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Science mapping approach to assisting the review of mine water disaster prediction and evaluation in China between 2009 and 2019

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Abstract. Mine water inrush occurs frequently in China, and it can cause serious economic losses and heavy casualties. Thus, it is very important to realize risk assessment of mine water inrush. After collecting 4082 journal documents on risk assessment of mine water inrush from 2009 to 2019 in CNKI journal database, and using CiteSpace visualization software to do data analysis, the research hotspot and frontier trend in mine water inrush research in China are obtained. The prevention and prediction of different types of water disasters is a major trend in this field.

1. Introduction

The mining conditions of coal mines in China are relatively complex and difficult, and the resources suitable for open-pit mining account for a relatively small proportion. In the process of coal mine production and construction, the threat of water cannot be underestimated. Although the probability of water inrush accident is not high compared with gas accident, it can cause serious casualties and economic losses. Therefore, the mine water disaster is one of the most grievous disasters in the process of coal mine production. At the same time, it has also been concerned about the water disaster accidents at home and abroad. However, it is one-sided research and discussion on a small problem, lacking of comprehensive knowledge structure system analysis. In recent years, the map of scientific knowledge has been used to study the development law of a certain field, and to analyse the knowledge structure system of this field, which has attracted more and more attention.

The map of scientific knowledge is an image that takes scientific knowledge as the research object and shows the development vein and structure of scientific knowledge[1], uses citation analysis method[2] and information visualization technology, and uses CiteSpace software to understand the "paper map" of mine water disaster. The systematic analysis shows that under the selected literature, a creative and brand-new idea and method are provided for the mine water disaster.

2. Data sources and research methods

2.1. Data source



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In order to sort out the water disaster accidents comprehensively, this paper takes CNKI periodical database as the information source, and sets "mine water disaster, mine water inrush, floor and roof water inrush, old air ponding" as the subject words for literature retrieval. During the 10 years from 2009 to 2019 (as of October), a total of 4253 literatures have been published. After cleaning the data and selecting the foreign literatures, 4082 periodical literatures that can be used for atlas analysis have been obtained, source categories are journal papers, doctoral papers, conference papers and newspaper papers. Based on statistical analysis and bibliometric methods, CiteSpace visual analysis software is used to draw scientific knowledge maps and analyze the maps to mine the tacit knowledge contained therein.

2.2. Research methods

CiteSpace is a visualized document analysis tool developed by Professor Chen Chaomei of Drexel University in the United States. It is the first knowledge map applied to international competitive intelligence research in China, and is now widely used in research hotspot and frontier discussion in the field of Economics [3]. With the help of CiteSpace software, based on the visual analysis method, it can clearly analyse the core authors, research institutions, research hotspots and the frontier of development laws in the field of mine water disaster research in the past 10 years, so as to make the prediction and evaluation of mine water disaster in China.

3. Statistical analysis

3.1. Statistics of document quantity

Figure 1 is the statistical chart of the number of papers published in the field of mine water disaster research in the past 10 years. According to the change trend of the volume of publications, the research can be divided into two stages: a stable stage (2009-2011, 2016-2018) and development stage (2012-2015).

In the stable stage, from 2016 to 2018, there was only a small fluctuation in the number of posts, but the number of Posts still remained more than 400. From 2009 to 2011, the number of Posts was almost the same around 300. In the development stage, since 2012, the number of papers in the field of mine water disaster research in China has shown a rapid growth trend. From 2012 to 2015, the total number of papers increased by 121, and in 2015, the number of papers reached the peak of 485. Although the number of posts in 2016 decreased was higher than that in 2015, it was still above 400.

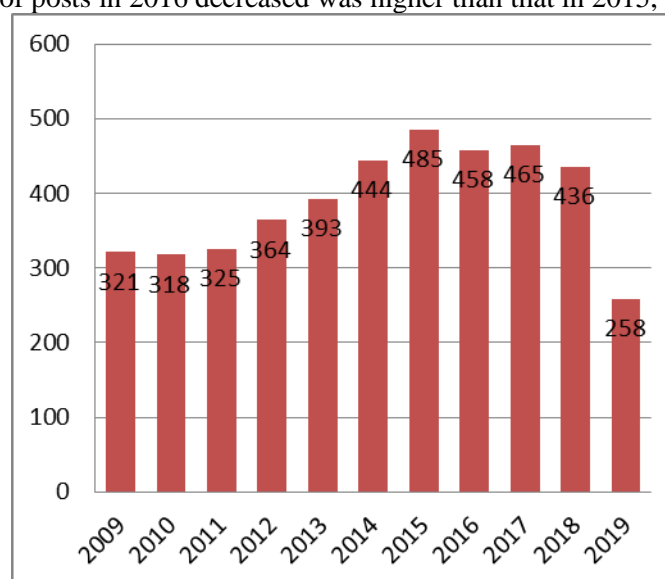


Figure 1. Statistics of the number of papers issued in the field of mine water disaster research in recent 10 years.

3.2. Research team analyses

Through the statistics of the number of articles issued by the authors in the field of mine water damage research and the number of documents issued by the research institutions, respectively, using knowledge maps to compare and analyse. With the help of CiteSpace software, when the threshold is selected as the system default value, i.e. top50, the cluster points are set separately. For "Author" and "Institution", you can get high-yield authors and high-yield research institutions on mine water damage research from 2009 to 2019. Depending on the influential core authors and research institutions in this field, infer the research direction, which is more helpful to analyse the development law and research hotspot in the current research field.



Figure 2. Core author knowledge map

Based on the statistics of the amount of papers published by the authors in this research field, the scientific knowledge map (Figure 2) is drawn, and the authors with large nodes and high centrality are selected. There are 94 nodes in the figure, but the nodes are spread, which shows that the communication and cooperation between the core authors are deficient. Among the core authors, Professor Shi Longqing[4] vice president of the school of Geoscience and engineering of Shandong University of science and technology, holds the largest number of papers, 49 papers and the largest node in the atlas. He has made systematic research achievements in the field of mine water disaster prevention and control, not only reaching the international advanced level, but also putting forward the theory of "four belt" division of stope floor and developing the theory of safe mining. Wu Qiang[5], professor and doctoral supervisor of China University of mining and Technology (Beijing), director of Institute of water disaster prevention and control and water resources, issued 34 papers in total; Wei Jiuchuan[6], Dean of School of Geoscience and engineering, Shandong University of science and technology, leader of "geological engineering" doctoral discipline, and leader of "geological engineering" construction of key disciplines in Shandong Province, issued 22 papers in total. His research involves mine water damage prevention research, resource exploration and evaluation. Besides, Liu Weitao, Xu Yanchun, Xu Xing, Gao Zhaoning, Meng Xiangrui, etc. are closely followed, making unique contributions to the field of mine water disaster research.

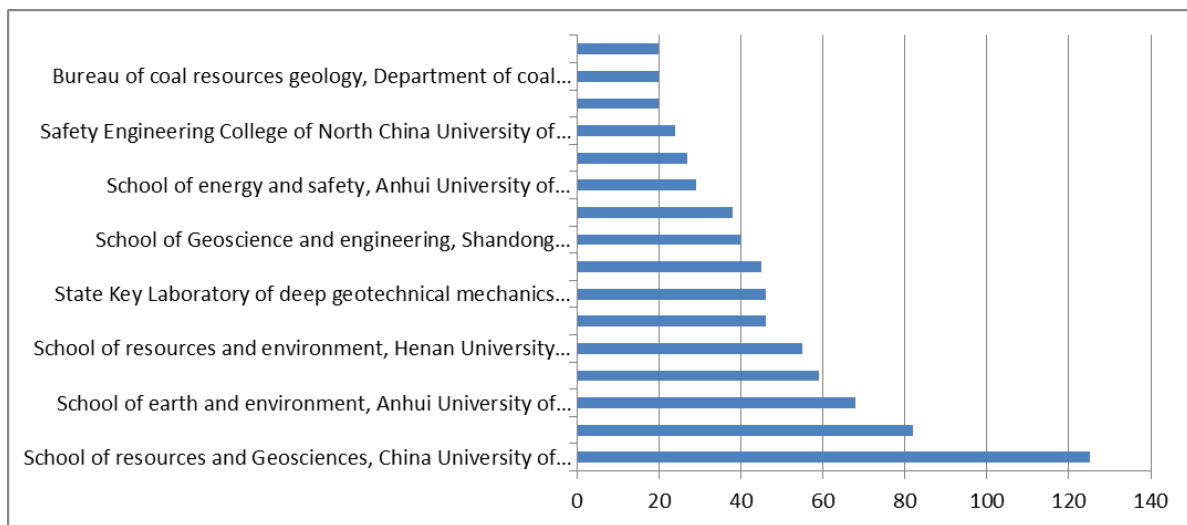


Figure 3. volume of documents issued by research institutions

According to the CiteSpace software, the frequency and centrality of each node are obtained, and then the number of research institutions is plotted according to the word frequency sequence (Figure 3). It can be observed in the figure that in the past 10 years, among the rankings of high-yield research institutions, China University of Mining and Technology has the highest number of publications. As the number one high-yield institution, it has published 125 papers and its geosciences and surveying engineering in CNKI journals. The College has published 46 articles, its Resource and Safety Engineering Institute has published 45 articles, and its School of Mechanics and Architectural Engineering has published 17 high-level articles. High levels articles. Shandong University of science and technology followed closely, with 62 papers published in 2009 and 131 in 2014. Centrality, otherwise known as intermediate centrality, is an indicator commonly used to measure centrality. It refers to the ratio of the shortest path passing through a point and connecting the two points in the network to the total number of shortest path lines between the two points [7-8]. Among all the selected research institutions, China University of mining and technology, Shandong University of science and technology and North China University of science and technology have higher centrality, which shows that they have far-reaching influence in the research group.

4. Research hotspot and trend analysis

4.1. Research hotspot analyses

Keywords have the function of explaining and commanding the entire text. They are at the root of obtaining core information and the key to mastering important information of the text. Use CiteSpace software to analyse the keywords of 4082 selected documents. The threshold value is the default, i.e. Top50, and the cluster point is set as "keyword". The results presented in Figure 4 are obtained. The year increases from left to right. The size of the node represents the importance of the keywords, and the connecting line between nodes represents the closeness of the keywords. It can be seen from the figure that 2009 is the year with the greatest contribution to the study of mine water disaster, not only with large nodes, but also with high centrality, which is closely related to other years. The largest node in the figure is "floor water inrush", followed by "mine water disaster", which is the subject word used in the retrieval, and will be ignored in the later analysis. In addition, the keywords with high frequency of words include "numerical simulation", "water damage control", "hydrogeological conditions", "risk assessment" and "water inrush coefficient". In the purple circle, the higher centrality, such as "water inrush mechanism", "water inrush coefficient" and so on, is a more important node. At the same time, it also shows that in the research field of mine water disaster, the research on mine water inrush and prevention is the focus and hot spot of scholars and research institutions in this field. The prediction and prevention of water inrush have been the key topic in recent years.

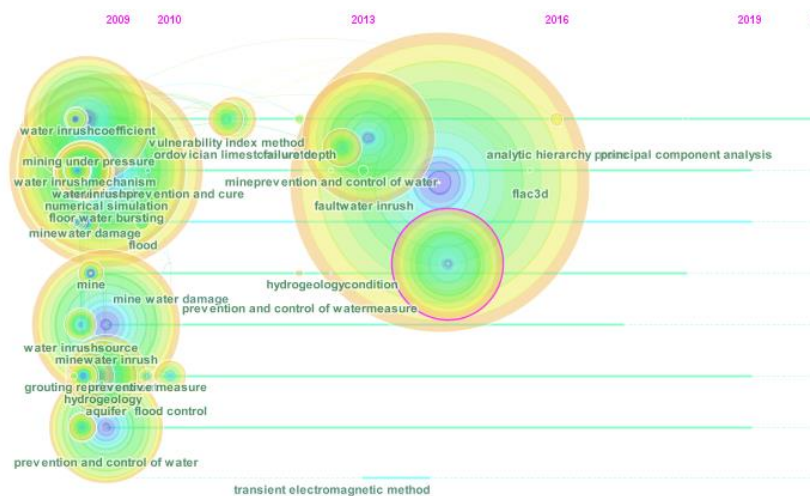


Figure 4. keyword map of research field

4.2. Dynamic evolution of research hotspot

Through the analysis of high-frequency keywords[9], we can get the hot spot and research frontier of the problem, which is the focus of theoretical research. The keywords are counted according to the year. The year is divided into three stages: 2009, 2010-2014 and 2015-2019. The results are presented in Table 1. The size of node centrality indicates its importance in the network. Therefore, when selecting keywords, the keywords with centrality of 0 are removed. It can be observed in Figure 4 that 2009 is the year with the most keywords, with 59 in total. In 2009, keywords with frequency ≥ 10 are selected in Table 1. Table 1 lists the dynamic evolution of research hotspots in the field of mine water disaster in the past 10 years. The keywords of each stage are sorted according to word frequency. It can be seen that the centrality and word frequency of floor water inrush, risk assessment and water hazard prevention and control are all in the forefront of the three stages. Since 2009, the research on the floor has been performed. In the second stage, there is even some research on it, but by 2019, the research on the floor is slightly reduced. Risk assessment and safety assessment run through the entire research, and have been involved in the past 10 years. In the prediction method of mine water disaster, it can be seen from Table 1 that the “water inrush coefficient method” can no longer meet the requirements of deep pressure mining and modern coal mining methods, and the “vulnerability index method” has received increasing attention. The basic model is an evaluation model that combines the GIS with powerful spatial information analysis and processing functions with the information that can determine the weighting factors of multiple main control factors for floor water inrush.

Table 1 key words with centrality greater than 0.01 in each stage

stage	Centrality	word frequency	Key word	stage	Centrality	word frequency	Key word
2009	0.06	472	Floor water inrush	2009	0.12	49	Water Inrush Source
	0.16	461	Water inrush		0.07	43	Fluid solid coupling
	0.19	309	Flood control		0.05	43	Fault activation
	0.11	280	numerical simulation		0.06	41	Collapse column
	0.09	196	Mining under pressure		0.06	41	Prevention and cure
	0.1	195	Mine water disaster		0.14	31	Forecast
	0.08	188	Water inrush coefficient		0.08	31	mining engineering
	0.09	100	Water inrush mechanism	2010 - 2014	0.07	115	coal mine
	0.06	97	Hydrogeology		0.1	82	Risk of water inrush
	0.12	94	Coal seam floor		0.06	75	Ordovician limestone water
	0.07	91	Confined water		0.12	56	Vulnerability index method
	0.05	84	fault		0.05	50	Floor failure
	0.06	81	Risk assessment		0.04	36	Control technology
	0.07	78	Aquifer		0.07	29	Water inrush from coal mine
	0.07	73	Hydrogeological conditions		0.07	29	Transient electromagnetic method
	0.05	64	mine		0.02	27	Hydrogeological characteristics
	0.11	59	floor		0.05	25	Coal mine water damage
	0.09	59	Roof water inrush	2015 - 2019	0.08	40	Analytic hierarchy process
	0.06	53	Water inrush coefficient method		0.06	10	Safety evaluation
	0.08	49	Aquifer		0.06	8	geophysical prospecting

4.3. Research trend frontier

To a certain extent, the mutation of keywords can reflect the research trend in the field of mine water disaster. By using the "burst detection"[10] of CiteSpace software, we can detect the words with high change rate from a large number of subject words according to the keyword co-occurrence frequency in the past 10 years, so that we can find the keyword mutation in the field in the past 10 years. The result is presented in Figure 5, and the red dot in the figure is the mutation word.

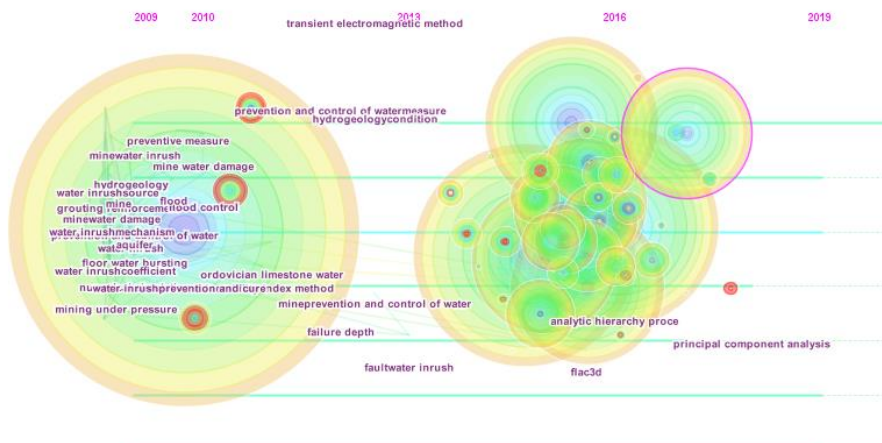


Figure 5. knowledge map of mutation words

According to the red node shown in Figure 5, the mutation words are given in Table 2. It can be seen that the mutation intensity of "water inrush coefficient method", "mining engineering", "risk assessment", "fluid structure coupling" and "geophysical exploration" is large, among which "water inrush coefficient method" and "prevention" are the mutation words in 2009. It shows that the prevention and control of mine water disaster are a major trend in the research field, and at that time, the water inrush coefficient method was used to predict the use of water inrush. At present, the development of "geophysical prospecting" technology provides a choice to find out the geological problems of the mine. With the advent of digitalization and intellectualization, its methods and technologies are becoming ever more perfect, and its application scope is expanding. It uses computers to address and interpret all kinds of geophysical data collected underground in various ways. A variety of geophysical data combined with a comprehensive interpretation of mine geology and other data have achieved obvious geological effect. Mine geophysical prospecting has become an indispensable means in mine geological work.

Table 2 list of mutation words

time	Abrupt word	Strength
2009	collapse column	41
2009	prevention	27
2009	fluid-structure coupling	43
2009	mining engineering	31
2009	fault activation	43
2009	water inrush coefficient method	53
2010	hydrogeological characteristics	27
2013	sources of inrush-water	49
2014	water source identification	21
2015	analytic hierarchy process	40
2015	risk assessment	59
2015	deep mining	26
2019	geophysical prospecting	45

5. Conclusions

The journals retrieved from CNKI cannot fully represent all the research results in the field of mine water disaster research, so the prediction and evaluation of mine water disaster in China have certain limitations. However, disciplines are related to each other, and any method of reference and improvement cannot be separated from the existing literature. Therefore, the use of scientific knowledge maps for the analysis of mine water disaster is reasonable. The conclusions are as follows:

1) from the analysis of the core authors and research institutions in the field of mine water disaster research in the past 10 years, most of the high-yield authors come from the universities or institutions that have done a lot of research in this field, and most of the research institutions are the units of the high-yield authors. However, high-yield authors and high-yield research institutions are relatively independent and lack of communication, discussion and cooperation between them, which is not conducive to promoting the development and innovation in this field.

2) floor water inrush, risk assessment and water disaster prevention and control are the research focuses of mine water disaster in the past 10 years, especially for the prevention and prediction of different types of water disaster, which is a major trend in this field.

3) with the progress and development of science and technology, in the aspect of water inrush prediction, new technology is constantly integrated into the prediction method, which makes the prediction result more accurate and ideal.

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