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TREND EDITORIAL

Trends on $PM_{2.5}$ research, 1997–2016: a bibliometric study

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Introduction

Particulate matter with the aerodynamic equivalent diameter ≤ 2.5 μm is considered as fine particulate matter ($PM_{2.5}$) (Callen et al. 2012). Because of its small size, light weight, long-time retention and drift in the atmosphere, it has become the primary pollutant in large cities and has attracted wide attention. $PM_{2.5}$ has attracted scholars' wide attention because the massive evidence indicated that $PM_{2.5}$ had significant impact in many aspects, including air quality (Buczynska et al. 2014; Collins et al. 2014), human health (respiratory system, cardiovascular health) (Weichenthal et al. 2014; Xing et al. 2016), and climate (cloud and rain) (Huo et al. 2009; Lin et al. 2015).

The study interest on $PM_{2.5}$ has been increasing dramatically recently, and many academic journals have published papers about it. Bibliometric provides a good choice to assess the trend in research activity over time, analyzes the contributions of countries, and institutes journals and scholars (Wang et al. 2016). Presently, there is no study on $PM_{2.5}$ bibliometric.

The present study attempted to get a comprehensive understanding of the current state of $PM_{2.5}$ research. By analyzing publication, we captured the collaboration pattern between countries/territories, institutions, and authors, better understood the global trend, and discovered the research frontiers in this field.

Methods

Data collection

All data were obtained from the Web of Science Core Collection (WoSCC) of Thomson Reuters on a single day,

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December 1, 2017. The WoSCC, including the Science Citation Index-Expanded (SCI-E) and the Social Sciences Citation Index (SSCI), provides detailed information for bibliometric analysis (Yi et al. 2016).

In this study, the data retrieval strategy was as follows: (1) TOPIC: ("pm2.5") or TOPIC: ("fine particulate matter") or TOPIC: ("pm 2.5") or TOPIC: ("pm(2.5)") or TOPIC: ("fine particulate") or TOPIC: ("particulate matter 2.5"). (2) All references were from 1997 to 2016. (3) Document Types were articles or reviews. (4) Languages were English. Flow chart of literature inclusion is shown in Fig. 1.

Statistical analysis

The data of all eligible publications, including publication years, countries/territories, institutions, journal sources, research areas, co-cited references, and keywords, were downloaded for further analysis.

To predict the time trend of the publication, the model $f(x) = ax^3 + bx^2 + cx + d$ was used by Microsoft Excel 2016 (Redmond, WA, USA). The symbol x was the "publication year: 1997–2016" and $f(x)$ was the cumulative papers by year.

The statistical results were displayed by the CiteSpace V (Drexel University, Philadelphia, USA), a visualization software for analyzing data by network modeling (Chen et al. 2012; Synnestvedt et al. 2005).

The analyses at the literature level (contributing countries/institutions/authors, citing journals and cited journals, co-citation on authors and references, changes in research areas) were based on CiteSpace V. The parameters of CiteSpace were as follows: (1) Time Slicing: 1997–2016; (2) Years Per Slice: "1"; (3) Term Source: Title, Abstract, Author Keywords, and Keyword Plus; (4) Node Type: select the corresponding one each time; (5) Selection Criteria: the top 50, (6) Pruning: Minimum Spanning Tree and Pruning Sliced Networks; and (7) Visualization: Cluster View-Static and Show Merged Network.

Results and discussion

Global publications and growth prediction

From 1997 to 2016, a total of 13,681 publications matched with the search criteria of this study (Fig. 1). The distribution of yearly outputs is shown in Fig. 2a. As time went on, the number of publications was continually increasing, but the growth rate of publications had some fluctuations. The overall publishing trend increased from 51 publications in 1997 to 2088 publications in 2016, revealing that the research on $PM_{2.5}$ had nearly consistently been the focus of scholars' attention.

Figure 2b shows the growth trend of the model-fitting curve, indicating a significant correlation between the number of yearly publications and the publishing years (R2 = 0.9834). Using the prediction model, nearly 2300 publications will be published in 2017.

In the past 20 years, the overall trend of $PM_{2.5}$ research has been growing. The publication year can be divided into the following three phases. The first phase ran from 1997 to 2003 with slowly increased publications and can be considered as the initial stage of $PM_{2.5}$ research. The second phase ran from 2004 to 2011 maintaining a steady growth rate, indicating that people gradually paid attention to $PM_{2.5}$ and attached importance to the related environmental problems. Compared with the past 15 years, the publication of the third phase (2012–2016) was exploding, counting for more than 50% (7275/13,681).

Contributions of countries/territories

Geographical distribution map can be created using Generate Google Earth Maps in CiteSpace (Fig. 3). It showed that countries/territories in East Asia (China, Taiwan, Japan, and South Korea), North America (The USA, Mexico, and Canada), and Europe (England, Italy, Germany, and Spain) participated in $PM_{2.5}$ research actively. The results of the geographical map were consistent with the Network map (Fig. 4a). Furthermore, there was extensive cooperation between countries/regions. The USA ranked first in the number of publications (5941, 43.43%), followed by China (2863, 20.93%) and Canada (832, 6.08%) (Table 1).

The number of citation and H-indexes of the top 20 countries/regions are shown in Table 1 and Fig. 5. The USA had both the highest citation frequencies (217,009) and the highest value of H-index (172). China ranked second both in citation frequency (70,822) and in H-index (103). The rest of the top 20 countries/regions had no clear gaps in these two items.

Contributions of journals

Almost half of the publications on $PM_{2.5}$ research were published in the top 15 scholarly journals (6814, 49.81%), as shown in Fig. 6a. Atmospheric Environment, in which impact factor (IF) 2016 is 3.629, published the most studies (2254, 17.11%), and Journal of the air & Waste management association ranked second (578, 4.41%).

A dual-map overlay of journals was displayed using the CiteSpace (Fig. 7). The citing journals map and the cited journals map were the right cluster and the left cluster, respectively. The longitudinal axis of ellipses represented the paper numbers, and the horizontal axis represented the author numbers. The lines that started from the left to the right were citation links. This dual-map overlay

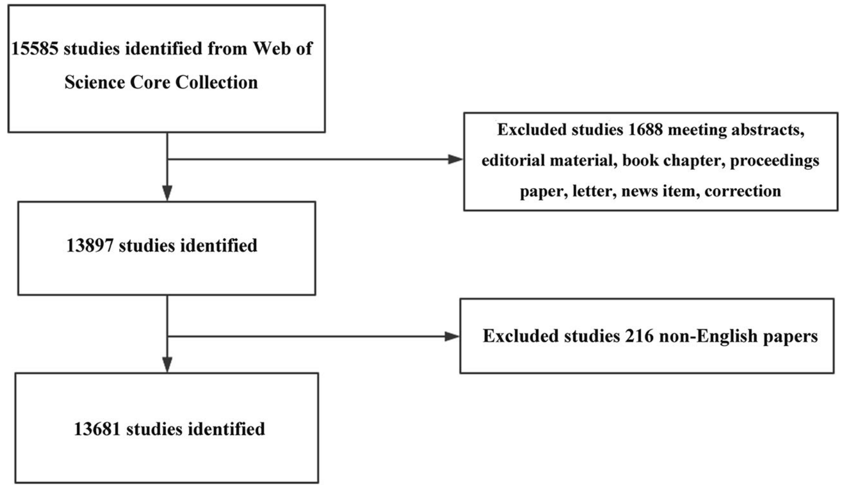


Fig. 1 The process of retrieval and exclusion criteria

indicated that most articles were published in medicine, medical, clinical, molecular, biology, immunology, veterinary, animal, and science journals, and they mainly cited journals from health, nursing, medicine, molecular, biology, genetics, environment, toxicology, and nutrition.

Regarding the top 15 journals, Environmental Health Perspectives (IF2016, 9.776) had an impact factor (IF) greater than 9.000. Three of the journals, including Environmental Science Technology (IF2016, 6.198), Atmospheric Chemistry and Physics (IF2016, 5.318), and Environmental Pollution (IF2016, 5.099) had IF between 5.000 and 9.000. Five of the journals, including Atmospheric Environment (IF2016, 3.629), Science of the Total Environment (IF2016, 4.900), Journal of Geophysical Research (IF2016, 3.454),

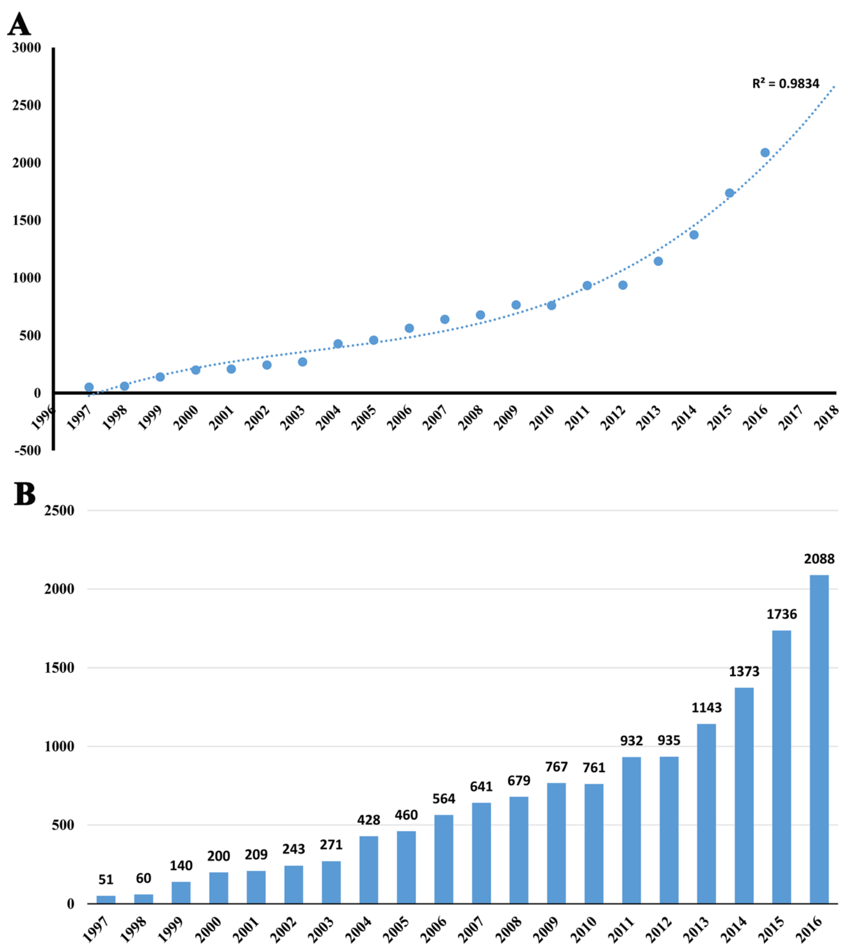


Fig. 2 Publication outputs and growth prediction. **a** The number of annual publications on $PM_{2.5}$ research from 1997 to 2016. **b** The model-fitting curve of growth trend of $PM_{2.5}$ publications

Fig. 3 Geographical map of countries/territory publication from 1997 to 2016

Atmospheric Research (IF2016, 3.629), and Environmental Research (IF2016, 3.83), had IF between 3.000 and 5.000. There was five articles in the New England Journal of Medicine (IF2016, 72.406), three reviews and five articles in the Lancet (IF2016, 47.831), and two articles in Nature (IF2016, 40.137). In summary, future development in the $PM_{2.5}$ field would likely be showcased in Atmospheric Environment because it published the most articles in the past.

Contributions of institutions

The cooperation between institutions is shown in Fig. 4b, and over 7600 institutions contributed to the publications on $PM_{2.5}$ research. The top 20 institutes are listed in Table 2. Chinese Academy of Sciences accounted for 5.80%, followed by University of California System (5.42%) and the United States Environmental Protection Agency (5.05%). Among the top 20 institutions, there were 14 American institutes, five Chinese institutes and one Canadian institution.

Through the above analysis, we found that the USA ranked first in productivity, and contribution of Asian and European countries was also prominent. Among top 20 countries/territories, only four development countries (China, India, Brazil, and Mexico) were development countries. China ranked second in publication, making significant progress in the $PM_{2.5}$ field. Furthermore, in the list of top 20 institutions, there were 14 American institutes, five Chinese institutes, and one Canadian institution. These results indicate that the USA and China were the leading countries in the $PM_{2.5}$ research.

Research areas

Figure 6b shows the $PM_{2.5}$ research areas. Obviously, environmental science ecology is still a hot area, with 8365 documents. Other hot fields included meteorology atmospheric science, engineering, public environmental occupational health, and toxicology.

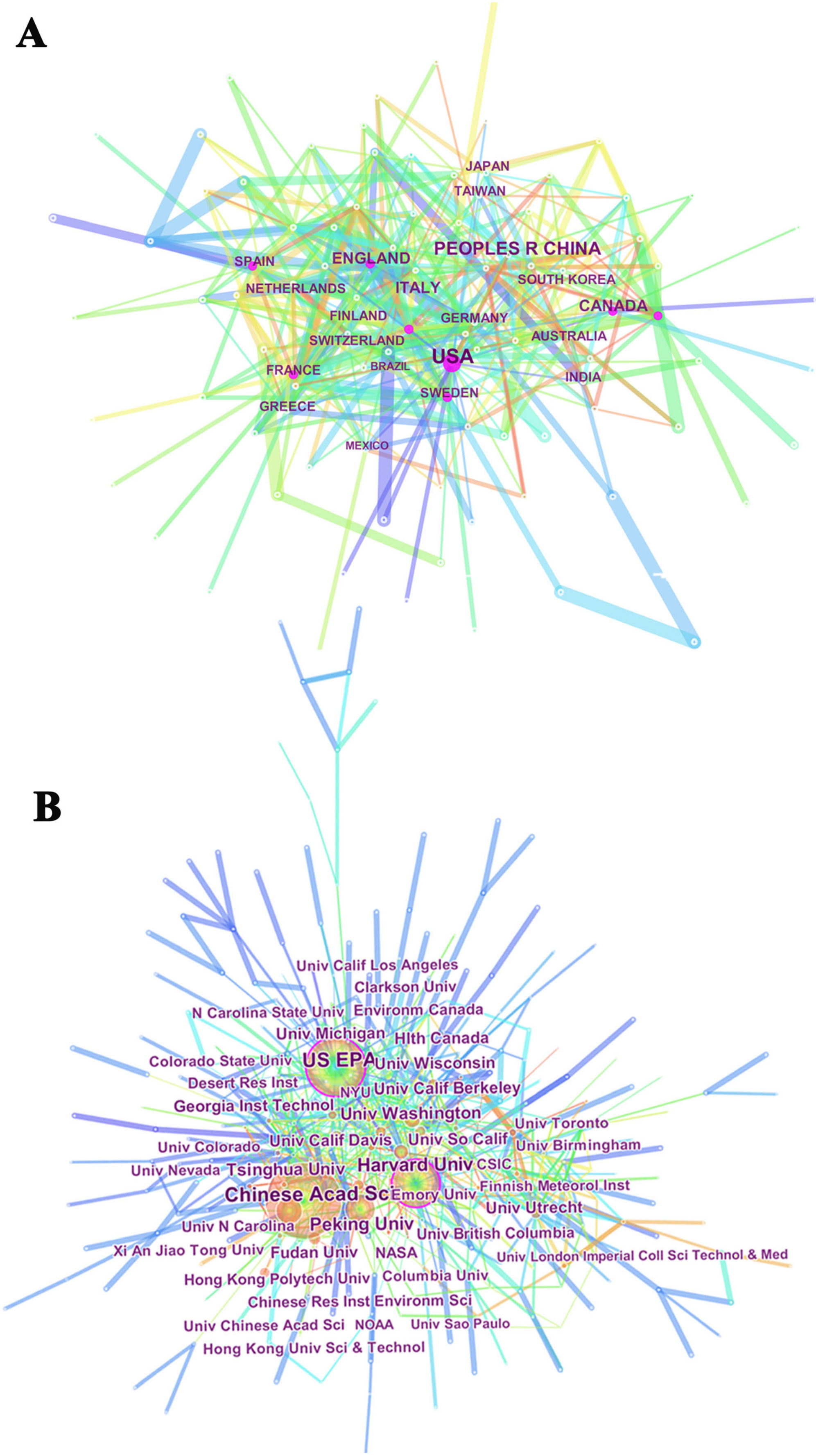
Contributions of authors

Generating a co-author map using CiteSpace outlined the cooperation between authors (Fig. 8a). Regarding the authors who were active, Querol X ranked the first (187 publications), followed by Schauer JJ (161 publications) and Hopke PK (159 publications). The top 10 authors are presented in Table 3.

To estimate the scientific relevance of publications, author citations have been analyzed using CiteSpace and presented as citation networks (Fig. 8b). As shown in Table 3, the top three co-cited authors are Pope CA (5019 citations), Chow JC (3447 citations), and Schwartz J (2563 citations).

Regarding the top 10 authors, each contributed to at least 135 publications, known as "prolific authors." Querol X et al. (2014, 2016, 2004) focused on atmospheric environmental assessment of particulate matter pollution in Spain. Schauer JJ et al.'s (Schauer 2015; Schauer et al. 2002, 2001) articles emphasized the environmental health research and atmospheric chemistry. Hopke PK et al. (Hwang et al. 2008; Ogundele et al. 2016; Tiwari et al. 2015) looked into the environmental monitoring and analytic technology of air pollution source. Three of the prolific authors (Chow JC, Schauer JJ, and Schwartz J) were listed in the top 10 co-cited authors of the citation, indicating that they played an important role in the $PM_{2.5}$ study. For co-cited authors, the authors with at least 2500 co-citation counts, including Pope CA, Chow JC and Schwartz J, and Pope CA et al. (Lux and Pope 2009; Pope 2015; Pope et al. 1999) mainly explored the heart disease associated with particulate air pollution. Chow JC et al. (Chow et al. 2015, 2005, 2006) made crucial contributions to atmospheric chemistry and $PM_{2.5}$ monitoring. Schwartz et al.(2015, 2005) and

Fig. 4 The analysis of countries/territories and institutions. **a** Network map of countries/territories engaged in $PM_{2.5}$ research. **b** Network map of institutions engaged in $PM_{2.5}$ research ▶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Columbia Univ
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Table 1 The distribution, citation frequency, and H-index of publications in the top 20 countries/territories

Number	Countries/territories	Publication	%	Total citations	H-index
1	USA	5941	43.43%	217,009	172
2	People's Republic of China	2863	20.93%	70,822	103
3	Canada	832	6.08%	34,787	75
4	England	730	5.34%	32,721	86
5	Italy	692	5.06%	20,817	68
6	Germany	667	4.88%	33,189	87
7	Spain	560	4.09%	22,791	70
8	Taiwan	558	4.08%	13,382	47
9	India	492	3.60%	11,372	43
10	Japan	454	3.32%	12,817	53
11	South Korea	428	3.13%	12,634	48
12	France	411	3.00%	15,805	57
13	The Netherlands	390	2.85%	24,811	75
14	Greece	357	2.61%	15,536	56
15	Finland	325	2.38%	13,024	63
16	Switzerland	304	2.22%	18,432	58
17	Australia	286	2.09%	11,275	45
18	Sweden	278	2.03%	13,858	53
19	Brazil	222	1.62%	4910	35
20	Mexico	193	1.41%	9290	42

Schwartz and Neas (2000) studied the relationship between air pollution and health. These scholars were leaders in the $PM_{2.5}$ research, and their reports could have a huge impact in the future and help others to open their minds.

Reference analysis on $PM_{2.5}$

Reference analysis is one of the most important indexes of bibliometrics. A cited reference co-citation map was generated with 532 nodes and 926 links (Fig. 9a). Each cluster revealed the core literature group, high citation, and academic relationship in each period, and revealed research field, structure, and branches, showing a distinct specialty or a thematic concentration. Among the 17 clusters, cluster #0 (particulate pollution) was largest, followed by cluster #1 (Beijing), cluster #2 (chemical mass balance), and cluster #3 (sulfate). All clusters were also presented in a timeline view, showing the progress of the subject and the development trend (Fig. 9b).

The reference co-citation time-view map indicated that most clusters were concentrated between 2006 and 2012. The top ten co-cited references are listed in Table 3, which were regarded as the knowledge base for the $PM_{2.5}$ research. Among them, an article that Dockery DW published in the New England Journal of Medicine had the highest value of citations (1993, 1200 citations), suggesting that it played fundamental and important role in the $PM_{2.5}$ research, followed by articles published by Pope CA (2002, 1103 citations) in JAMA, Pope CA (2006,

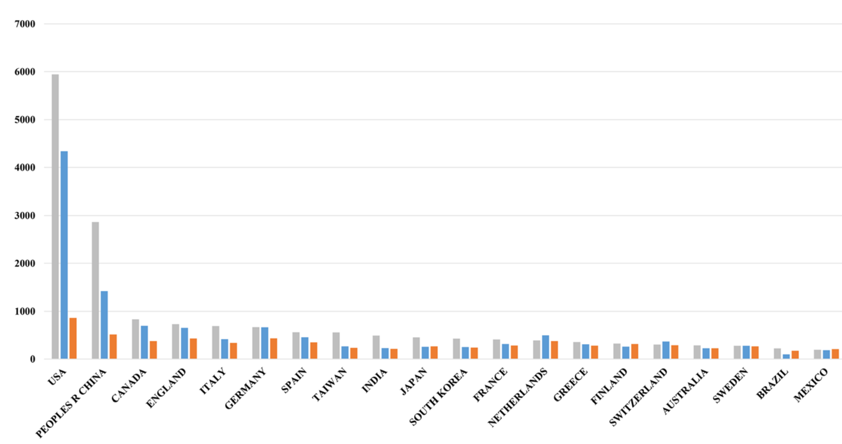
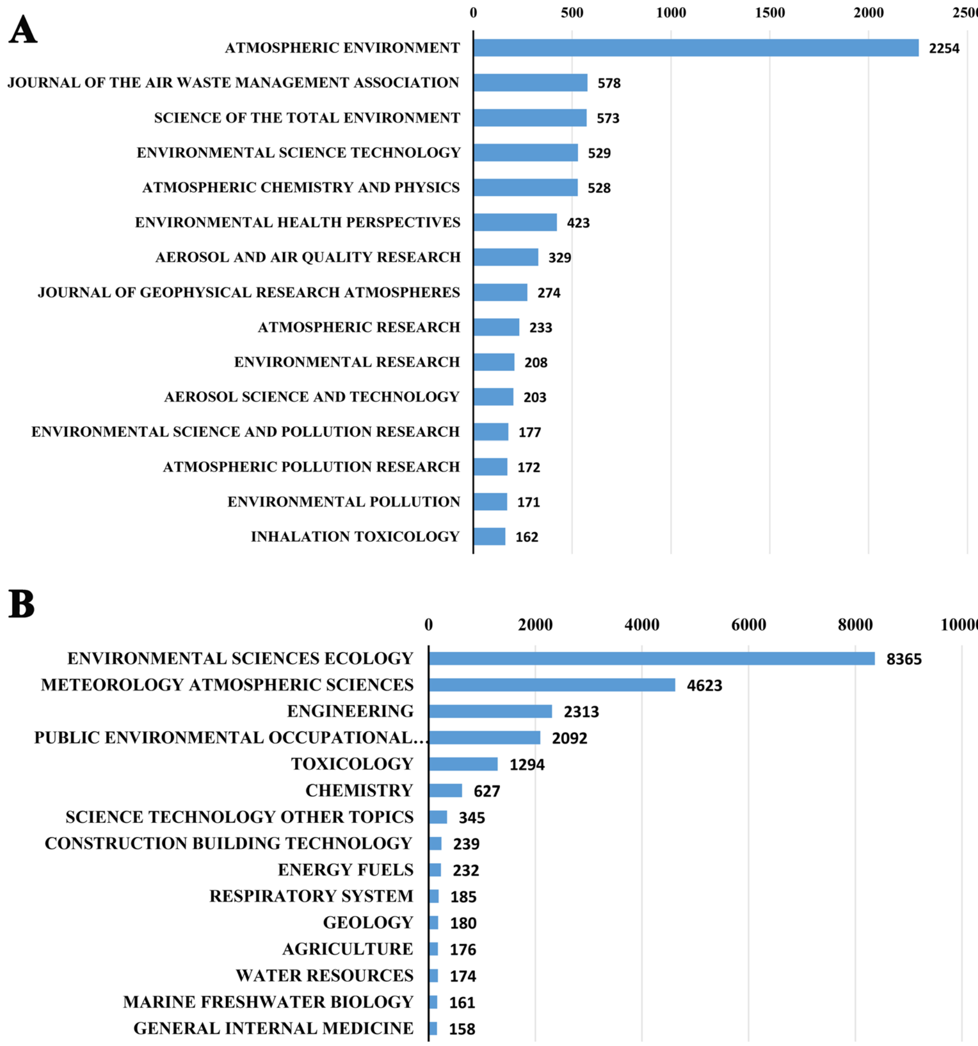


Fig. 5 The number of publication, citations, and H-indexes on $PM_{2.5}$ research of the top 20 countries/territories

Fig. 6 Contributions of different journals and institutes to $PM_{2.5}$ research. **a** Distribution of top 15 journals published on $PM_{2.5}$ research. **b** the top 15 research areas focusing on $PM_{2.5}$ research



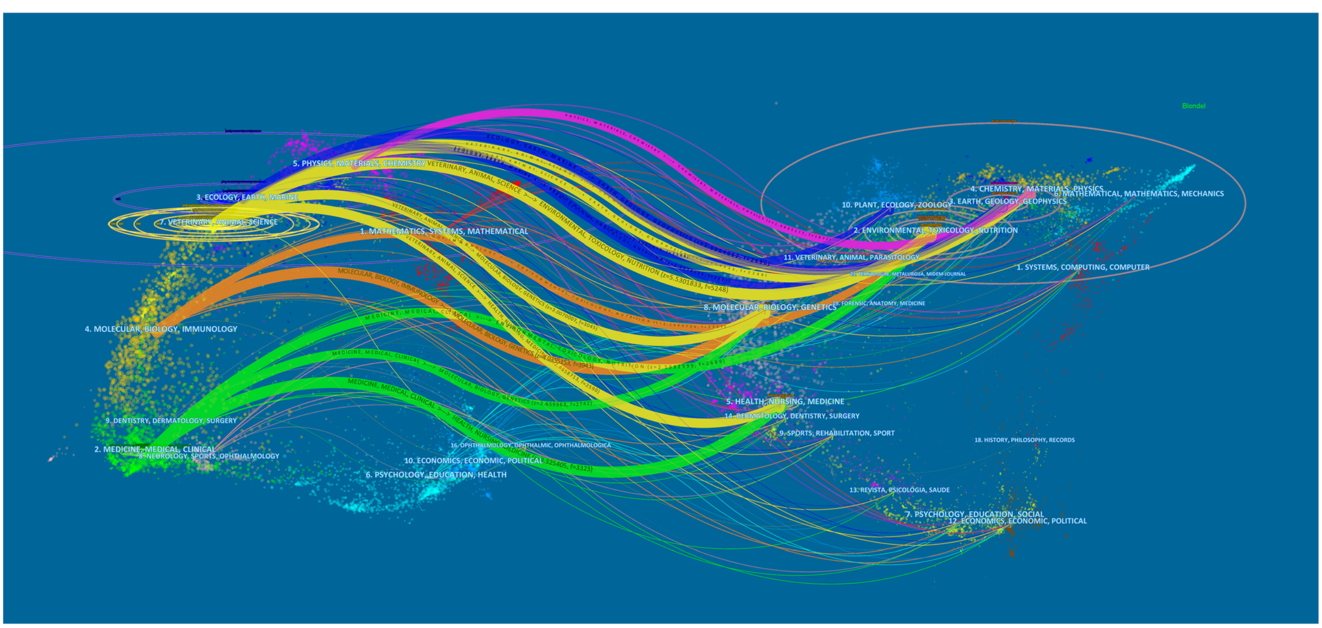


Fig. 7 The dual-map overlay of journals related to $PM_{2.5}$ research

Table 2 The top 20 institutions contributed to publications on $PM_{2.5}$ research

Rank	Institutes	Publication	%
1	Chinese Academy of Sciences	793	5.80%
2	University of California System	742	5.42%
3	United States Environmental Protection Agency	691	5.05%
4	Harvard University	612	4.47%
5	Peking University	344	2.51%
6	University System of Georgia	308	2.25%
7	Nevada System of Higher Education NSHE	282	2.06%
8	Tsinghua University	279	2.04%
9	University of North Carolina	279	2.04%
10	University of Washington	270	1.97%
11	Desert Research Institute NSHE	264	1.93%
12	University of Washington Seattle	264	1.93%
13	University of California Davis	245	1.79%
14	Consejo Superior de Investigaciones Cientificas CSIC	240	1.75%
15	Georgia Institute of Technology	232	1.70%
16	University of California Berkeley	231	1.69%
17	Institute of Atmospheric Physics CAS	218	1.59%
18	University of Southern California	209	1.53%
19	United States Department of Energy DOE	201	1.47%
20	HLTH Canada	193	1.41%

957 citations) in Journal of the Air & Waste Management Association 1995, and Brook RD (2010, 624 citations) in Circulation. Furthermore, Atmospheric Chemistry and Physics, American Journal of Respiratory, and Critical Care Medicine and Atmospheric Environment also published some highly influence articles in this field. These journals were fundamental for $PM_{2.5}$ research.

Analysis of keywords

Keywords can reflect reasonable descriptions of research hotspots (some researchers' concerns about a series of related research questions and concepts), and burst words (emerging trends and abrupt changes over a period) could indicate new frontier topics. Therefore, we can comprehend an understanding of the development of research topic through the keywords of an article (Chen et al. 2012; Synnestvedt et al. 2005). Keywords with the strongest citation bursts were detected and analyzed using CiteSpace, shown in Fig. 10, and we deduced the top four research hotspots and listed the following: climate change (2015–2016), meta-analysis (2015–2016), cardiovascular mortality (2015–2016), and long-term exposure (2015–2016).

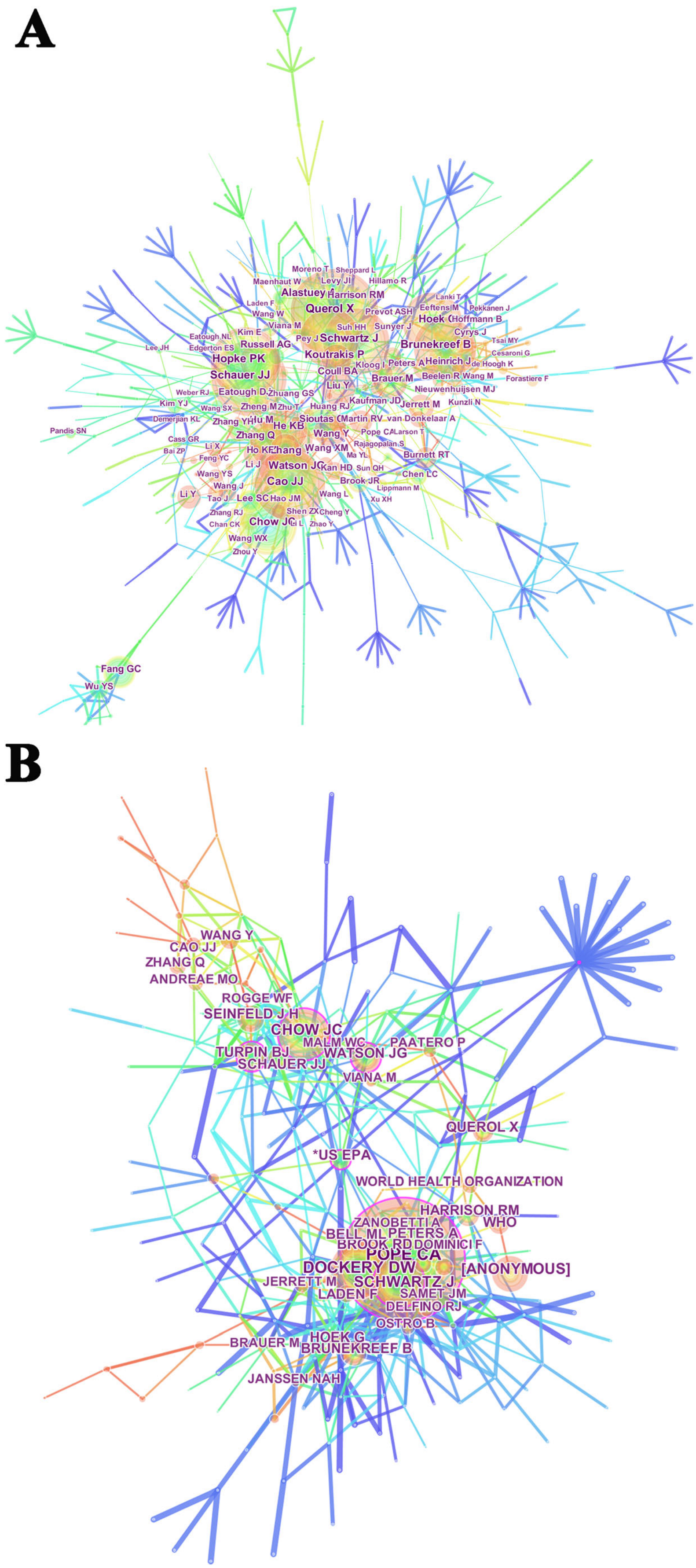
Climate-change Climate change, exclusive of changes in air pollutant emissions, can significantly increase levels of $PM_{2.5}$ and affects mortality associated with $PM_{2.5}$ pollutants. (Forsberg et al. 2012; Garcia-Menendez et al. 2015; Madaniyazi et al. 2015; Tagaris et al. 2009).

Meta-analysis The statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings (Tucker 1996). Many meta-analysis papers on $PM_{2.5}$ research have been published in recent years, including some high-quality papers (Atkinson et al. 2014; Avery et al. 2010; Singh et al. 2017).

Cardiovascular mortality Cardiovascular diseases (CVD) include disorders of the heart and blood vessels, particularly those supplying the brain (ischemic and hemorrhagic stroke) (Wang et al. 2015). Long-term exposure to $PM_{2.5}$ can increase risk of cardiovascular disease (CVD) morbidity and mortality (Lee et al. 2014; Pope et al. 2015; Tillett 2012).

Long-term exposure To assess the effect of long-term exposure to $PM_{2.5}$, increasing scholars have been committed to this field and have reported that long-term exposure to $PM_{2.5}$ can elevate the risk of various diseases, including type 2

Fig. 8 The analysis of authors. **a** Network map of active authors contributed to $PM_{2.5}$ research. **b** Network map of co-cited authors contributed to $PM_{2.5}$ research ▶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diabetes mellitus (Wang et al., 2014a, b), cardiovascular diseases (Pope et al. 2015), and chronic airway diseases (Ren et al. 2016).

$PM_{2.5}$ and PM_{10}

From 1997 to 2016, a total of 10,355 papers of PM_{10} were published (Supplementary Fig. 1). The overall trend of PM_{10} research was growing and maintaining a steady growth rate (Supplementary Fig. 1). However, the publication of $PM_{2.5}$ started to explode from 2012, indicating that more researches focused on $PM_{2.5}$. Similarly, Figs. 9 and 10 show that PM_{10} research was the hotspot about 5 years ago. Admittedly, PM_{10}, as well as $PM_{2.5}$, has adverse health effects. Accumulated evidence reported that PM_{10} could harm the human respiratory system, immune system, and circulatory system (Reyes-Zarate et al. 2016; Saygin et al. 2017; Xu et al. 2017). However, $PM_{2.5}$ should be attached more importantly. Firstly, many cities have exceeded the WHO air quality guidelines of PM_{10} (50 $\mu g/m^3$) and $PM_{2.5}$ (25 $\mu g/m^3$) (Lu et al. 2015). By analyzing the published data, Zhou et al. (2016) claimed that abatement of $PM_{2.5}$ was crucial for cutting down pollution and improving air quality in China. Secondly, because their chemical composition, trace element content, strong acid content, sulfate content, and particle size distribution are different, $PM_{2.5}$ are more toxic than PM_{10} (Harrison and Yin 2000). In addition, the WHO stated that $PM_{2.5}$ was more hazardous than coarse particles (PM_{10}) regarding mortality and cardiovascular and respiratory endpoints (Englert 2004). In the future, we should make an intensive study of $PM_{2.5}$.

Contributions of bibliometric analysis

This study not only presented the global trend in $PM_{2.5}$ research but also provided useful information for future $PM_{2.5}$ research.

Why should we take $PM_{2.5}$ seriously? The present study showed that $PM_{2.5}$ increased the global burden. The first, high-density population and industrial production will inevitably discharge a large number of fine particles. Nowadays, $PM_{2.5}$ has been used for ambient air quality management worldwide (Weichenthal et al. 2013). As shown in Figs. 9 and 10, developing countries are currently facing severe air pollution in the rapid development stage, especially China. Less than 50 largest cities can reach air quality standards in China recommended by the WHO (Xing et al. 2016). Seven of these cities are listed as one of the 10 most polluted cities in the world. The second, $PM_{2.5}$, as well as PM_{10}, caused assignable negative effects on human health. By reference and hotspots analysis, related keywords are listed the following: inflammation, low birth weight, mortality, long-term exposure, and cardiovascular mortality. Exposure to them, the risk of cardiovascular mortality, heart rhythm abnormalities, and stroke could increase. However, the long-term effect of them is more severe, with evidence showing potentially harmful effects on cardiopulmonary function, neurodegeneration (Kioumourtzoglou et al. 2016), kidney function

Table 3 The top 10 authors, co-cited authors, and co-cited references in $PM_{2.5}$ research

Number	Author	Count	Co-cited author	Count	Co-cited reference	Count
1	Querol X	187	Pope CA	5019	Dockery DW, 1993, New Engl J Med, v329, p1753	1200
2	Schauer JJ	161	Chow JC	3447	Pope CA, 2002, Jama-J Am Med Assoc, v287, p1132	1103
3	Hopke PK	159	Schwartz J	2563	Pope CA, 2006, J Air Waste Manage, v56, p709	957
4	Cao JJ	151	Dockery DW	2227	Brook RD, 2010, Circulation, v21, p2331	624
5	Alastuey A	147	Watson JG	2087	Turpin BJ, 2001, Aerosol Sci Tech, v35, p602	541
6	Chow JC	145	Schauer JJ	1740	Seinfeld J. H., 1998, Atmospheric Chem Phy	525
7	Schwartz J	145	Brook RD	1579	Birch ME, 1996, Aerosol Sci Tech, v25, p221	465
8	Koutrakis P	144	US EPA*	1540	Schwartz J, 1996, J Air Waste Manage, v46, p927	462
9	Brunekreef B	140	Paatero P	1501	Pope CA, 1995, Am J Resp Crit Care, v151, p669	439
10	Watson JG	135	Turpin BJ	1494	He KB, 2001, Atmos Environ, v35, p4959	424

*US EPA is a group author

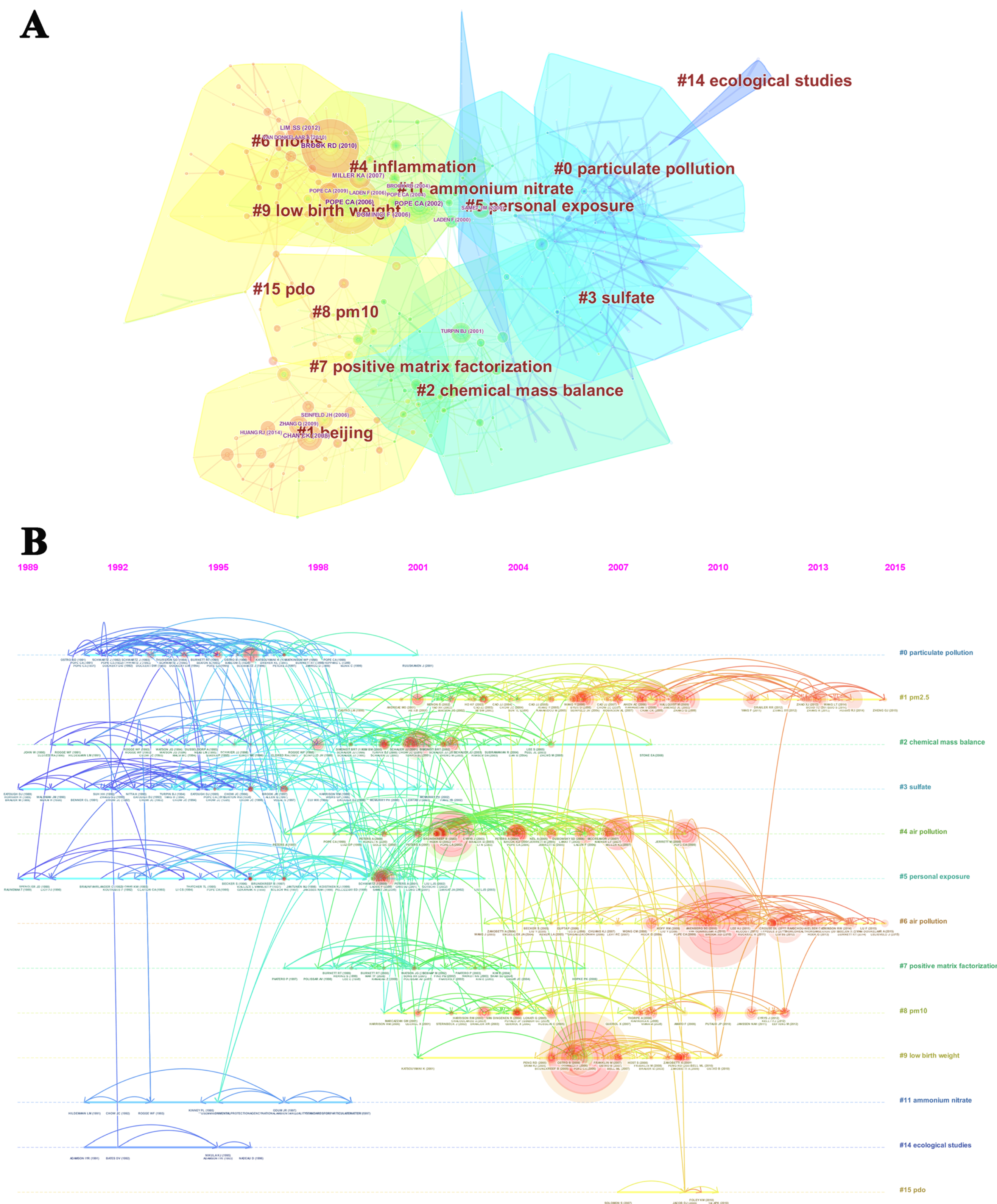

Fig. 9 The analysis of references. **a** Co-citation map of references from publications on $PM_{2.5}$ research. **b** Co-citation map (timeline view) of references from publications on $PM_{2.5}$ research

(Seltenrich 2016), pregnant women, and children. Global burden of environment and disease is becoming increasingly heavy under the catalysis of $PM_{2.5}$, so we should face up to the harm of $PM_{2.5}$ and reduce it.

How to evaluate $PM_{2.5}$? Figures 9 and 10 show keywords, including "positive matrix factorization," "ecological study," "size distribution," "use regression-model," and "meta-analysis". Mathematical statistics and epidemiological methods can be used to study the trace composition (Hu et al. 2014), the mechanism (Wang et al., 2014a, b), and harmful effects of $PM_{2.5}$. In addition, we can use various statistical models (such as regression-model, Bayesian Hierarchy Model) to predict spatial variation (Wu et al. 2015), estimate global burden (Arnold 2014), study the source apportionment of $PM_{2.5}$ (Taghvaee et al. 2018), and simulate the spatiotemporal distribution (Lee et al. 2016). In the future, the establishment of the models will be an important part of the $PM_{2.5}$ research.

What should we do? Countries have actively taken measures to deal with $PM_{2.5}$. In July 1997, the United States Environmental Protection Agency (EPA) first proposed to use $PM_{2.5}$ as the national environmental air quality standard. The German government is energetically encouraging the installation of vehicle-exhaust-cleaning devices. In Tokyo, all taxis use natural gas. And in China, the government is establishing a nationwide monitoring network for air pollution to master characteristics and composition differences of $PM_{2.5}$ in different regions. Moreover, for the individual, the awareness, like reducing diesel exhaust and personal exposure, is particularly important. Such awareness has the potential to create a cleaner environment and protect ourselves. Frank et al. suggested that such awareness is largely dependent on the best

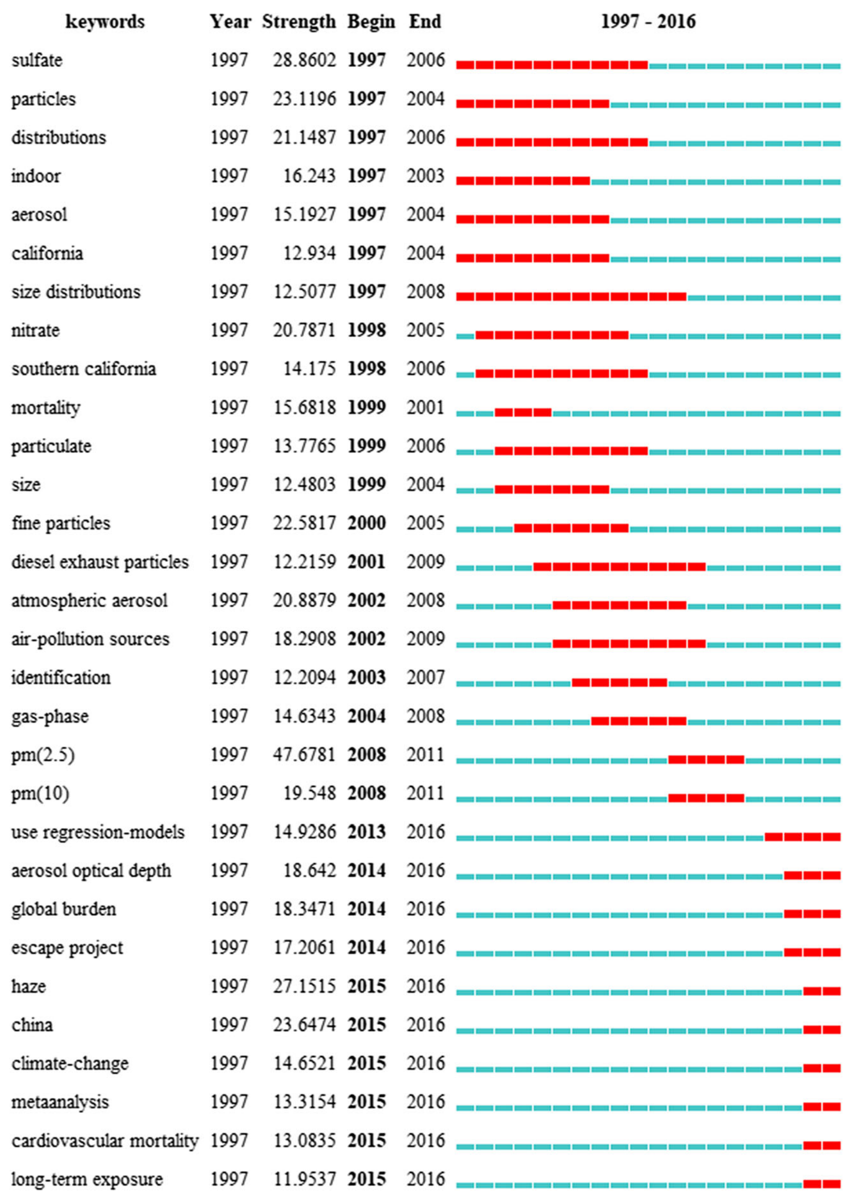

Fig. 10 The keywords with the strongest citation bursts of publications on $PM_{2.5}$ research. The time intervals were plotted on the blue line, while the periods of burst keywords were plotted on the red line, indicating the beginning and end of the time interval of each burst

monitoring, prediction, and reporting of air pollution (Kelly and Fussell 2015). Sensitive populations (the elderly, children, and patients with chronic cardiopulmonary problems) should strengthen self-protection awareness, such as reducing personal exposure and taking antioxidant supplements or nutritious food (Xing et al. 2016). Therefore, in the future, scholars can be committed to the study of clean energy, and the public should improve the awareness of personal health and environmental protection.

Strengths and limitations

The present study is the first bibliometric analysis of the trend in $PM_{2.5}$ research over the past decade. Data on $PM_{2.5}$ publications in this study were retrieved and collected from WoSCC, and the analysis was relatively objective and comprehensive. This bibliometric study provided information about $PM_{2.5}$ research, including the trend of $PM_{2.5}$ research, cooperative institutions or authors, papers and journals with the reference value, and research frontiers in this field.

However, this study is not perfect with some limitations. First, the WoSCC database mainly includes literature in English and few non-English publications. Therefore, some high-quality non-English research studies on $PM_{2.5}$ may be excluded, resulting in an incomplete analysis. Future work should involve other non-English language studies. Second, papers published in 2017 were not included in this study, so the analysis of popular topics did not cover the keywords of 2017.

Conclusion

Over the last 20 years, there have been increasing findings from many research disciplines (e.g., environmental science ecology, atmospheric science, engineering, public environmental occupational health, and toxicology) that mainly committed to reducing the impact of $PM_{2.5}$ on health.

By the present a bibliometric study, including annual global publications, reference analysis, and research hotspots, we can find that more scholars have paid attention to $PM_{2.5}$, especially cardiovascular mortality and the impact of long-term exposure to $PM_{2.5}$. In conclusion, $PM_{2.5}$ is a significant public health problem, responsible for potential long-term health effects, and we should pay attention to it, monitor it, and reduce it.

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