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A Review of Urban Street Valley Greening and Pollutant Research Based on CiteSpace

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ABSTRACT

With the continuous development of cities and the rapid increase of urban population, the problem of air pollution in cities has become increasingly prominent. Improving the living environment has become a hot topic at present. As one of the areas where people stay the longest, the street is directly connected to the atmosphere and is most affected by air pollutants. To explore the current research status and hotspot evolution of pollutants in urban street valleys, a bibliometric method was adopted. Through the classification and statistics of 182 papers in the WOS core collection on the diffusion mechanism of pollutants in street valleys, the research on street valley greening and pollutant emission characteristics, and the improvement of air quality in street valleys, The existing research results are summarized and sorted out from multiple aspects such as the number of published articles, co-cited journals of the literature, publishing institutions, and co-occurring keywords. The analysis of 182 literatures in the WOS core collection shows that the papers on urban street valley greening and pollutants began in 2012, and the number of published papers has shown a trend of increasing year by year and then decreasing. The research content mainly focuses on fields such as environmental science and architecture; The key words co-occurrence network graph reveals that the research hotspots in this direction are developing towards the wind environment. The research on the impact of urban street and valley greening on pollutant diffusion started relatively early. It is suggested that further related research be carried out in the fields of atmospheric science, physics, ecology, etc., to make greater contributions to improving the urban living environment.

KEYWORDS

Greening of the Street Valley; Pollutant; Micro-Environment; Citespace 6.2.R4.

1. INTRIDUCTION

With the rapid development of cities and the continuous increase in population, the problem of urban air pollution is becoming more and more serious. Therefore, improving the living environment has become a topic of great concern at present. Many studies have shown that air pollutants are closely related to human health and many common diseases [1]. For instance, particles absorbed by blood vessels can cause changes in human body functions, leading to diseases such as myocardial infarction and arrhythmia. The concentrations of PM2.5 and PM10 are positively correlated with daily cardiovascular mortality and respiratory mortality[2-5]. In addition, high concentrations of gaseous pollutants such as ozone, carbon monoxide, nitrogen dioxide and sulfur dioxide can lead to problems such as low fertility, respiratory diseases and neurasthenia[6, 7].

Streets, as one of the areas where people stay the longest, are directly connected to the atmosphere and are affected by air pollutants. Due to the density of buildings, the environmental characteristics of urban streets can be similar to those of natural canyons, which are called street canyons. The flow pattern within the street canyon is strongly influenced by the street scale. The air quality in the street canyon seriously affects the exposure level of pedestrians to pollutants and is directly related to the indoor air quality of the surrounding buildings. In order to improve the environment of the street canyon, it is necessary to clarify the distribution and diffusion characteristics of pollutants[8].

At present, most of the research on pollutants in street valleys focuses on specific aspects, such as the influence of environmental wind speed on pollutant diffusion and methods to improve the environment of street valleys. However, there is a lack of comprehensive assessment of the diffusion mechanism, distribution pattern, influencing factors and improvement measures of pollutants under the greening conditions of the street valley[9, 10]. Therefore, this study aims to summarize and sort out the existing literature and use CiteSpace visualization diagrams to explore the impact of street valley greening on pollutant diffusion, providing a basis for the efficient natural ventilation design of buildings and the improvement of air quality in street valleys. Specifically, this study will be explored from the following aspects:

Summarize and sort out the existing literature, and analyze the influence mechanism and degree of street valley greening on the diffusion of pollutants. By sorting out the relevant literature, understand the mechanism of pollutant diffusion and the research progress of the impact of street valley greening on it, providing a reference for further research.

(2)Using CiteSpace visualization diagrams, analyze the research hotspots and frontiers of the impact of street valley greening on pollutant diffusion. The literature was visually analyzed through CiteSpace software to understand the research hotspots and frontiers at home and abroad regarding the impact of street valley greening on pollutants, providing directions for subsequent research.

The significance of this study lies in that by deeply exploring the influence mechanism and degree of street valley greening on pollutant diffusion, and studying the wind environment and the convective diffusion law of pollutants in the street valley under the influence of trees, it is helpful to analyze the mechanism of air flow and the distribution law of pollutants in the street valley, improve the living comfort of residents on both sides of the street, and focus on clarifying the ventilation mechanism of the street valley. To expound the urban heat island effect indirectly. At the same time, it can contribute to maintaining the stability of the urban living environment and promoting the harmonious development of human culture and the natural environment[11].

2. RELATED CONCEPTS AND THEOIES

2.1. Street layout

The three-dimensional landscape pattern of urban blocks is an important factor determining the air flow and the diffusion effect of air pollutants within the blocks, and it affects the air environmental quality within the blocks. The spatial layout and structure of urban streets and canyons are unreasonable, often causing local air pollution. High-density buildings reduce the ventilation and self-purification capacity of cities. From the perspective of the composition of the spatial form of the street valley, the aspect ratio (H/W), aspect ratio (L/W), and height ratio (h2/h1) of the buildings on both sides of the street valley are the main factors affecting the air flow and the diffusion and dilution of pollutants within the street valley. In addition, the roof form of buildings, the sky landscape factor (SVF), ground vegetation, and the external environment all have certain influences on the diffusion of pollutants in street canyons. There is a strong positive correlation between the width-to-height ratio of street canyons and the pollutant concentration of street canyons. That is, the larger the length-to-diameter ratio is, the worse the diffusion ability of pollutants is and the higher the concentration is[12, 13]. The influence of the length-to-width ratio of the street canyon on pollutant diffusion is the same as that of the height-to-width ratio, and there is also a high positive correlation between the two. The influence of vegetation on the diffusion of pollutants in street canyons is mainly reflected in two aspects: aerodynamic factors and sedimentation effects[14-16]. The effect of sedimentation in reducing the concentration of pollutants through filtration. Aerodynamic factors have altered the air flow organization within and above the street canyon, reducing air exchange, lowering the pollutant concentration near the windward wall, and increasing the pollutant concentration near the leeward wall.

2.2. Tree characteristic factors

The influence of trees on air flow and pollutant diffusion within the street valley involves many factors, such as leaf area density, tree planting layout, canopy shape, trunk, and whether the trees are continuous[17-22]. The shape of trees has an important influence on the damping effect of the wind field. More and more studies have refined the shape of tree canopies, changing them from the original rectangular shape to other regular shapes (such as circles, triangles, and conical shapes), until the irregular shape of the tree can be roughly described[23]. Finally, the leaf area density of trees is an important research factor. To describe trees more accurately, some scholars have adopted the leaf area density curve that considers the variation of leaf area density with tree height. Given different leaf area densities to describe leaf density, it is usually possible to distinguish the influence of trees in different seasons[24-26].

2.3. Describe the trees in the urban street canyons with mathematical models

In the mathematical model, the dynamic information of the airflow is described by the Navier-Stokes equations, including the mass equation, the momentum equation and the energy equation. The turbulent flow of air is described by using the Large Vortex Model (LES), the Reynolds stress Model (RSM) or the Reynolds average Navier-Stokes Model (RANS). The LES model has advantages in terms of computational accuracy, while the RANS model is more prominent in terms of computational efficiency. The transport of pollutants in the air is generally described by La- in Lagrange or Euler frames. Under the Euler framework, the convection-diffusion model Outlines the pollutant concentration distribution caused by air convection and turbulence effects. This model ignores the gravitational effect of pollutants and holds that air and pollutants form a miscible phase. Some scholars also use particles to characterize pollutants based on the Lagrange framework, but there are drawbacks such as large numerical simulation workload and fewer particles. In conclusion, the coupling of the above-mentioned mathematical models forms the basis of numerical models for simulating air flow and pollutant diffusion in the field of urban street canyon computing. When studying the influence of trees in urban street canyons on the wind environment and the diffusion of pollutants, tree trunks and branches impede the airflow, thus the tree canopy forms a damping effect on the airflow. Accurately describing the damping and blocking effects of trees on air currents is the basis and key to obtaining aerodynamic information of urban street canyons[27, 28]. Different researchers adopt different mathematical or physical models to describe trees [29]. When the tree crown is regarded as dense tree vegetation, it can be seen as a solid circle in mathematical simulation. However, this method is only applicable to very dense vegetation. Most researchers adopt the porous medium model and the vegetation resistance source model to study the influence of tree crowns (leaves) on airflow. The basic principle is to achieve the influence of the tree canopy on the airflow by adding the source term to the momentum equation, but the expression of its mathematical model is quite different [30, 31].

3. A REVIEW OF THE IMPACT OF URBAN STREET VALLEY GREENING ON POLLUTANT DIFFUSION

3.1. Data sources and methods

Regarding the impact of urban street valley greening on pollutant diffusion, there are no specific studies in China at present. Therefore, in this study, the core database of SCI Science Citation Index (i.e., Web of Science, hereinafter referred to as WOS) was used as the search source. The search time was January 2, 2024, and the time span of the retrieved journals was all set from 1992 to 2023. WOS used "city street canyon greening" and "pollutants" as the search keywords and initially screened out 1,602 English documents. In order to further ensure that the sources of the literature are more in line with this study, the author screened 1,602 literatures, eliminated the literatures with little relevance to this study, selected 182 literatures, and then imported them into Citespace and used the Citespace 6.2.R4 version software for format conversion. After the transformation was completed, this study used Citespace 6.2.R4 software to conduct visual analysis on the issuing countries, issuing institutions, keywords, etc., in order to explore in detail the evolution of the research on the correlation between pollutant emissions and street canyon greening, etc.

3.2. Research tool

CiteSpace is a software developed by Dr. Chaomei Chen from the School of Information Science and Technology at Drexel University in the United States[21], and it is used for data mining, information analysis, bibliometrics and visual presentation. This software comprehensively utilizes the theories and research methods of multiple disciplines such as information science, scientometrics and statistics. This interdisciplinary integration enables the software to conduct a comprehensive analysis of knowledge from multiple perspectives and dimensions. It can not only generate static "knowledge structure framework diagrams", but also display dynamic "knowledge development process spectra". This combination of static and dynamic aspects enables researchers to not only understand the current structure of knowledge but also track its historical development, thereby obtaining a more comprehensive understanding. Meanwhile, this software can also detect the future development trends or directions of knowledge and present them in a visual way**错误!未找到引用源。**.Whether in the fields of scientific research, education or industry, understanding the knowledge structure and development trends of a specific area is of vital importance. CiteSpace provides strong decision support for these fields through its powerful analytical capabilities.

After CiteSpace was introduced to China, many disciplines began to use knowledge graphs to analyze the research hotspots of their disciplines. For instance, in the field of carbon sink research for traffic pollutants, some researchers have utilized this tool to conduct data mining and knowledge graph analysis in areas such as factor analysis, evaluation, system analysis, control measures, and pollutants.

4. ANALYSIS OF BIBLIOMETRIC RESULTS

4.1. The number of published articles and the co-cited journals of the literature

4.1.1. Statistics of the number of documents

Statistical analysis was conducted on the 182 valid literatures screened out, and the results are shown in Figure 1. As can be seen from Figure 1, the trend of the number of research literatures on the impact of urban street and valley greening on pollutant diffusion abroad shows an inverted V-shaped development and can be divided into three stages: ①The period from 2013 to 2018 was the initial development period, with a small number of published papers and slow growth.②From 2019 to 2022, it was a period of rapid development, with a rapid increase in the number of papers and abundant achievements. ③From 2023 to the present, the number of journal articles has shown a downward trend, and the research enthusiasm has declined to a certain extent.

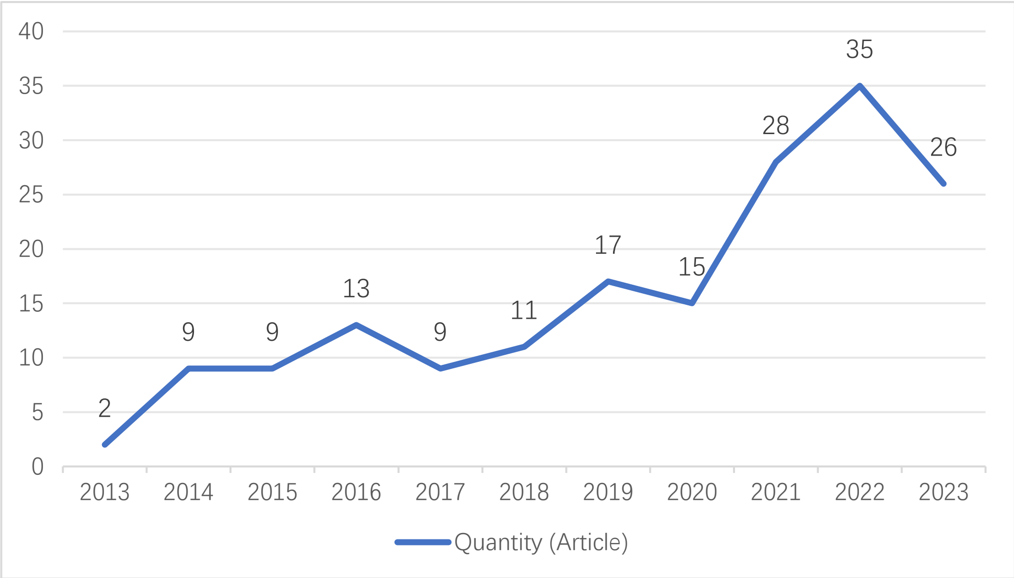

Figure 1. The annual variation in the number of research literatures on the relevant impacts of street valley greening on pollutant emissions

4.1.2. Distribution of co-cited journals in the literature

Knowledge graph analysis of co-cited journals can examine the main sources and type characteristics of knowledge dissemination in the field related to the impact of urban street and valley greening on pollutant diffusion. In the Citespace software, the network nodes were set as Cite Journals for statistics (Table 1). It was found that there were more natural science journals involved, but mainly those of types such as environmental science and architecture. Among them, the top three are atmospheric environment, built environment and SCI overall environment, which to a certain extent lead the development of this field.

Table 1. A list of highly cited Journals on the Correlation between Urban Street Valley Greening and Pollutant Diffusion

serial number	quantity	centrality	Year of publication	Journal Name
1	148	0.00	2014	ATMOS ENVIRON
2	140	0.02	2014	BUILD ENVIRON
3	129	0.01	2014	SCI TOTAL ENVIRON
4	124	0.01	2014	ENVIRON POLLUT
5	116	0.01	2014	URBAN FOR URBAN GREE
6	92	0.01	2014	BOUND-LAY METEOROL
7	83	0.02	2015	LANDSCAPE URBAN PLAN
8	80	0.00	2017	SUSTAIN CITIES SOC
9	77	0.02	2014	ENERG BUILDINGS
10	69	0.02	2014	J WIND ENG IND AEROD

4.2. Country and institution analysis

The Citespace software was used to analyze the publishing institutions and generate the network map of the countries to which the authors of the published papers belong (Figure 2). In the "By Citation" section of the Control Panel, the Threshold value of "Threshold" was set to 5 and the number of generated network nodes was 200. The number of connections between nodes is 507. By collating the data of more than 5 published articles (Table 2), it can be known that the overall number of published articles in China and some developed countries in Europe and America is relatively large.

The number of published articles in China is 85, ranking first. The United States, the United Kingdom, Italy, Germany, France and others followed closely behind and made significant contributions to the research in this field. Due to the relatively serious air quality in domestic cities during this period, there is a necessity and urgency for research. Most of the research fields focus on the mathematical models of street valley greening and pollutant diffusion. There are many related studies on the impact of urban street valley greening on pollutant diffusion. Therefore, it leads in the number of published papers in the research direction.

Figure 2. Network map of the country to which the author of the article belongs

Table 2. Issuing country

The country to which the document belongs	The number of published articles
PEOPLES R CHINA	85
USA	21
ENGLAND	20
ITALY	20
GERMANY	13
FRANCE	12
AUSTRALIA	11
SOUTH KOREA	8
SPAIN	8
BELGIUM	5
IRELAND	5

The Citespace software was used to analyze the publishing institutions and generate the institutional cooperation network map (Figure 3). Among them, "N" represents nodes and "E" represents lines. The lines between nodes represent the connections between institutions. The more lines there are, the closer the connections between institutions will be. From this, we can see the cooperative relationship between institutions. It can be known from the figure that N=179, S=223, the node network density is 0.014, the density is at a relatively low level, the cooperation network is relatively loose, and the cooperation among institutions is not close. There are a total of 8 institutions with more than 4 published articles (Table 3). These issuing institutions are mainly universities and conservation associations, which have high scientific research capabilities and academic levels in the field of environmental science.

Figure 3. Institutional cooperation network graph

Table 3. The impact of Street Valley Greening on Pollutant Diffusion from 2012 to 2023: High-yield structure

Issuing institution	Number of published articles (Articles)
University of Salento	8
Centre National de la Recherche Scientifique (CNRS)	5
Centro de Investigaciones Energeticas	5
Hong Kong Polytechnic University	5
City University of Hong Kong	5
University of Shanghai for Science & Technology	4
Sun Yat Sen University	4
Chinese Academy of Sciences	4

4.3. Keyword analysis

Keywords are concise summaries of the main content of a paper, which can directly reflect the research hotspots in a certain research field over a period of time. In the Citespace analysis results, the word frequency and mediating centrality of keywords can measure the attention to keywords, while the co-occurrence, clustering, emergent, time zone and other knowledge graphs of keywords help highlight the core position of keywords. The comprehensive application of these methods can, to a certain extent, reflect the research hotspots and cutting-edge trends in a certain field.

4.3.1. Keyword co-occurrence analysis

The Citespace software was used to conduct a visual analysis of the related research on pollutant emissions from urban street and valley greening. The time range was set from 2012 to 2023. The threshold was set at Top50 (Top N indicates that the final network was generated based on the first frequently occurring keyword before each time slice), and the time slice was set at 1. In the Control Panel, select "By Frequency", and set the "Threshold" value to 5. The number of generated network nodes is 257, and the number of connections between nodes is 993. The keyword frequency distribution table with a network density of 0.0302 (Table 4) and the keyword co-occurrence map (Figure 4). Generally speaking, keywords with high occurrence frequency can be regarded as research hotspots. However, since the mediation centrality reflects the ability of a node to "mediate" in the entire network, it can also reflect the research hotspots to a certain extent. Therefore, the frequency and the mediation centrality are integrated as the basis for judging the research hotspots. Using

Compute Node Centrality in Nodes to generate the centrality of keywords, it can be found that The main keywords with centrality greater than 0.1 are "street canyon", "dispersion", "impact", "pollutant dispersion", "air pollution", "vegetation", "trees", and "wind" tunnel, flow, environment. Therefore, it can be found that in recent years, the research hotspots in this field have mainly focused on conducting detailed analyses of the diffusion mechanism of pollutants in street canyons and the impact of street valley greening on air flow.

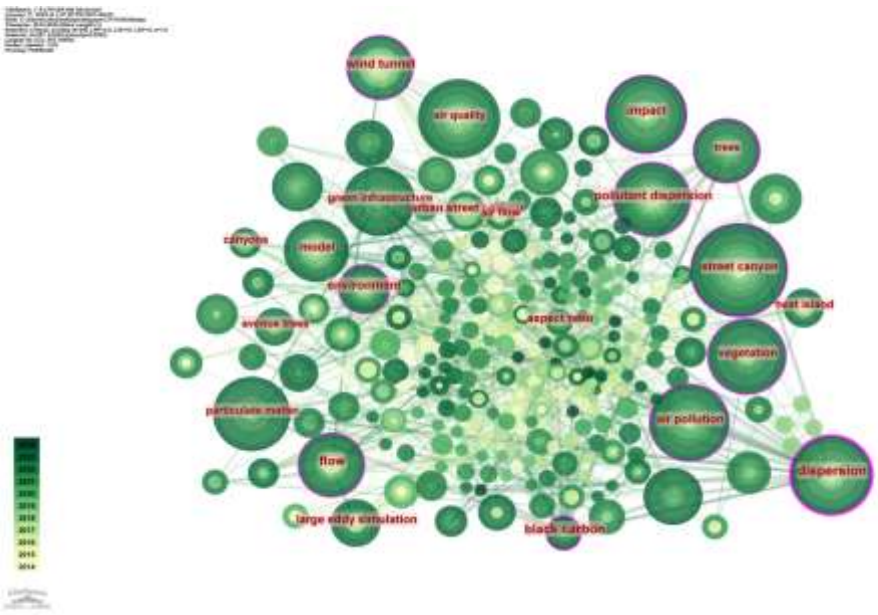

Figure 4. Keyword co-occurrence graph

Table 4. Centrality statistics of some key words

keyword	Frequenc-y	centrality	keyword	Frequenc-y	centrality
street canyon	59	0.11	street canyons	19	0.08
air quality	47	0.06	simulation	18	0.04
dispersion	42	0.22	large eddy simulation	18	0.05
impact	41	0.13	deposition	17	0.05
pollutant dispersion	40	0.11	environment	16	0.11
air pollution	40	0.15	pollution	15	0.05
particulate matter	39	0.07	thermal comfort	13	0.08
vegetation	39	0.14	urban vegetation	12	0.01
green infrastructure	34	0.07	heat island	12	0.06
quality	26	0.05	urban street canyon	12	0.08
model	25	0.05	avenue trees	10	0.04
trees	25	0.10	neighborhood	10	0.04
wind tunnel	25	0.11	ventilation	9	0.00
flow	25	0.13	outdoor thermal comfort	9	0.01

4.3.2. Keyword cluster analysis

In order to improve the accuracy of summarizing the research field, with the help of the keyword clustering function of Citespece, the keywords with relatively close connections were summarized to form clusters. The K value of Display the largest K clusters was set to 25 to obtain the keyword clustering map (Figure 5). The value of Q is 0.4776. The value of S =0.7926. Based on the network structure and the clarity of clustering, Citespace provides two indicators: the module value (Q value, namely ModularityQ) and the average Silhouette value (s value, namely Mean Silhouette). When the Q value is greater than 0.3, the clustering structure is significant, and when the s value reaches 0.6, the clustering can be considered convincing. Therefore, the result of the keyword clustering graph obtained from this keyword clustering analysis is convincing. The clustering modules in sequence are: large turbine simulation, outdoor thermal comfort, inhalable particulate matter, building energy consumption, air pollution, and Street Canyon.

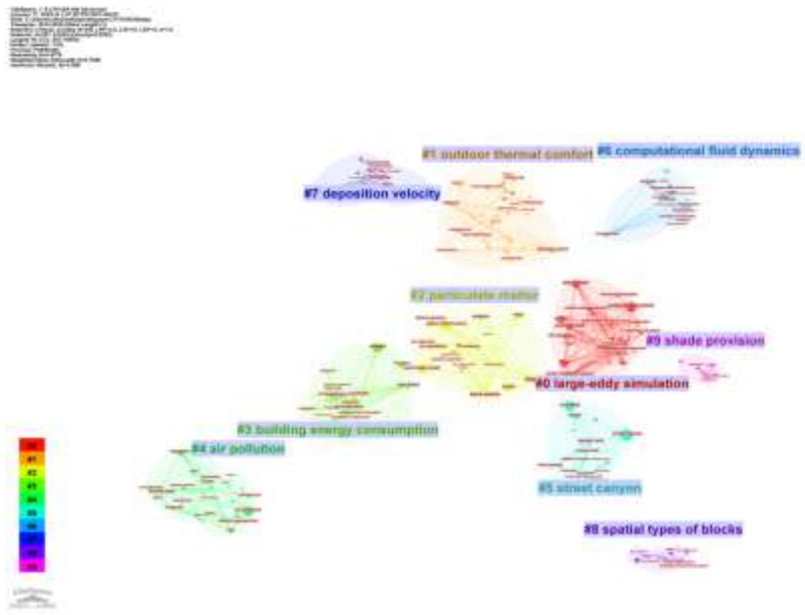

Figure 5. Key word clustering graph

In this study, the "Summary Table | Whitelists" function of Clusters in Citespace 6.2.R4 software was used to explore the detailed information of keyword clustering, and the LLR algorithm was employed. The details are shown in Table 5.

The Silhouette value of keyword clustering in Citespace 6.2.R4 software isgenerally greater than 0.7, indicating that the reliability of the clustering analysis results is good.

Table 5. Detailed information of the keyword clustering LLR algorithm

Keyword clustering number Cluster ID	Size Size	Contour value Silhouette	Label（LLR）
#0	46	0.741	large-eddy simulation (22.51, 1.0E-4); pollutant dispersion (12.64, 0.001); particulate matter (8.25, 0.005); urban street canyon (7.98, 0.005); greens function (7.45, 0.01)
#1	37	0.731	outdoor thermal comfort (9.25, 0.005); street canyon (5.98, 0.05); microclimate (5.17, 0.05); environmental simulation (4.62, 0.05); stormwater (4.62, 0.05)
#2	37	0.818	particulate matter (13.1, 0.001); vegetation barriers (6.87, 0.01); black carbon (6.22, 0.05); pedestrian exposure (3.45, 0.1); traffic pollution (3.45, 0.1)
#3	31	0.837	building energy consumption (8.13, 0.005); air pollution (5.42, 0.05); air temperature (4.06, 0.05); monte carlo method (4.06, 0.05); tree forms (species) (4.06, 0.05)
#4	30	0.776	air pollution (4.94, 0.05); traffic emissions (4.82, 0.05); rans (4.18, 0.05); urban forest (4.18, 0.05); machine learning (4.18, 0.05)
#5	24	0.762	street canyon (9.63, 0.005); aspect ratio (7.07, 0.01); street canyon classification (3.73, 0.1); synergistic effect (3.73, 0.1); street view image data (3.73, 0.1)

5. CONCLUSION AND PROSPECT

This paper, through the visual analysis of bibliometrics and CiteSpace software, has made certain interpretations of the research situation of foreign literatures with a high correlation of the impact of urban street and valley greening on pollutant diffusion, and drawn the following conclusions.

In terms of the time and quantity of published papers, the relevant research on the impact of urban street valley greening on pollutant diffusion in foreign cities began in 2012. The number of published papers has gone through a stage from slow growth in the early stage to rapid increase. This field has gradually come into people's view and received attention.

From the perspective of the co-cited journals of the literature, the impact of urban street and valley greening on pollutant diffusion is mainly published in journals specializing in environmental science, architecture, and urban planning.

From the perspective of the issuing countries and institutions, there are more studies on the impact of urban street and valley greening on pollutant diffusion in countries with higher urbanization rates around the world, mainly concentrated in China and European and American countries. The issuing institutions are mainly concentrated in universities and scientific research centers. Including the University of Salento, the Centre National de la Recherche Scientifique (CNRS), and Centro de Investigaciones Energeticas (Energy Survey Center), Hong Kong Polytechnic University, City University of Hong Kong Kong (City University of Hong Kong), University of Shanghai for Science & Technology, Sun Yat Sen University, Chinese Academy of Sciences (Chinese Academy of Sciences).

It can be seen from the keyword co-occurrence network that in recent years, the research hotspots in this field have mainly focused on the detailed analysis of the diffusion mechanism of pollutants in street canyons and the influence process of street valley greening on air flow. From the perspective of keyword cluster analysis, the research hotspots are concentrated in aspects such as large turbine simulation, outdoor thermal comfort, inhalable particulate matter, building energy consumption, air pollution, and street canyons.

The morphology of street canyons, as another aspect affecting the wind environment and pollutant distribution of street canyons, often influences the airflow behavior within street canyons from a macroscopic perspective. Generally speaking, the influence of building structures on air flow and pollutant diffusion within street canyons mainly includes building layout and the shape of street canyons, such as the width-to-height ratio of street canyons, asymmetry and unevenness of street canyons, etc. In addition, the layout of trees affects the distribution of pollutant concentrations and temperature. The more trees there are on the street, the more conducive it is to lowering the temperature, which is closely related to the living environment. Therefore, conducting research on the impact of urban street and valley greening on pollutant diffusion has very important theoretical research value and practical application value. It is hoped that in the future, more researchers will pay attention to this field and make more contributions to reducing the diffusion of urban pollutants and improving urban air quality and even the quality of the living environment.

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