks and derived materials for environmental remediation and electrochemical energy storage and conversion. *Coord. Chem. Rev.* **2022**, *461*, 214505. [CrossRef]
20. Grace, R.K.; Manju, S. A Comprehensive Review of Wireless Sensor Networks Based Air Pollution Monitoring Systems. *Wirel. Pers. Commun.* **2019**, *108*, 2499–2515. [CrossRef]
21. Gulia, S.; Tiwari, R.; Mendiratta, S.; Kaur, S.; Goyal, S.K.; Kumar, R. Review of scientific technology-based solutions for vehicular pollution control. *Clean Technol. Environ. Policy* **2020**, *22*, 1955–1966. [CrossRef]
22. Chen, J.; Hu, L.; Chen, Q.; Yang, T.; Yi, C. Hotspots and trends in solar-driven interfacial evaporation technology based on bibliometric management and analysis. *Surf. Interfaces* **2024**, *46*, 104184. [CrossRef]
23. Dias-Ferreira, C.; Kirkelund, G.M.; Jensen, P.E. The influence of electrodialytic remediation on dioxin (PCDD/PCDF) levels in fly ash and air pollution control residues. *Chemosphere* **2016**, *148*, 380–387. [CrossRef]
24. Li, Y.; Niu, G.; Wang, X.; Tang, J.; Duan, Y. Effects of Air/H_2O Discharge Plasma on Propane Combustion Enhancement Using Dielectric Barrier Discharges. *Plasma Chem. Plasma Process.* **2018**, *38*, 831–850. [CrossRef]
25. Jafari, A.J.; Charkhloo, E.; Pasalari, H. Urban air pollution control policies and strategies: A systematic review. *J. Environ. Health Sci. Eng.* **2021**, *19*, 1911–1940. [CrossRef] [PubMed]
26. Liu, X.Y.; Guo, C.Y.; Wu, Y.Z.; Huang, C.; Lu, K.D.; Zhang, Y.H.; Duan, L.; Cheng, M.M.; Chai, F.H.; Mei, F.Q.; et al. Evaluating cost and benefit of air pollution control policies in China: A systematic review. *J. Environ. Sci.* **2023**, *123*, 140–155. [CrossRef]
27. Zhang, L.; Feng, Y.K. Bibliometrics and visualization analysis of artificial blood vessel research. *Curr. Sci.* **2014**, *106*, 816–822.
28. Sharifi, A.; Simangan, D.; Kaneko, S. Three decades of research on climate change and peace: A bibliometrics analysis. *Sustain. Sci.* **2021**, *16*, 1079–1095. [CrossRef]
29. Wu, D.S.; Wang, S.Y. Environment damage assessment: A literature review using social network analysis. *Hum. Ecol. Risk Assess.* **2018**, *24*, 904–924. [CrossRef]
30. Schubert, A. Handbook Bibliometrics. *Scientometrics* **2021**, *126*, 5379–5385. [CrossRef]
31. Chen, C. Information visualization. *WIREs Comput. Stat.* **2010**, *2*, 387–403. [CrossRef]
32. Chen, C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J. Am. Soc. Inf. Sci. Technol.* **2006**, *57*, 359–377. [CrossRef]
33. Merigó, J.M.; Pedrycz, W.; Weber, R.; de la Sotta, C. Fifty years of Information Sciences: A bibliometric overview. *Inf. Sci.* **2018**, *432*, 245–268. [CrossRef]
34. Shibata, N.; Kajikawa, Y.; Takeda, Y.; Matsushima, K. Detecting emerging research fronts based on topological measures in citation networks of scientific publications. *Technovation* **2008**, *28*, 758–775. [CrossRef]
35. Xu, Y.C.; Chen, L.; Li, B.; Liu, W. Density-based modularity for evaluating community structure in bipartite networks. *Inf. Sci.* **2015**, *317*, 278–294. [CrossRef]
36. Rousseeuw, P.J. Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *J. Comput. Appl. Math.* **1987**, *20*, 53–65. [CrossRef]
37. Freeman, L. A Set of Measures of Centrality Based on Betweenness. *Sociometry* **1977**, *40*, 35–41. [CrossRef]
38. van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef] [PubMed]
39. Aria, M.; Cuccurullo, C. bibliometri: An R-tool for comprehensive science mapping analysis. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]
40. Chen, C.M.; Leydesdorff, L. Patterns of Connections and Movements in Dual-Map Overlays: A New Method of Publication Portfolio Analysis. *J. Assoc. Inf. Sci. Technol.* **2014**, *65*, 334–351. [CrossRef]
41. Petrov, D.; Oborina, A.; Giupponi, L.; Stitz, T.H. Link performance model for filter bank based multicarrier systems. *Eurasip J. Adv. Signal Process.* **2014**, *2014*, 169. [CrossRef]
42. Trujillo, C.M.; Long, T.M. Document co-citation analysis to enhance transdisciplinary research. *Sci. Adv.* **2018**, *4*, 1701130. [CrossRef]
43. Alvarez-Taboada, F.; Tammadge, D.; Schlerf, M.; Skidmore, A. Assessing MODIS GPP in Non-Forested Biomes in Water Limited Areas Using EC Tower Data. *Remote Sens.* **2015**, *7*, 3274–3292. [CrossRef]
44. Spiridonov, V.; Jakimovski, B.; Spiridonova, I.; Pereira, G. Development of air quality forecasting system in Macedonia, based on WRF-Chem model. *Air Qual. Atmos. Health* **2019**, *12*, 825–836. [CrossRef]

45. Xie, Y.; Liu, X.R.; Li, D.Y.; Zhao, M.D.; Weng, Z.X.; Zhang, L.; Xu, M. Health and economic benefits of reducing air pollution embodied in GBA's green and low-carbon development. *Urban Clim.* **2023**, *52*, 101755. [CrossRef]
46. He, J.J.; Gong, S.L.; Liu, H.L.; An, X.Q.; Yu, Y.; Zhao, S.P.; Wu, L.; Song, C.B.; Zhou, C.H.; Wang, J.; et al. Influences of Meteorological Conditions on Interannual Variations of Particulate Matter Pollution during Winter in the Beijing-Tianjin-Hebei Area. *J. Meteorol. Res.* **2017**, *31*, 1062–1069. [CrossRef]
47. Song, Y.; Li, Z.; Yang, T.; Xia, Q. Does the expansion of the joint prevention and control area improve the air quality?—Evidence from China's Jing-Jin-Ji region and surrounding areas. *Sci. Total Environ.* **2020**, *706*, 136034. [CrossRef]
48. Lin, W.F.; Lin, K.; Du, L.Z.; Du, J.H. Can regional joint prevention and control of atmospheric reduce border pollution? Evidence from China's 12th Five-Year Plan on air pollution. *J. Environ. Manag.* **2023**, *342*, 118342. [CrossRef] [PubMed]
49. Wang, J.; Gao, A.; Li, S.; Liu, Y.; Zhao, W.; Wang, P.; Zhang, H. Regional joint $PM_{2.5}$-O_3 control policy benefits further air quality improvement and human health protection in Beijing-Tianjin-Hebei and its surrounding areas. *J. Environ. Sci.* **2023**, *130*, 75–84. [CrossRef]
50. Yang, Y.D.; Chen, Z.Q.; Sun, X.D.; Yao, S.; Zhang, X.Y.; Liu, W.Q. Li_4SiO_4 adsorbent derived from industrial biomass fly ash for high-temperature CO_2 capture. *Fuel* **2023**, *337*, 126853. [CrossRef]
51. Chen, Z.L.; Chang, W.; Jiang, X.G.; Lu, S.Y.; Buekens, A.; Yan, J.H. Leaching Behavior of Circulating Fluidised Bed MSWI Air Pollution Control Residue in Washing Process. *Energies* **2016**, *9*, 743. [CrossRef]
52. Yang, Z.Z.; Tian, S.C.; Ji, R.; Liu, L.L.; Wang, X.D.; Zhang, Z.T. Effect of water-washing on the co-removal of chlorine and heavy metals in air pollution control residue from MSW incineration. *Waste Manag.* **2017**, *68*, 221–231. [CrossRef] [PubMed]
53. Li, H.L.; Zheng, Y.; Yu, Q.; Jiao, B.Q.; Li, D.W. Optimization for enhanced electrokinetic treatment of air pollution control residues using response surface methodology focusing on heavy metals leaching risk and extractability. *Process Saf. Environ. Prot.* **2022**, *159*, 534–546. [CrossRef]
54. Ahmad, M.R.; Qian, L.P.; Fang, Y.; Wang, A.G.; Dai, J.G. A multiscale study on gel composition of hybrid alkali-activated materials partially utilizing air pollution control residue as an activator. *Cem. Concr. Compos.* **2023**, *136*, 104856. [CrossRef]
55. Ling, X.; Schollbach, K.; Chen, Y.X.; Brouwers, H.J.H. The effect of nano-silica and silica fume on the sodium carbonate-activated slag system containing air pollution control residues. *Waste Manag.* **2024**, *176*, 52–63. [CrossRef] [PubMed]
56. Sun, J.J.; Huang, L.; Liao, H.; Li, J.Y.; Hu, J.L. Impacts of Regional Transport on Particulate Matter Pollution in China: A Review of Methods and Results. *Curr. Pollut. Rep.* **2017**, *3*, 182–191. [CrossRef]
57. Ge, B.Z.; Wang, Z.F.; Lin, W.L.; Xu, X.B.; Li, J.; Ji, D.S.; Ma, Z.Q. Air pollution over the North China Plain and its implication of regional transport: A new sight from the observed evidences. *Environ. Pollut.* **2018**, *234*, 29–38. [CrossRef]
58. Huang, X.; Ding, A.J.; Wang, Z.L.; Ding, K.; Gao, J.; Chai, F.H.; Fu, C.B. Amplified transboundary transport of haze by aerosol-boundary layer interaction in China. *Nat. Geosci.* **2020**, *13*, 428. [CrossRef]
59. Zhang, Y.; Bai, X.M.; Mills, F.P.; Pezzey, J.C.V. Rethinking the role of occupant behavior in building energy performance: A review. *Energy Build.* **2018**, *172*, 279–294. [CrossRef]
60. Guan, Z.Z.; Chen, D.Z.; Astrup, T.F. Influences of ammonia contamination on leaching from air-pollution-control residues. *Waste Manag. Res.* **2014**, *32*, 1169–1177. [CrossRef]
61. Zhu, Y.M.; Zhang, H.; Fan, S.S.; Wang, S.J.; Xia, Y.; Shao, L.M.; He, P.J. In-situ determination of metallic variation and multi-association in single particles by combining synchrotron microprobe, sequential chemical extraction and multivariate statistical analysis. *J. Hazard. Mater.* **2014**, *276*, 241–252. [CrossRef] [PubMed]
62. Lin, X.N.; Niu, J.Z.; Yu, X.X.; Berndtsson, R.; Wu, S.S.; Xie, S.Y. Maize residue effects on $PM_{2.5}$, PM10, and dust emission from agricultural land. *Soil Tillage Res.* **2021**, *205*, 104738. [CrossRef]
63. Rafaj, P.; Amann, M. Decomposing Air Pollutant Emissions in Asia: Determinants and Projections. *Energies* **2018**, *11*, 1299. [CrossRef]
64. Song, Y.; Chang, D.; Cui, L.Z. The Evolutionary Game of Cooperative Air Pollution Management under Complex Networks. *Sustainability* **2023**, *15*, 246. [CrossRef]
65. Zhu, T.; Tang, M.J.; Gao, M.; Bi, X.H.; Cao, J.J.; Che, H.Z.; Chen, J.M.; Ding, A.J.; Fu, P.Q.; Gao, J.; et al. Recent Progress in Atmospheric Chemistry Research in China: Establishing a Theoretical Framework for the "Air Pollution Complex". *Adv. Atmos. Sci.* **2023**, *40*, 1339–1361. [CrossRef]
66. Qi, L.Q.; Wang, X.; Wang, W.; Li, J.X.; Huang, Y. Mercury removal from coal combustion flue gas by pyrite-modified fly ash adsorbent. *Environ. Sci. Pollut. Res.* **2022**, *29*, 39228–39238. [CrossRef] [PubMed]
67. Ge, J.C.; Kim, J.Y.; Yoon, S.K.; Choi, N.J. Fabrication of low-cost and high-performance coal fly ash nanofibrous membranes via electrospinning for the control of harmful substances. *Fuel* **2019**, *237*, 236–244. [CrossRef]
68. Ayub, K.S.; Abbas, Z.; Zaman, W.Q.; Rauf, S.; Arshad, M.; Ali, M.; Miran, W.; Mushtaq, U.; Khalid, H.; Yang, J. Nonthermal plasma catalysis using ferrites as an efficient catalyst for toluene degradation. *Res. Chem. Intermed.* **2023**, *49*, 2399–2415. [CrossRef]
69. Chen, S.H.; Cheng, M.M.; Guo, Z.; Xu, W.; Du, X.H.; Li, Y. Enhanced atmospheric ammonia (NH_3) pollution in China from 2008 to 2016: Evidence from a combination of observations and emissions. *Environ. Pollut.* **2020**, *263*, 114421. [CrossRef]
70. Li, J.Y.; Bi, C.K. Visual analysis of air pollution spatio-temporal patterns. *Vis. Comput.* **2023**, *39*, 3715–3726. [CrossRef]
71. Zareba, M.; Dlugosz, H.; Danek, T.; Weglinska, E. Big-Data-Driven Machine Learning for Enhancing Spatiotemporal Air Pollution Pattern Analysis. *Atmosphere* **2023**, *14*, 760. [CrossRef]

72. Wang, X.P.; Shao, T.Q.; Qin, J.Y.; Li, Y.L.; Long, X.; Jiang, D.B.; Ding, J.G. Promotion Effect of Micro-Hole in Dielectric on Ozone Generation of Dielectric Barrier Discharge. *Ozone-Sci. Eng.* **2024**, *46*, 1–10. [CrossRef]
73. Vedrenne, M.; Borge, R.; Lumbreras, J.; Conlan, B.; Rodríguez, M.E.; de Andrés, J.M.; de la Paz, D.; Pérez, J.; Narros, A. An integrated assessment of two decades of air pollution policy making in Spain: Impacts, costs and improvements. *Sci. Total Environ.* **2015**, *527*, 351–361. [CrossRef] [PubMed]
74. Ti, C.; Han, X.; Chang, S.X.; Peng, L.; Xia, L.; Yan, X. Mitigation of agricultural NH3 emissions reduces $PM_{2.5}$ pollution in China: A finer scale analysis. *J. Clean. Prod.* **2022**, *350*, 131507. [CrossRef]
75. Li, M.Q.; Hou, Z.G.; Dai, Y.; Song, Z.C.; Xiong, Z.L. Capture of NH_3 using air plasmas to form NH_4NO_3 for N recycling: Impact factors and mechanisms. *J. Clean. Prod.* **2023**, *428*, 139434. [CrossRef]
76. Xiong, B.; Wang, R.M. Effect of Environmental Regulation on Industrial Solid Waste Pollution in China: From the Perspective of Formal Environmental Regulation and Informal Environmental Regulation. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7798. [CrossRef] [PubMed]
77. Potocki, M.; Dixon, D.A.; Kurbatov, A.V.; Casassa, G.; Zamora, R.; Handley, M.J.; Introne, D.; Grigholm, B.; Korotkikh, E.V.; Birkel, S.D.; et al. Trace metal emission history captured in a Chilean ice core. *Atmos. Environ.* **2022**, *276*, 119002. [CrossRef]
78. Cai, L.Z.; Guo, L. Environmental Decentralization, Environmental Regulation and Environmental Pollution: Evidence from China. *Pol. J. Environ. Stud.* **2023**, *32*, 2053–2068. [CrossRef]