Bibliometric analysis of research progress on karst groundwater pollution

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Abstract. The hydrological conditions in karst areas are complex. Due to the special karst structure, the surface and aquifers are closely connected through surface karsts, sinkholes, etc., making the karst aquifers vulnerable to pollution. In recent years, human activities and climate change have also exacerbated this phenomenon. Understanding the key knowledge and research status of karst groundwater pollution is an important prerequisite for subsequent research. Based on the CiteSpace software, this paper analyzed the related papers on karst groundwater pollution in the core database of Web of Science, intending to sort out the research results in this field and explore potential research hotspots. Analysis results show that: (1) In recent years, the number of publications and citations in this field has gradually increased, and there is a large space for research and development; (2) The United States, China, Germany are the countries that have contributed the most in this field. The number of research results in this field supported by the National Natural Science Foundation of China is in a leading position in the world; (3) The identification and protection of the vulnerability of karst aquifers, modeling of groundwater flow and pollutant migration are the main research directions. Water chemical analysis, tracer experiment and numerical modeling are the main research methods in this field; (4) The migration of organic micro-pollution, the trace of groundwater flow, the distribution of biodiversity and control factors, the characterization of karst conduits and the simulation of conduit flow, and the development of new tracer isotope fractions are potential development directions and breakthrough points in this field. In general, the research on karst groundwater pollution in the future is inseparable from the cross-integration of various disciplines, the mutual verification of multiple methods, and the introduction of new technological methods.

1. Introduction

The water cycle is the link between the geosphere, biosphere, and atmosphere in the earth system. It is the development direction of the terrestrial hydrologic cycle research to study the earth’s surface, atmosphere, and underground as a whole [1]. As one of the main driving forces of environmental change, the hydrologic effect caused by human activities has become the focus of domestic and foreign scholars [2,3], and it is also valued by international organizations and programs such as the Intergovernmental Panel on Climate Change (IPCC), the International Association for Hydrological Sciences (IAHS), the International Hydrological Program (IHP), and the International Global Environmental Change Human Factors Program (IHDP) [4]. Groundwater circulation is the basis of...
human social and economic development, groundwater quality and pollution condition was found and the various factors affecting the analysis of groundwater quality change, the correct understanding of human activities on the land water cycle and water resources evolution process, the influence of for environmental protection, improvement, and control of groundwater, realize the sustainable utilization of water resources to provide effective protection. It is of great significance to the protection and restoration of the ecological geological environment [5].

The karst system with its karstification is an important part of the earth’s surface system and the global carbon-water-calcium cycle. The study of the karst water cycle and karst carbon sink has become an important research content under the framework of responding to global environmental changes. As a typical ecologically fragile region, the hydrogeological environment and hydrologic cycle process in the karst region are significantly different from those in the non-karst region. The karst hydrodynamic system is sensitive to feedback from changes in the external environment, and severe human disturbance has changed the hydrological and water cycle process in karst areas to varying degrees, leading to increasingly prominent karst ecological environmental problems, such as rocky desertification, engineering water shortage, and karst groundwater pollution [6].

With the development of urbanization, karst water has been polluted [7]. In addition to non-point source pollution such as manufacturing production, urban sewage discharge or garbage, there are also non-point source pollution such as agriculture (fertilization, pesticide spraying), urban or residential area ground runoff, which makes some areas that rely on karst groundwater resources face the shortage of water resources, this dilemma has greatly restricted social and economic development and ecological civilization construction, it is urgent to carry out karst groundwater pollution risk assessment and control the current pollution situation.

As an important method for literature statistics and visual analysis, bibliometrics is an interdisciplinary subject integrating mathematics, statistics, and philology [7]. With the development and promotion of many bibliometrics software in recent years, bibliometrics has been developing in many fields [8]. CiteSpace is a visualization software developed by Dr. Chen Chaomei, which is based on the Java platform [9]. It can reveal the research context and development direction of the subject field by combining the hot spot of the subject research frontier of network data analysis, the topic evolution trend, and the relationship between probing the knowledge base [10]. Compared with the traditional literature review, the CiteSpace method will make the research context in this field clearer and more intuitive, and at the same time, it is repeatable to a certain extent, to avoid the potential deviation caused by subjective judgment [11]. In the field of hydrogeology, CiteSpace has been used to analyze the current situation and predict some hot spots, such as groundwater pollution [12], surface water-groundwater interaction [11], karst water characteristics [13] and groundwater microbes [14]. In this study, network analysis and bibliometrics are adopted to collect, process, and sort out the research status of karst groundwater pollution combined with CiteSpace. Through co-occurrence analysis (keywords and co-citations) and cluster analysis (article topics and keywords), the interrelationships between the content represented by keywords are refined. This method shows the current research status and hot trends, and discusses common methods and future development directions, aiming to provide some inspiration and ideas for future research on karst groundwater pollution.

2. Method
The core database of the Web of Science (WoS) is adopted as the retrieval platform, and the research data of karst groundwater pollution included in the WoS core collection database represents the relevant research status in the world. In the study, we choose [Karst* and groundwater and (pollut* or contamina*)] subject terms to search related papers such as "Article", "Review" and "Proceedings paper" published in 1982-2020. A total of 870 papers were obtained after screening and elimination. The contents of the records were selected as full records and the last update date of the literature data searched above was July 25, 2020.

CiteSpace is a software used to identify and display new developments in scientific papers. Based on keywords, authors, research institutions, etc, this software can be used to display author citations,
word frequencies, and other visual analysis maps, to learn about the development of hotspots and cooperation relationships in this field. In the keyword co-occurrence map, each node represents a keyword, and the nodes adjacent to each other represent that they occur in the same article. The size of each node annotation indicates the frequency of occurrence of its corresponding keyword. In the country cooperation map, each node represents a country, and connections between nodes indicate cooperation between different countries. The size of the node indicates the frequency of publication of the paper in the country or region.

The reliability of the results produced by CiteSpace has been tested by numerous studies. In this paper, we analyze the key nodes of the article, compare and integrate the main content and conclusions with the analysis results of CiteSpace, and explore the hotspots and frontiers in the field to ensure the reliability of the analysis results. Connections between nodes reflect cooperation between different countries. The size of the node indicates the frequency of publication of the paper in the country or region.

3. Result and Discussion

3.1. Analysis of the number of papers published, times of citation and subject classification

Based on the analysis and retrieval report in WoS, there were a total of 870 papers in the field of karst groundwater pollution from 1982 to 2020, with a total of 11279 citations.

It can be seen from Fig.1, the related research based on karst groundwater pollution has been increasing in recent years, and the amount of citations has also increased year by year based on the core database of WoS. It is associated with many factors: firstly, with the economic development and population increasing, more and more groundwater environmental problems appear in karst areas. The efficient use of water resources is an urgent need for the development of human society; Second, it is possible to further understand groundwater pollution in complex karst areas with the emergence of various new technologies.

![Figure 1. The number of cited and published papers on Karst Groundwater Pollution from 1990 to 2020.](image_url)

From the perspective of discipline(Fig.2), the study of karst groundwater pollution is the result of multiple factors such as surface geological process, underground geological process, geological structure and energy utilization, environmental conditions and engineering applications, etc.

It is influenced by surface geological process, underground geological process, geological structure, and energy utilization, environmental conditions, and engineering applications, etc., and these research directions are often interlinked with each other. Technically speaking, the study of Karst Groundwater Pollution needs the coordination of different technical methods in the fields of hydrology and water resources geology, environmental science, civil engineering, environmental engineering, engineering
geology, geochemistry, and geophysics. This brings both challenges and opportunities to the study of karst groundwater pollution.

In the search period, the earliest article discussing the study of Karst Groundwater Pollution can be traced back to 1982. Sores found that the regional groundwater system in southeastern Minnesota is particularly vulnerable to pollution from many sources, including surface runoff, domestic sewage, and industrial waste. He investigated the characteristics of groundwater in karst areas and proposed methods to reduce groundwater pollution[15]. The top 3 cited papers in WoS are all related to the vulnerability of karst groundwater. Groundwater resources from karst aquifers play an important role in water supply in karst regions of the world, such as Switzerland. However, karst groundwater in some areas has been polluted with the extensive exploitation[16], recharge sources and runoff processes are important factors affecting groundwater vulnerability[17]. It is an important method to establish a karst groundwater vulnerability assessment system in combination with different indicators. Working Group 1 of the European COST Action 620 proposed a method based on "Vulnerability mapping for the protection of carbonate (karst) aquifers" at the beginning of the 21st century, and this method was widely used in Europe[18]. Therefore, papers related to the vulnerability of karst groundwater and protection methods show high total citations in WoS.

3.2. Analysis of countries and regions, the number of papers published, times of citations and subject classification

According to the core database of WoS, researchers on Karst Groundwater Pollution are mainly distributed in more than 30 countries and regions in the world from 1982 to 2020. The top 10 countries in the total number of published papers are shown in Table 1.

In this part, the period was set from 1982 to 2020, the time slice was set as 3, the CiteSpace analysis node was set as a country, and the data selection standard was Top20. That means that the Top 20 countries or regions with high frequency appearing in the number of papers published in each time slice was analyzed and recorded, and the cooperation map of countries and regions were obtained in Fig.3.
Figure 3. Map of published papers and cooperation between countries and regions.

It can also be seen from Fig.3, the United States has the largest number of papers published in this field, with a total of 256 papers, accounting for 29.43% of the total number of papers, ranking second is China, with a total of 186 papers, accounting for 21.38%, and the third place in Germany, with 77 papers in total, accounting for 8.85%, followed by Italy, Sweden, France, and Slovenia. These countries and regions have strong comprehensive scientific research capabilities, with high demands for technology. At the same time, the connections between the various nodes are close in Fig.3, indicating the extensive cooperation among countries around the world.

Table 1. Top ten countries with publication volume

| Rank | Countries /Regions   | Record Count | % of 870  | h-index | Average citations per item | Sum of Times Cited |
|------|----------------------|--------------|-----------|---------|----------------------------|-------------------|
| 1    | USA                  | 256          | 29.43%    | 31      | 14.12                      | 3,614             |
| 2    | CHINA                | 186          | 21.38%    | 21      | 8.51                       | 1,582             |
| 3    | GERMANY              | 77           | 8.85%     | 21      | 17.7                       | 1,363             |
| 4    | ITALY                | 57           | 6.55%     | 12      | 7.67                       | 437               |
| 5    | SWITZERLAND          | 40           | 4.60%     | 23      | 45.75                      | 1,830             |
| 6    | FRANCE               | 40           | 4.60%     | 15      | 20.98                      | 754               |
| 7    | SLOVENIA             | 31           | 3.56%     | 10      | 11.23                      | 348               |
| 8    | MEXICO               | 28           | 3.22%     | 13      | 21.39                      | 599               |
| 9    | SPAIN                | 21           | 2.41%     | 11      | 34.55                      | 691               |
| 10   | CANADA               | 20           | 2.30%     | 9       | 19.81                      | 416               |

The top 3 research institutions in the world in terms of numbers of publications are CHINA UNIVERSITY OF GEOSCIENCES (39), HELMHOLTZ ASSOCIATION (39), STATE
UNIVERSITY SYSTEM OF FLORIDA (38), UNITED STATES DEPARTMENT OF THE INTERIOR (36).

China started relatively late in the field of karst groundwater pollution, but its development speed is fast. From the analysis of the number of papers related to karst groundwater pollution research funded by funding agencies around the world, National Natural Science Foundation of China (NSFC) and CHINA GEOLOGICAL SURVEY(CGS) are respectively ranked first and second, 91 and 21 published papers are funded by NSFC and CGS. The development of research on Karst Groundwater Pollution in China cannot be separated from the support of NSFC and CGS. These research achievements benefit from the attention of the Chinese government, and also show the improvement of research and research capacity on Karst Groundwater Pollution. Second place was the FEDERAL MINISTRY OF EDUCATION RESEARCH BMBF, which funded 20 published papers.

Besides, China ranks second in the number of published papers in this direction, but the number of cited papers is relatively small (table 1). According to the influence of cited quantity, the research on this direction is still dominated by the United States, Germany, Switzerland, and other countries. This suggests that we should not only pay attention to the research of scholars in these high-impact countries but also pay attention to the quality of the papers, to improve the influence of the papers.

The first conference article in this field whose first author is a Chinese scholar was published in 1997 by Zhu XY (Zhu et al., 1999) of Nanjing University at XXVII International-Association-of-Hydrogeologists Congress on Groundwater in the Urban Environment[19]. Besides, the first paper in this field whose first author is a Chinese scholar was published in ENVIRONMENTAL GEOLOGY in 2000. This paper introduces that the karst aquifer in Dawu of Zibo city was seriously polluted by the petrochemical plant, the hydraulic interception can prevent the transport of pollutants[20].

3.3. Analysis of core papers and Identification of basic knowledge

The number of citations of paper on WoS refers to the total number of citations in the database, so highly cited papers are not necessarily basic papers in the field [11,21]. In this study, 870 papers from WoS were analyzed by co-citation. A co-citation analysis section was set in CiteSpace. The data selection standard is Top50, which means that the top 50 papers in each section are chosen to analyze. The top 10 papers in the citation relationship knowledge network based on WoS, as shown in Table 2.

Based on co-citation analysis, the top two are both reviews of the Karst Groundwater Pollution papers in the core database of WoS. Hartmann A introduced the evolution characteristics of karst landforms and special hydrological processes, systematically summarized different numerical models describing the karst system, and analyzed the limitations of current karst models, and finally discussed the development and research directions of prediction models[22]. Bakalowicz M compared several conventional methods of groundwater survey in karst areas, analyzed, and pointed out the applicability of each method[23]. Daly D interpreted the measures proposed by Working Group 1 of the European COST Action 620 to protect karst aquifers and explained related methods, providing a reference for subsequent protection and exploitation of karst groundwater[24]. Ravbar N used four groundwater vulnerability mapping methods in the Slovenian karst basin, and verified them through tracer tests, laying the foundation for subsequent research[25]. Pronk M studied the dynamic change trends of organic carbon (OC), turbidity, fecal indicator bacteria, and parameters in a karst system near Yverdon, Switzerland. Tracer experiments showed that the sinkhole is an important source of groundwater pollution, OC seems to be a better indicator of bacterial contamination than turbidity[26]. Andreo B introduced the first application of the karst groundwater protection method proposed by European COST action 620 in the Sierra de Libar in southern Spain, providing a reference for the application in other regions[27]. Goldscheider N introduced the application of the karst groundwater vulnerability assessment diagram in Swabian Alb in Germany, and compared it with the other two methods (EPIK and the German method), acknowledged the role of vulnerability maps in the plan of groundwater protection[28]. Gutierrez F reviewed the main disasters of the karst environment, especially focused on the analysis of caves, floods, and slope movements, and summarized the main achievement in assessing environmental impact and methods to prevent disasters from karst scientists, providing ideas
for subsequent research[29]. Ghasemizadeh R reviewed the basic concepts of karst systems and mathematical modeling methods. As a case study, the north coast limestone aquifer system of Puerto Rico (USA) is introduced to illustrate and discuss the application of groundwater models in karst aquifer systems to assess aquifer pollution, which provides a research foundation for subsequent model studies[30]. Goppert N tracked solute and colloid migration in karst pipes under low flow rate and high flow rate conditions respectively and made comparison and analysis, which provided a research basis for subsequent studies[31].

Table 2. Co-citation analysis of Karst Groundwater Pollution in Web of Science dataset.

| Times | Year | Author           | Title                                                                 | Journal                        |
|-------|------|------------------|----------------------------------------------------------------------|--------------------------------|
| 34    | 2014 | Hartmann A       | Karst water resources in a changing world                           | Reviews of Geophysics          |
| 25    | 2005 | Bakalowicz M     | Karst groundwater: a challenge for new resources                    | Hydrogeology Journal           |
| 22    | 2002 | Daly D           | Main concepts of the "European approach" to karst-groundwater-vulnerability assessment and mapping | Hydrogeology Journal           |
| 21    | 2009 | Ravbar N         | Comparative application of four methods of groundwater vulnerability mapping in a Slovene karst catchment | Hydrogeology Journal           |
| 20    | 2006 | Pronk M          | Dynamics and interaction of organic carbon, turbidity, and bacteria in a karst aquifer system | Hydrogeology Journal           |
| 19    | 2006 | Andreo B         | Karst groundwater protection: First application of a Pan-European Approach to vulnerability, hazard, and risk mapping in the Sierra de Líbar (Southern Spain) | Science of The Total Environment |
| 19    | 2005 | Goldscheider N   | Karst groundwater vulnerability mapping: application of a new method in the Swabian Alb, Germany | Hydrogeology Journal           |
| 19    | 2014 | Gutierrez F      | A review on natural and human-induced geohazards and impacts in karst | Earth-Science Reviews          |
| 17    | 2012 | Ghasemizadeh R   | Review: Groundwater flow and transport modeling of karst aquifers, with particular reference to the North Coast Limestone aquifer system of Puerto Rico | Hydrogeology Journal           |
| 17    | 2008 | Goppert N        | Solute and Colloid Transport in Karst Conduits under Low- and High-Flow Conditions | Groundwater                   |
The results of co-citation analysis were visualized to obtain literature co-citation analysis map of Karst Groundwater Pollution (Fig.4). By extracting tags for keywords from papers, the network structure was clustered, and 11 clustering results were obtained. According to the literature co-citation analysis map, the research on Karst Groundwater Pollution can be divided into multiple sub-directions: organic micro pollution (Micropollutants), vulnerability assessment (intrinsic vulnerability), microbial community, ecological cluster, the dynamic characteristics of spring (springs), the natural process of karst groundwater (natural processes), seawater intrusion; the method of research: concentration-overburden-precipitation (COP method), spring hydrograph, artificial tracing, logistic regression model; and hot research areas: lijing river, mexico. The highly cited papers also focus on cluster labels such as Micropollutants and intrinsic vulnerability, which means that vulnerability assessment and organic micro pollution are important parts of Karst Groundwater Pollution research.
TimezoneView can display the distribution and dynamics of basic papers in a field over different periods [11]. From Fig. 5, we can see that high Co-cited papers appear in 2005-2014, it shows that the research on Karst Groundwater Pollution is a relatively new research direction that has been developed in recent years and has a good research foundation and application prospects. From the research content of the key paper, the research of this discipline is mainly in this direction: recognize the actual situation through monitoring or specific technical methods—generalize the actual situation and perform numerical simulation—summary and overview. With the development of new technological methods, the understanding of actual conditions or specific processes has become deeper, which makes the simulation closer to the real conditions or specific scenarios, and a new understanding can be obtained. In general, the research on karst groundwater pollution has shown a spiraling development process.

3.4. Analysis of evolution and frontier on Karst Groundwater Pollution
Keywords are the core of the paper, which indicates the research direction of the field by abstracting and summarizing the research content of the academic paper. By summarizing and analyzing the keywords with high suddenness, it is possible to dig out the characteristics of different keywords in a certain period and capture the trend changes of research frontiers and research hotspots. Combined with the analysis of co-word, some keywords or phrases are constructed to construct the co-word network, and then the structural changes of the theme are analyzed to analyze the research progress of Karst Groundwater Pollution.

![Top 20 Keywords with the Strongest Citation Bursts](image)

**Figure 6.** Top 20 Keywords with the Strongest Citation Bursts.

In CiteSpace, the period and time slice are unchanged, node type is set as the keyword in the co-word network, a total of 370 keywords and phrases are obtained, and the top 20 keywords with strongest citation bursts are selected in Fig.6.

The “karst” is the keyword with the highest suddenness, and the words produced in the same period include the “pollution” and the “groundwater”. The “European Approach” refers to vulnerability mapping for the protection of carbonate (karst) aquifers, which is a method of karst groundwater “resource” and “environment” which has been widely concerned and applied in Europe at the
beginning of this century, this method has played an important role in “groundwater protection” and has a profound influence on the research of modern karst groundwater pollution. Some pollutants can cause “groundwater contamination”, such as “uranium” and “nitrogen”. Through “surface water”, these pollutants may enter the groundwater aquifer, and they will diffuse under the action of “conduit flow”, then they may affect karst groundwater quality and “water supply”. Some major research methods, such as stable isotopes, can reveal the source of groundwater recharge in karst areas (Basin). Combined with radioactive isotopes in water, it can infer “climate change” and invert paleoclimatic patterns. At present, a wide range of investigations and studies on karst groundwater pollution have been carried out in many countries and regions, such as “China”, “France”, Slovenia, Switzerland, South Africa and so on.

Figure 7. The time-line view of keywords and noun-phases.

The node size represents the co-occurrence frequency of keywords, the red character is the clustering label, the length of the horizontal line represents the duration of each cluster, and the top number is the end year of each time slice. In CiteSpace, the analysis results of keywords are arranged in the form of a timeline to obtain the timeline map, as shown in Fig 7. Each node represents a specific keyword, and the size of the node represents the number of times the word appears as a keyword. The connection of nodes means that this word is used together with other words as keywords in different articles, and the coarser the connection means the more co-occurrence times [33]. There are 11 keyword clusters in Fig.7: “aquifer”, “karst groundwater”, “west rand”, “micro-pollutants”, “resources”, “micro-pollutants”, “biodiversity”, “conduit”, “carbonate rocks”, “sediments”, “karst water system”, “Switzerland”.

Among them, the characterization of the “karst groundwater” quality and description of the “aquifer” is the focus of continuous attention in the research of Karst Groundwater Pollution. As a famous gold mining site in South Africa, the Far “West Rand” has attracted wide attention. Due to mining activities, it has exerted a great impact on regional groundwater resources. How to improve the groundwater environment in mining areas is still the focus of current research. Organic “micro-pollutants” have been a hot topic in karst groundwater research in recent years. Although they appeared late, they have continuously integrated other keywords in recent years and are in a period of rapid development. “Biodiversity” assessment and protection is another research hotspot in the field of Karst Groundwater Pollution, which plays an important role in the indication of environmental karst groundwater systems and the description of pollution characteristics. Besides, the depiction of “karst
Conduit” in the “karst water system” shaped by “carbonate rocks” “sediments” and modeling the transport of pollutants in karst conduits are also important directions for karst groundwater pollution research. How to accurately and efficiently depict aquifers and simulate the movement of water flow and pollutants is also a huge challenge, which is of great significance to water resources and environmental ecosystems [33]. The keywords in each cluster are shown in A1.

In the cluster labels in A1, the research direction, research methods and some typical research areas of Karst Groundwater Pollution can also be further understood. Research directions also include “hydrochemical processes”, “health risk assessment”, “ecological risk assessment”, “Arsenic transport”, “Nitrate pollution”, etc. Research methods including the “Artificial neural networks”, “Geochemical modeling”, “Strontium isotope”, “Pumping test”, “Redundancy analysis”), etc. Typical research areas include “Switzerland”, “Red River Delta”, “Southern Spain”, etc.

4. Conclusion
Quantitative statistics and visual analysis of Karst Groundwater Pollution related research are carried out in this study from 1982 to 2020. The analysis results show the annual variation characteristics of the number of papers and citations in the field of Karst Groundwater Pollution research, the core countries, research institutions, and the knowledge base, research hotspots and trends of the field. The following conclusions can be drawn:

1. In recent years, the number of publications and citations in the research field of Karst Groundwater Pollution has been increasing gradually. In particular, the number of highly cited papers in this research field has increased since 2007, indicating that this research field is still in the development stage and has a broad research prospect.

2. The United States, China, Germany, Italy, and other countries have done more research in the field of karst groundwater pollution. These countries often have large karst areas in their own countries and rely on the karst water resources. At the same time, it also has a good scientific research foundation and financial support.

3. Based on the analysis of highly co-cited papers in the field of Karst Groundwater Pollution, the identification of karst aquifer vulnerability and the simulation of groundwater flow and solute are the main research directions. Hydrochemical analysis, tracer experiments and numerical simulation are the main research methods in this field. Besides, due to the heterogeneity of the geological structure in karst areas, the joint measurement of multiple methods can provide more reliable results. The introduction of new technical methods will also promote research in the field. The introduction of new technology and research methods will also promote research in the field.

4. The migration of organic micro-pollution, the trace of groundwater flow, the distribution of biodiversity and control factors, the characterization of karst conduits and the simulation of conduit flow, and the development of new tracer isotope fractions are potential development directions and breakthrough points in this field.

5. Research directions obtained from the analysis of keywords and nominal phrases also include “hydrochemical processes”, “health risk assessment”, “ecological risk assessment”, “Arsenic transport”, “Nitrate pollution”, etc. Research methods including the “Artificial neural networks”, “Geochemical modeling”, “Strontium isotope”, “Pumping test”, “Redundancy analysis”), etc. Typical research areas include “Switzerland”, “Red River Delta”, “Southern Spain”.

From the understanding of the importance of karst groundwater resources on production and life to the quantitative analysis of water pollution through specific technical methods, the research on Karst Groundwater Pollution gradually becomes mature. In the past few decades, the development of this field depends on the improvement of general technical methods and the application of new technology, the research direction is also gradually from highly generalized conditions to challenge for the complex natural conditions in the past few decades. With the global trend of extensive cooperation, the countries should strengthen international communication with scholars of other fields and countries to promote the development of Karst Groundwater Pollution.
Appendices
The data of the cluster of keywords in Table A1 can be found in the Supplementary document.

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