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A Bibliometric Analysis of the Impact of Air Pollutants on Cognitive Function: Global Trends and Research Hotspots (2005–2025)

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Abstract. This study conducts a bibliometric analysis to explore global research trends and hotspots in the impact of air pollutants on cognitive function from 2005 to 2025. A total of 307 English articles retrieved from the Web of Science Core Collection were analyzed using CiteSpace and VOSviewer. The results show a general increasing trend in publications, with a peak in 2024. Major contributing authors include Sunyer Jordi and Guxens Monica, while the United States, China, and Spain are the most productive countries. Keyword co-occurrence and cluster analysis identified key research themes such as Alzheimer's disease, particulate matter, prenatal exposure, older adults, and adolescents. The strongest burst terms include "prenatal exposure," "black carbon," and "older adults." The study provides a systematic overview of the evolving research landscape and highlights emerging directions in this field.

Keywords: Air pollutants; Cognitive function; Bibliometric analysis; Research hotspots; Global trends; Particulate matter; Dementia; Prenatal exposure.

1. Introduction

The development of industrial civilization has progressively intensified the impact of air pollution on cognitive function, attracting widespread attention in recent years. Air pollutants encompass gaseous pollutants, particulate matter, as well as other contaminants such as heavy metals and greenhouse gases. Air pollution affects various aspects of human health, with particularly significant impacts on the lungs and heart (Manisalidis et al., 2020; UDNRR, 2024). With ongoing urbanization, construction activities and fuel combustion have increased markedly, drawing considerable attention to the effects of particulate matter on the environment and populations. Black carbon has also emerged as a prominent research focus in the field of air pollution's impact on cognitive function. With the accelerating aging process, cognitive function has increasingly become a major focus of scientific research. Cognitive function is a broad term encompassing domains such as attention, perception, memory, learning, and executive function. It plays a crucial role in determining an individual's quality of life, health, and mortality. Decline in cognitive function is closely associated with an increased risk of dementia, reduced quality of life, and rising healthcare costs. Population aging has further accentuated the effects of air pollutants on cognitive function among specific demographic groups (Chen et al., 2023; Di Gessa et al., 2025). Numerous studies have indicated that air pollutants adversely affect cognitive function (Gao et al., 2021; Meo et al., 2024; Silva et al., 2019).

With the continual advancement of the research field, there is an urgent need for a systematic analysis and review of existing studies to synthesize the research framework within the current context. So far, no scholars have conducted a systematic analysis of the global research status and evolutionary trends in this area. Therefore, this study employs bibliometric methods to analyze

approximately two decades of research in the field, quantitatively delineating its development trajectory, research hotspots, and evolutionary trends.

2. Methods and Data Sources

This study retrieved 315 English articles on the impact of air pollutants on cognitive function published from January 2005 to August 2025 from the Web of Science database. We utilized CiteSpace 6.2 and VOSviewer 1.6.20 to conduct a bibliometric analysis of these studies, identifying and interpreting major patterns and trends in the field. CiteSpace, a Java-based information visualization tool developed by Dr. Chaomei Chen of Drexel University, integrates citation analysis theory with data mining algorithms (Zimmerman, 2000).It combines information visualization, bibliometrics, and data mining into an interactive platform, enabling the visualization and analysis of trends and patterns in scientific literature (Zimmerman, 2002).To ensure the coverage and authority of the data analyzed, the Web of Science (core collection) was selected as the data source, the indexes were selected as SSCI and SCIE, the search strategy selected was TS = ("air contaminant" OR "air contaminants" OR "air pollutant" OR "air pollutants" OR "air environmental pollutants" OR "environmental air pollutants") AND TS = ("cognitive" OR "cognitions" OR "cognition") , with a time span starting from January 2005 to August 2025, a search time cutoff of August 6, 2025, and a literature type selected as Articles or Review Article and a language of English, and literature records were obtained after the search.

We created a keyword cooccurrence map to visually display the frequency of keyword appearances in the literature， as well as we employed VOSviewer to conduct visual analyses of country collaboration, journal collaboration and keyword co-occurrence in this field, and utilized CiteSpace to perform visual examinations of author collaboration, , keyword clustering, timeline view, and burst terms, in order to identify key elements in the development and research frontiers of the impact of air pollutants on cognitive function.

3. Results

Following a rigorous evaluation and screening process, a total of 307 articles were included in the analysis. These 307 publications were contributed by 1,842 authors from 723 institutions across 53 countries, published in 145 journals, and collectively cited 15,338 references sourced from 4,214 distinct journals.

3.1 The overall trend of research in this field

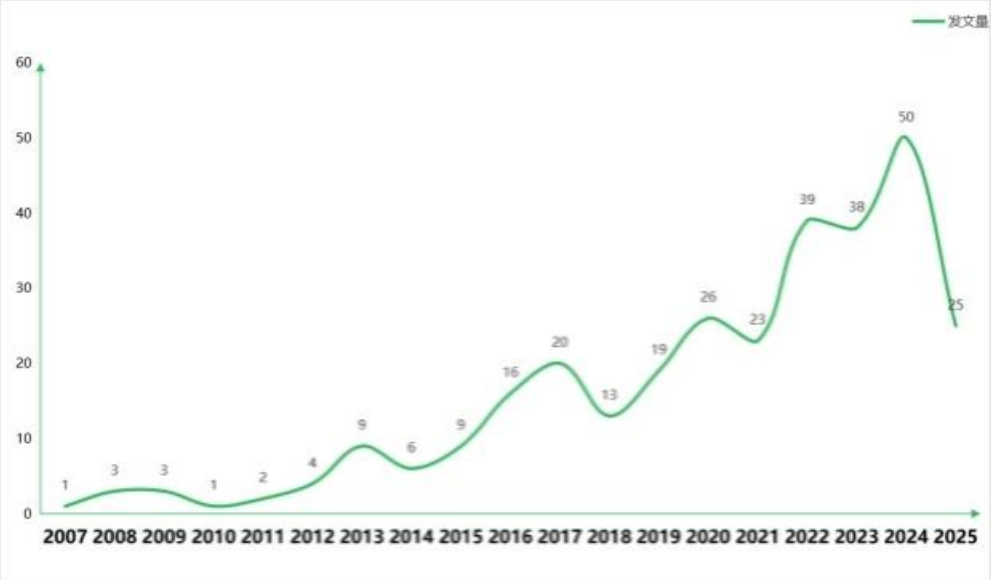

Figure1 Line graph of annual publication volume of papaers in the field

Figure 1 illustrates the temporal distribution of publications in the field of the impact of air pollutants on cognitive function. Overall, research publications in this area began in 2007. Although the total number of publications remains relatively limited, an overall upward trend is evident. Notably, since 2018, the annual publication count has increased rapidly. This growth may be attributed to growing awareness of the effects of air pollutants on human consciousness alongside industrial development and urban modernization, accompanied by the conceptual refinement of cognitive function. This upward trend reflects a significant rise in academic interest in the relationship between air pollution and cognitive performance, indicating continuous expansion in both the depth and scope of research. The year 2024 represents a peak in scholarly output within this domain. The apparent decrease in publications in 2025 is likely due to the literature retrieval cutoff date being August 2025; based on the observed trend, it is projected that the total number of publications for 2025 would eventually surpass that of 2024 if data were collected for the full year.

3.2 Author's anaiysis

Table1 Author Distribution of Literature

Author	Documents	Citations	Average Citation
sunyer, jordi	16	2144	17.07
guxens, monica	12	621	11.34
chen, jiu chiuan	10	812	9.15
kaufman, joel d.	9	246	7.42
alvarez pedrerol, mar	7	1468	10.24
querol, xavier	7	1375	9.64
rivas, ioar	7	1441	10.28
calderon garciduenas, lilian	6	374	3.58
forns, joan	6	1392	9.35
basagana, xavier	5	1150	6.67
lopez vicente, monica	5	1150	6.67

mortamais, marion	5	210	5.69
perera, frederica	5	646	4.88
thomson, errol m.	5	466	6.54
younan, diana	5	156	2.22

Table 1 presents information on the top fifteen authors with the highest number of publications. As shown in the table, there are notable differences in citation counts among authors who have published five or more articles. Sunyer Jordi holds the highest counts in both total publications and average citations per article, indicating sustained and focused involvement in the development of research on the impact of air pollutants on cognitive function, as well as conducting in-depth investigations and publishing high-quality research, Sunyer Jordi holds the highest counts in both total publications and average citations per article, indicating sustained and focused involvement in the development of research on the impact of air pollutants on cognitive function, as well as conducting in-depth investigations and publishing high-quality research, In a study examining the impact of prenatal exposure to PM2.5 and NO_2 on neuropsychological development in infants and young children, he and his team identified significant associations between maternal air pollutant exposure and impaired cognitive function in offspring, with sex-dependent effects observed at 4–6 years of age (Guxens & Sunyer, 2012).

Figure2 Author Collabroation

Analyzing the collaborative relationships among authors of the literature will help identify productive researchers and research groups in the field of the impact of air pollution on cognitive function. In Figure 2, nodes represent authors, with the size of each node corresponding to the number of publications—larger nodes indicate a greater volume of publications. The connecting lines between nodes reflect collaborative relationships among different authors. The co-occurrence knowledge graph of authors in this research domain shows that the number of connections exceeds the number of nodes, and the network density is relatively high. This indicates substantial collaborative relationships among researchers who have made significant contributions to the field internationally, with most maintaining a certain level of communication and cooperation. Notably, several authors, particularly Guxens Monica and Sunyer Jordi, exhibit close collaborative ties (Guxens & Sunyer, 2012).

3.3 National Analysis

Table2 Distribution of Published Literature by Country

Country	Documents	Citations	Advance Citation
usa	121	7573	62.59
china	69	1354	19.62
spain	32	2787	87.10
england	28	2152	76.86
netherlands	23	918	39.91
canada	22	2510	114.09
italy	19	1008	53.05
australia	15	955	63.67
sweden	14	528	37.71
germany	13	835	64.23
south korea	13	930	71.54
mexico	12	1144	95.33
brazil	10	221	22.10
france	10	474	47.40
poland	9	429	47.67

Table 2 lists the top 15 countries with the highest number of publications. The top five countries by publication count are the United States, China, Spain, the United Kingdom, and the Netherlands. The top five countries by average citation count per article are Canada, Mexico, Spain, the United Kingdom, and South Korea. However, although Chinese scholars rank second in terms of publication output in this field, the average citation count of their articles is among the lowest. This indicates that there remains significant room for deepening the research quality and impact of studies from China on the effect of air pollutants on cognitive function, suggesting substantial potential for further development in this area.

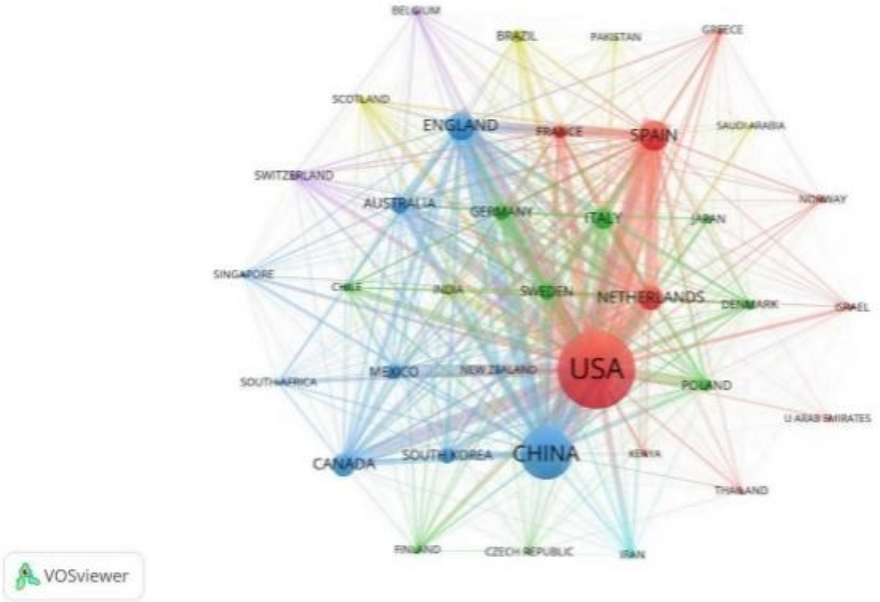

Figure3 Country Collaboration Network Map

To understand which countries have made the most prominent contributions to the research field of impact of air pollution on cognition funcftion, this study analyzed the number of publications from 51 countries. First, the countries with the number of publications greater than or equal to 4 were visualized through VOSviewer. and the results are shown in Figure 3. The larger the circle node in Figure 3 indicates the more articles issued; the node connecting line represents the association strength, and the thicker the line indicates the more articles issued by two countries cooperatively; the node color represents different clusters. From the figure 3, it can be seen that the distribution of countries publishing in this field is very uneven, and most papers were written by a few countries. While the United States has the most branches indicating that the United States has developed cooperative relationships with many countries.

3.4 Analysis of Journals and Publishing Institutions

Table3 Distribution of Literature Sources Table

Source	Documents	Citations	Advance Citaiion
environmental research	38	1475	37.48
environment international	25	849	23.82
environmental health perspectives	14	1984	18.44
journal of alzheimers disease	12	722	11.73
science of the total environment	11	386	13.94
international journal of environmental research and public health	9	193	4.96
bmc public health	5	22	6.39
environmental health	5	217	6.05
environmental pollution	5	193	4.11
neuroscience and biobehavioral reviews	5	84	4.29
particle and fibre toxicology	5	145	3.59

As shown in Table 3, an investigation of journals publishing papers in this field reveals that research has appeared in numerous academic journals and includes several publications in top-tier journals (Gao et al., 2021; Kristiansson et al., 2015; Schmidt, 2022)， These studies demonstrate the substantial impact of air pollutants on human respiratory and mental health, and highlight that the influence of air pollutants on cognitive function cannot be overlooked. This indicates that the field is experiencing vigorous development and possesses significant research value.

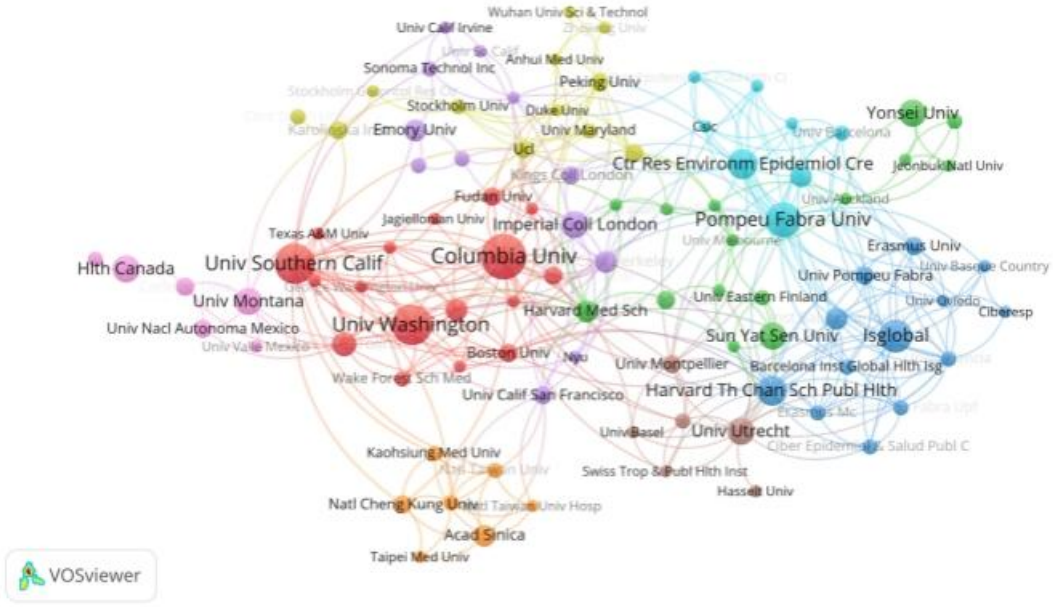

Figure4 Institutional Cooperation Diagram

Figure 4 shows the collaboration between publishing institutions in this field, where nodes represent institutions, with the size of each node corresponding to the number of publications—larger nodes indicate a greater volume of publications. The connecting lines between nodes represent collaborative relationships among institutions. Analyzing research institutions and their collaborations helps to understand the research capabilities and influence of relevant organizations in the field of the impact of air pollutants on cognitive function. The sample literature was processed uniformly and imported into CiteSpace for analysis of the selected database, with the time span set from 2001 to 2020. The analysis parameter was selected as "Institution," generating a co-occurrence map of research institutions studying the impact of air pollutants on cognitive function. Based on the visual analysis of institutional collaborations, Columbia University was found to have the greatest influence, followed by Harvard University and the University of Washington. Harvard University had the most branches, indicating collaborations with multiple institutions, among which its partnership with the University of Washington was the most extensive. This close collaboration may be attributed to both universities being members of the Association of American Universities (AAU), sharing deep consensus in academic research, and having established significant expertise in the field of public health.

3.5 Keyword Analysis

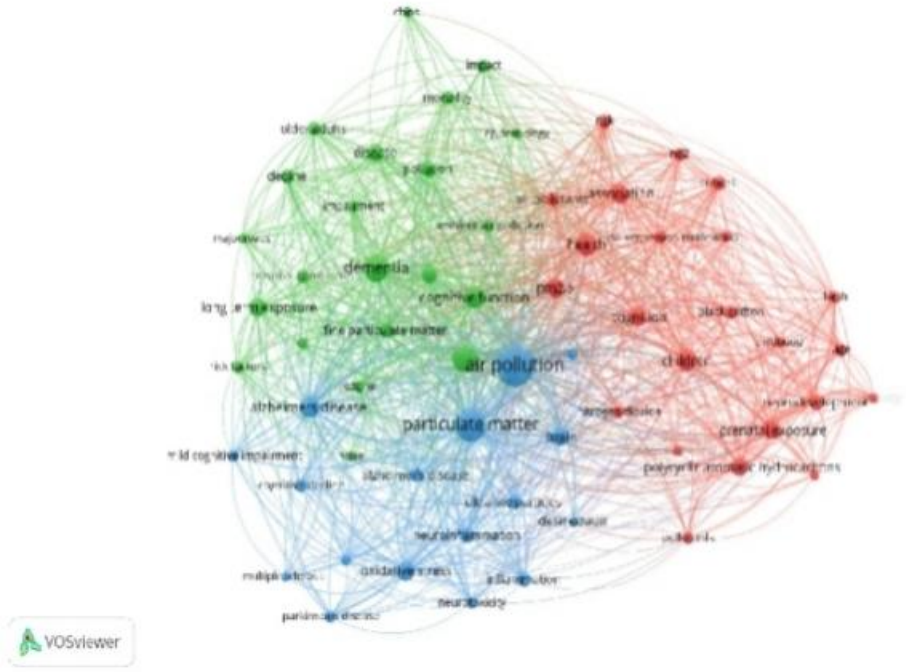

Figure5 Co-occurrence Network of Keywords

Keywords in academic research not only reflect the focal points within a research field but also indicate its research trends and popularity. Keyword co-occurrence analysis can effectively reveal the distribution of research hotspots in the study of the impact of air pollutants on cognitive function, thereby summarizing key topics of interest in this area. In this study, the standardized sample data were imported into VOSviewer, with the time frame set from 2005 to 2025 . The analysis parameter was selected as “Keywords”, resulting in the keyword co-occurrence map presented in Figure 5, which visualizes research related to air pollutants and cognitive function from 2005 to 2025. The size of each node corresponds to the frequency of the keyword (larger nodes indicate higher occurrence), and the connecting lines between nodes reflect the co-occurrence frequency among different keywords.

Table4 Keywords List

Keyword	Occurrences	Total link strength
air pollution	174	909
particulate matter	108	633
dementia	73	455
exposure	70	381
health	51	267
alzheimers disease	48	303
cognitive function	48	266
children	46	241
oxidative stress	38	204
association	37	232

This study identified a total of 62 keywords, with a cumulative frequency of 3,954 occurrences. The top ten keywords from the literature in the Web of Science (WOS) Core Collection were summarized, as shown in Table 4. It is evident from the table that "air pollution" is the most

frequently occurring thematic keyword, followed by "particulate matter," "dementia," "exposure," "health," among others. With the development of industrial society, air pollution has increased sharply, and scholarly attention to air pollutants has been gradually rising. Published studies indicate that particulate matter has become one of the most significant risk factors affecting cognitive function. Emerging evidence suggests a potential link between air pollution and brain health, as individuals in polluted areas have shown declines in cognitive performance, with particulate matter constituting a major proportion of air pollutant varieties (Meo et al., 2024).

Keyword clustering extends the keyword co-occurrence map by summarizing and extracting research themes, visually presenting the research domains as clustered blocks. Through these blocks, the distribution of research hotspots within this topic can be clearly observed.The map was clustered within the software to produce a keyword clustering map of research on the impact of air pollutants on cognitive function from 2005 to 2025 (Figure 6). Background data indicate that the modularity value of the keyword clustering map is greater than 0.3, suggesting a significant cluster structure. The average silhouette value S meets the required threshold ($S > 0.7$, $S = 0.9146$), indicating that the clustering results are highly credible (Yang, 2025).

The clustering map reveals a total of 10 major clusters, namely: older adults, alzheimer, pregnancy, inhalation, adolescents, dna methylation, cognitive function, carbon dioxide, noise, and public health. Thus, it is evident that research on the impact of air pollutants on cognitive function is closely associated with Alzheimer's disease, inhalable substances, adolescents, older adults, and other related areas. The largest cluster (#0) contains 28 members (silhouette $S = 0.899$), the second largest (#1) has 20 members ($S = 0.899$), the third (#2) has 18 members ($S = 0.932$), the fourth (#3) has 18 members ($S = 0.856$), the fifth (#4) has 17 members ($S = 0.938$), the sixth (#5) has 15 members ($S = 0.979$), the seventh (#6) has 13 members ($S = 0.184$), the eighth (#7) has 16 members ($S = 0.986$), the ninth (#8) has 11 members ($S = 0.841$), and the tenth (#9) has 10 members ($S = 0.896$). From a clustering perspective, research in this period demonstrates characteristics of concentration, diversity, and rapid growth. Studies on the impact of air pollutants on cognitive function are linked to the types of pollutants, specific populations, and different age groups. Scholars have developed numerous research directions around specific themes, advancing step by step in a systematic and progressive manner, focusing on particular hotspots at each stage to achieve targeted research breakthroughs.

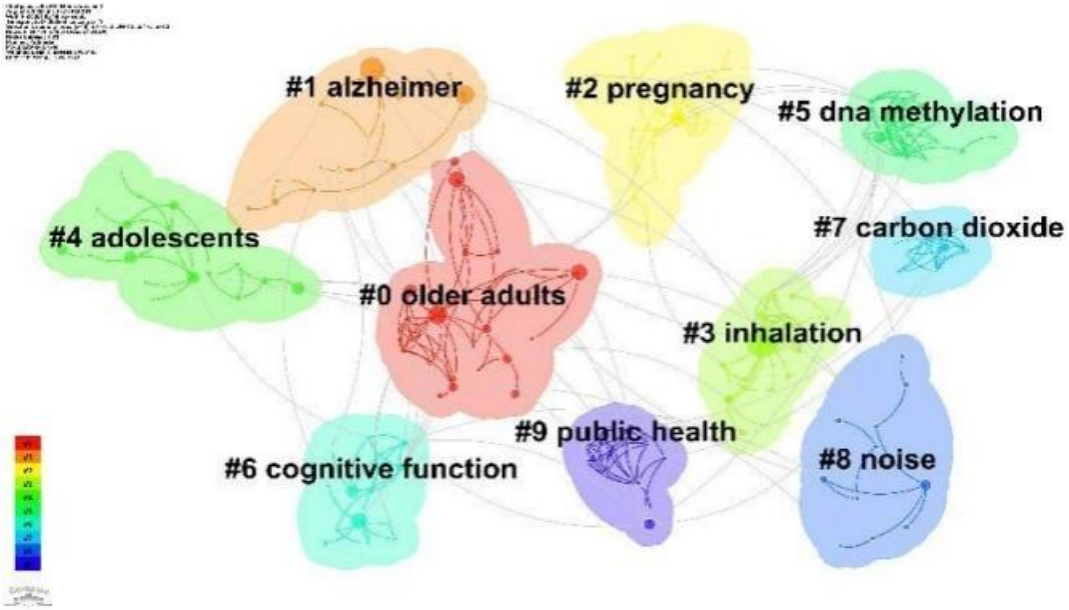

Figure6 Keyword Cluster Map

3.6 Research Hotspots Analysis

A timeline view consists of a series of horizontal bands arranged in chronological order, primarily representing the evolution of knowledge from a temporal perspective. The Keyword Timeline map in CiteSpace visualizes the distribution, evolution, and development trends of research hotspots over time, thereby helping to identify cutting-edge directions in the field. In this map, keywords are arranged from left to right in chronological order, and the size of each circular node is proportional to the frequency of the corresponding keyword.

Using CiteSpace, an evolutionary analysis of research hotspots in the selected literature was conducted. The time parameters were set from 2005 to 2025, with “Year per slice = 1” and “Node type = Keyword.” The resulting keyword evolution map is shown in the corresponding figure. The generated map (Figure 7) contains 174 nodes and 355 links. The modularity Q value of 0.7644 indicates a significant cluster structure (Song & Liu, 2025).The emergence of keywords on the timeline shows a progression from few to many across different periods, reflecting fluctuating phases in the development of related scientific literature. This suggests that research on the impact of air pollutants on cognitive function has undergone notable variations in focus and intensity over time. Aside from thematic keywords, “endotoxin” has the largest node size. Existing studies have explored the association between endotoxin and cognitive function as well as other mental disorders, indicating that this keyword represents a research hotspot and may imply an underlying mechanistic influence. This further highlights the importance of endotoxin in the broader study of how air pollutants affect cognitive function. The intrinsic properties of this keyword also justify its central role in scholarly research.

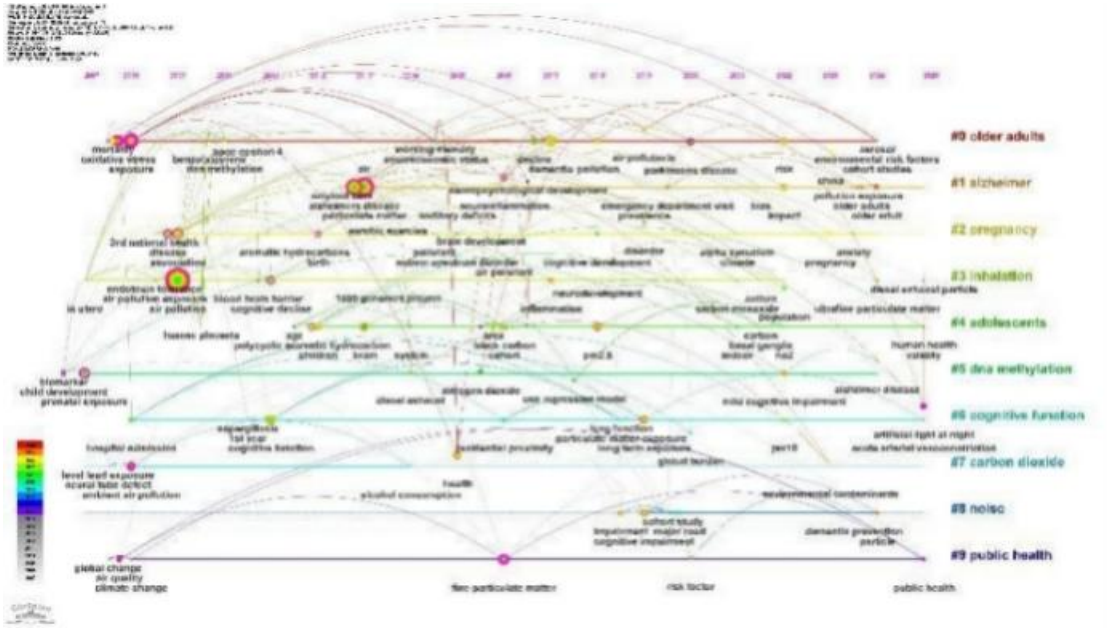

Figure7 Timeline Research Hotspots

Figure 8 displays the explosive word analysis. The gray lines represent the beginning of the keyword's influence, while the red lines indicate an increased focus, marking them as key research topics during their respective periods. This figure highlights a total of 21 emergent terms that have shaped research between 2008 and 2025. The evolution of these keywords reflects the shifting focus of research at the intersection of air pollution and cognitive over time. The Strength indicator shows

the intensity of research interest in specific topics during particular periods. By examining these emergent keywords, and considering their co-occurrence over time, we can infer the overall trajectory and trends in the development of the air pollution and cognitive field, identifying several subresearch areas.

The term with the strongest burst intensity is "prenatal exposure." This is because prenatal exposure involves not only pregnant women but also infants and young children as vulnerable populations. Existing studies have indicated that prenatal exposure to environmental pollutants can adversely affect the cognitive function of infants and young children(Lertxundi et al., 2019).Research on black carbon, which began to gain attention in 2016, ranks second in burst intensity. With continued urbanization and increased combustion of vehicle fuels and other sources, black carbon became a major research focus during that period(Annavarapu & Kathi, 2016).Meanwhile, research on older adults, emerging in 2024, has become a recent hotspot. Among the screened literature, 56 studies published between 2024 and 2025 specifically addressed the impact of air pollutant exposure on cognitive function in older adults. Some scholars have investigated the association between long-term exposure to low concentrations of environmental pollutants and cognitive function in this population(Chen et al., 2023)， finding that cognitive function in older adults is more significantly affected by environmental pollutants.

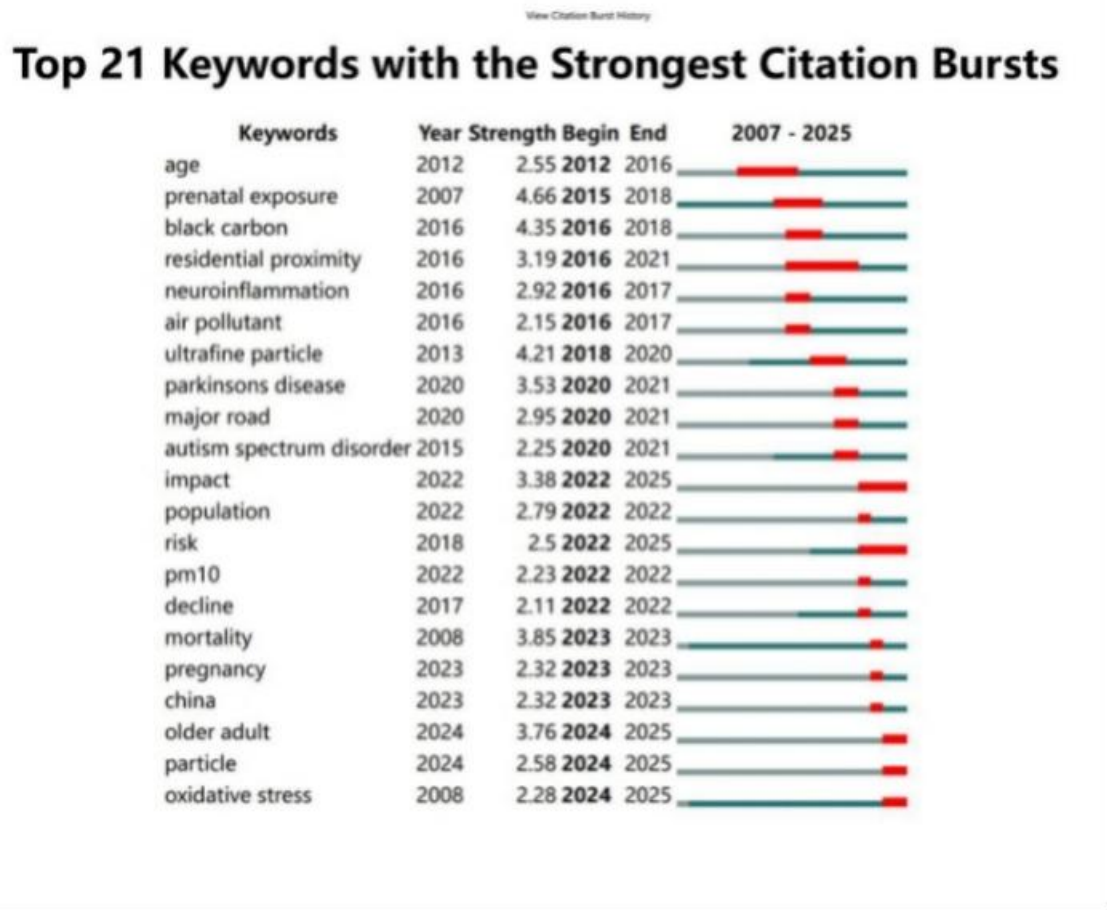

Figure8 Burst Detection Map

4. Conclusions and Prospects

4.1 Conclusions

The impact of air pollutants on cognitive function, as a research area that has garnered widespread attention in recent years, is particularly important for the advancement of public health and is therefore a rapidly evolving field. This study utilized VOSviewer and CiteSpace to analyze relevant research from the past two decades on the effects of air pollutants on cognitive function, systematically reviewing the developmental trajectory of the field and discussing and analyzing research authors, relevant countries and institutions, key journals, keyword co-occurrence, keyword clustering, timeline view, and burst terms. The conclusions drawn from the bibliometric analysis are summarized as follows:

(1) Research in this field showed an overall increasing trend from 2005 to 2025, with 2024 marking a peak in scholarly output on the impact of environmental pollutants on cognitive function. The decline in 2025 may be attributed to the literature retrieval cutoff in August 2025; based on observed trends, the total number of publications for 2025 is expected to eventually exceed that of 2024.

(2) Several authors, notably Guxens Monica and Sunyer Jordi, demonstrated close collaboration. Although collaborative networks among authors are still forming, several well-known scholars have emerged. Sunyer Jordi ranked highest in both publication output and average citation count, reflecting in-depth research and high-quality publications.

(3) Scholars from the United States contributed the most publications in this field, with a total of 121 articles. However, in terms of average citation count per article, Canadian scholars received higher recognition. Based on author and network analyses, the United States cooperated with numerous countries. Harvard University also established extensive collaborations with multiple institutions, among which its partnership with the University of Washington was the strongest.

(4) An investigation of journals publishing papers in this field revealed that research has appeared in a wide range of journals, including publications in high-impact factor (Q1) journals.

(5) Keyword co-occurrence and cluster analysis indicated significant clustering results, with several stable research themes having emerged. Research on the impact of air pollutants on cognitive function is closely associated with Alzheimer's disease, inhalable substances, adolescents, and older adults. The evolution of keywords over time reflected fluctuating phases in the development of related scientific literature, indicating that research efforts in this area have experienced notable variations in focus and intensity.

(6) The term with the strongest burst intensity was "prenatal exposure." Research on black carbon, which emerged in 2016, ranked second in burst intensity. As well as research on older adults, rising sharply since 2024, has become a recent hotspot.

4.2 Value, Limitations, and Prospects

As an active and cutting-edge interdisciplinary research field, the impact of environmental pollutants on cognitive function undoubtedly holds great potential for further development. Therefore, a bibliometric perspective offers valuable insights into the research landscape, providing direction and ideas for researchers in the field. Specifically:(1) It can help scholars interested in the effects of air pollutants on cognitive function establish a clear framework of existing research, deeply understand the field’s development process, popular research directions, and hotspots—such

as prenatal exposure, the impact on older adults, and the role of particulate matter;(2) The cluster and evolution analysis of high-frequency keywords in this study can help researchers identify focus areas and hotspots related to the impact of air pollutants on cognitive function, such as older adults, Alzheimer, pregnancy, inhalation, adolescents, dna methylation, cognitive function, carbon dioxide, noise, and public health, thereby providing valuable reference for topic selection;(3) This study analyzed several high-quality articles in the field, such as "Urban air pollution, poverty, violence and health - Neurological and immunological aspects as mediating factors" and "The impact of long- and short-term exposure to different ambient air pollutants on cognitive function in China," which can help researchers quickly locate literature for reference and also offer some guidance for scholars submitting papers on this topic to relevant journals (Kristiansson et al., 2015).It is reasonable to believe that research on the impact of air pollutants on cognitive function, as a relatively new field, holds prospects in the context of increasing air pollution. Therefore, this study remains significant and valuable for further development. Future research should first integrate literature from multiple databases to ensure comprehensive data screening, actively communicate with scholars in the epidemiology field to stay updated on cutting-edge trends, and enhance and deepen objective understanding of the field to form a more rational and impartial perspective.

This study has certain limitations due to objective factors. First, bibliometric analysis software requires highly standardized data; to ensure data quality and completeness, only journal articles from the SSCI and SCIE indices in the Web of Science Core Collection were included, excluding other databases such as PubMed, which may lead to insufficient comprehensiveness of the analysis. Additionally, quantitative analysis requires data interpretation, which demands researchers have a relatively deep and comprehensive understanding of the field; otherwise, some subjectivity is unavoidable.

It is reasonable to believe that research on the impact of air pollutants on cognitive function will continue dynamically. Therefore, this study remains significant and worthy of further development. Future research should first integrate literature from multiple databases to make the screened data as comprehensive as possible, actively communicate with scholars in the field of air pollutants and cognitive function to understand cutting-edge dynamics, enhance and deepen objective understanding of the field, and minimize personal subjectivity in analysis and interpretation.

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