

Original Research

# Knowledge Mapping Analysis of Water Ecological Risk Studies in Mining Areas Based on Web of Science

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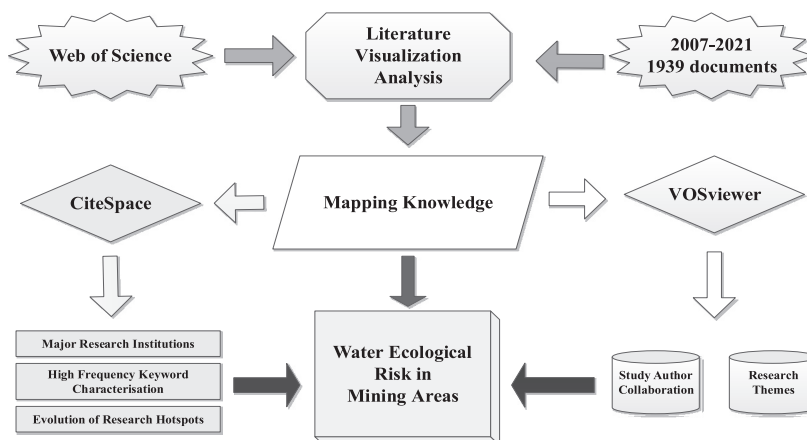
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Received: 11 May 2023

Accepted: 25 July 2023

## Abstract



With the over-exploitation of mineral resources leading to major conflicts such as water shortage, water quality deterioration, and water ecology deterioration, the risks arising from water ecology in mining areas have received extensive attention from scholars at home and abroad. Using the Web of Science core collection as the data source, 1939 papers from 2007-2021 were used as research objects. CiteSpace and VOSviewer were used to draw a knowledge map for literature visualization and analysis, with the aim of exploring the inner rules, research hotspots and evolutionary trends in the field of water ecology risks in mining areas. The study shows that: (1) The number of publications has been steadily increasing, with China being the country with the highest number of publications. (2) Many studies are conducted within research teams, but cooperation between teams is not strong enough. (3) The current research area has shifted from single substances to coupled research on multiple substances generated

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by mining. (4) Pollutants from mining areas have a direct impact on the ecological and health safety of humans.

**Keywords:** water ecological risk, CiteSpace, VOSviewer, Web of Science, mining areas

## Introduction

Water resources worldwide are unevenly distributed in space and time, requiring rational water resources development and management [1]. With the continuous promotion of green urbanization, many Region are facing the problem of balancing socio-economic development and eco-environmental protection [2-3]. With the over-exploitation of mineral resources leading to increasingly prominent environmental conflicts such as water shortage, water quality deterioration and water ecology deterioration, the water ecology risk in mining areas has become a significant hidden danger hindering the water ecology safety management and civilization construction in Region [4-5], and has become a significant bottleneck restricting socio-economic development. The water ecology risk in mining areas has become a hot focus of regional development worldwide.

After the 1980s, the concept of “ecological risk” was developed in the environmental field, which led to an influx of related literature and an increasingly affluent theoretical basis and scientific basis [6]. Research on water ecological risk at home and abroad has focused on three main areas: firstly, theoretical research, such as defining the concept of water ecological risk, exploring the development of water ecological risk, constructing evaluation index systems and designing water ecological risk evaluation models [7-10]. The second is empirical research, using the evaluation index system and evaluation model to evaluate and analyse the research object [11-15]. The third is object research, mainly focusing on watersheds [11-12], plateaus [13], cities [14], and mining areas [15-16]. This paper takes mining areas as the primary research subject and combines them with watersheds and soils. These specific studies are more focused, but all play an essential role in digging deeper into water ecological risk.

To objectively demonstrate the evolution laws of ecological risks both domestically and internationally, scholars have conducted literature visualization analysis on ecological risks. Jiang Y.P., et al. have applied VOSviewer software to visualize the number of publications, themes, countries, institutions, highly cited papers, and keywords, exploring the research progress of the interaction between plastics and microorganisms [17]. Liu Y.J., et al. used CiteSpace and ArcGIS software to conduct global scientific quantitative visualization analysis, intuitively demonstrating how urban resilience research (URR) changes over time and analyzing research frontiers. URR can help cities resist sudden natural disasters and quickly recover from adversity through reasonable resource allocation [18]. Hu W., et al.

analyzed 2099 references in the Web of Science (WOS) Core Collection using CiteSpace software, bibliometric methods and literature sorting methods to determine the hot spots, frontiers and development trends of ecological model application in Eutrophication [19].

In summary, this paper compares the literature related to water ecological risks in mining areas based on the Web of Science database from 2007 to 2021, and conducts literature visualization analysis with the help of citation analysis software CiteSpace and VOSviewer, and explores the research hotspots and cutting-edge trends in the field of water ecological risks in mining areas in terms of the annual distribution of publications, the main countries of publications, the main journals of publications, keyword co-occurrence and cluster analysis, so as to provide theoretical ideas and governance paths for solving water ecological risks in mining areas.

## Material and Methods

### Data Sources

The data selected for this paper were sourced from the Web of Science Core Collection, with data retrieved on 25 October 2022, and the search criteria were Mining and Water ecology risks or Mining and Water ecological risks as the topic, with the time span of 2007-2021, Document Types as Article, excluding Review Article, Editorial Material and other non-research documents were excluded, and a total of 1939 documents were retrieved, which made the research process more complete, the research results more precise and the research conclusions more representative.

### Research Methodology

Common software for mapping knowledge is CiteSpace [20-21], VOSviewer [22-23], UCINET [24], Bibexcel [25], et al., which are widely used in major fields for visual analysis of literature. In this paper, based on the principles of aesthetics and intuitiveness, the software chosen is CiteSpace (6.1.R3) and VOSviewer (1.6.18), the former was introduced to China by Professor Chaomei Chen in 2007 [26] and the latter was designed in 2009 [27].

VOSviewer is mainly used for visual analysis of literature co citation networks, which can display the relationships between literature through different colors, sizes, shapes, and other methods. At the same time, VOSviewer can also perform cluster analysis, Thematic analysis, co word analysis, etc. to help users better

understand the relationship between documents and research hotspots.

CiteSpace pays more attention to the Knowledge graph analysis of documents, and can show the relationship between documents through nodes, edges, labels, etc. CiteSpace can also conduct thematic evolution analysis, author collaboration network analysis, etc., to help users better understand the development process and research trends of literature.

In this paper, research topics are analysed in terms of the number of publications, countries, institutions, journals and authors, and the knowledge map related to water ecological risks in mining areas is mapped, while keyword clustering and keyword mutation are used to summarise and analyse research hotspots and future trends. This paper provides a systematic analysis of the field of water ecological risk in mining areas, which can complement and enrich the field of water ecological risk.

## Results

### Time-Series Distribution of Publications

The pace of development of the research field can be reflected by the chronological change in the number of articles published. In the 1940s, international research on water ecological risks in mining areas began to focus on regional water ecological risks, but from 2007 onwards, the focus of international research shifted to water ecological risks in mining areas. In the WOS Core Collection, the years 2007-2012 were in a slow growth phase, with the number of growth stabilising at around 50 per year, in the formation of basic concepts, as shown in Fig. 1b).

2013-2015 showed a steady growth trend, with the number of growth increasing by around 10 per year, and the theoretical foundation was basically completed; 2016-2021 showed a more rapid growth trend the overall volume of publications has increased significantly, with a large number of empirical studies

published, as shown in Fig. 1a). The international research environment is consistent with China's Development and Reform Commission and the Ministry of Natural Resources, which have been emphasising the "prominent issue of water resources ecosystem quality and function".

### Main Countries of Study

An analysis of the breadth of countries studied reveals the coverage of this research area worldwide, with more than 130 countries and regions conducting research on water ecological risks in mining areas. peoples R China has the most research in the area of water ecological risks in mining areas, with 605 papers published, accounting for 31.202% of the total number of papers published. Meanwhile, USA, Spain, Australia and Canada were in the top four positions, accounting for 12.532%, 9.128%, 6.498% and 6.292% of the total, respectively. This is followed by Brazil, Portugal, India, Germany and France. The TOP 20 countries in terms of number of articles published are shown in Table 1.

### Major Research Institutions

A collaborative mapping of research institutions on water ecological risks in mining areas was developed with the help of CiteSpace and is shown in Fig. 2. The parameters of the collaboration mapping are: N = 322, E = 335, Density = 0.0065, Largest CC: 175 (54%), and Nodes Labeled: 2.0%. And combined with Table 2, it can be seen that Chinese institutions accounted for 7 of the TOP 10 research institutions in terms of publication volume, with 147 articles in Chinese Acad Sci, 53 articles in Univ Chinese Acad Sci, 31 articles in Beijing Normal Univ, 29 articles in China Univ Min & Technol, 21 articles in Chinese Res Inst Environm Sci, 19 articles in China Univ Geosci, and 17 articles in Guangzhou Univ. The Univ Aveiro of Portugal with 53 articles is the second, the US Geol Survey of USA with 33 articles is the fourth and the Univ Queensland

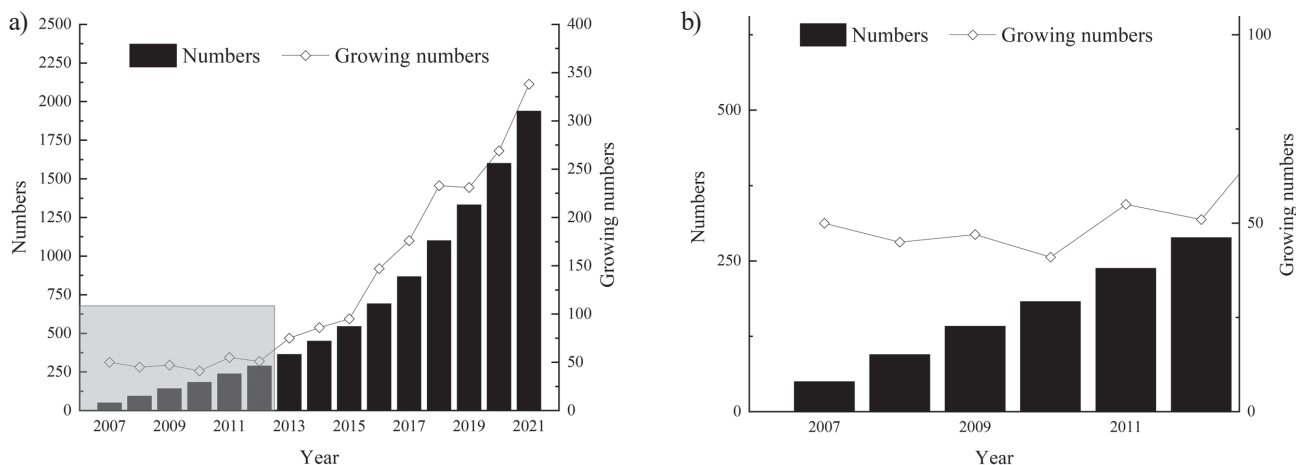


Fig. 1. Time-series distribution of publications by research area.

Table 1. Global distribution of main study countries (TOP 20).

Country	N	P	Country	N	P	Country	N	P	Country	N	P
Peoples R China	605	31.202%	Brazil	110	5.673%	Italy	55	2.837%	Turkey	38	1.960%
USA	243	12.532%	Portugal	88	4.538%	England	54	2.785%	South Korea	36	1.857%
Spain	177	9.128%	India	66	3.404%	Mexico	44	2.269%	South Africa	34	1.753%
Australia	126	6.498%	Germany	64	3.301%	Poland	43	2.218%	Colombia	32	1.650%
Canada	122	6.292%	France	59	3.043%	Iran	40	2.063%	Sweden	30	1.547%

Table 2. Spatial and temporal distribution of major research institutions (TOP 10).

Count	Year	Institutions	Count	Year	Institutions
147	2009	Chinese Acad Sci	29	2008	China Univ Min & Technol
53	2007	Univ Aveiro	21	2015	Chinese Res Inst Environm Sci
53	2014	Univ Chinese Acad Sci	19	2016	China Univ Geosci
33	2007	US Geol Survey	17	2015	Univ Queensland
31	2012	Beijing Normal Univ	17	2019	Guangzhou Univ

of Australia with 17 articles is tied for the 9<sup>th</sup> place with the same number of articles published by the Guangzhou Univ of China. China ranks first in the world in terms of publications on water ecological risks in mining areas, with Chinese Acad Sci dominating, while other research forces, although more dispersed, are still generally higher than those in Portugal, the USA and Australia, which is in line with the specialisation areas (hydrology, resource environment, remote sensing, etc.) offered by

domestic institutions, which also have corresponding MSc and PhD programmes.

### Major Published Journals

Knowing the distribution of papers in journals helps to get a more accurate picture of the hot spots and frontiers of research in the field. The TOP 20 journals in terms of number of publications are all



Fig. 2. Mapping of research institution collaboration.

Table 3. Ranking of journal publications (TOP 20).

Journal	N	P	IF	Journal	N	P	IF
Science of the Total Environment	194	10.005%	10.754	Journal of Environmental Management	36	1.857%	8.91
Environmental Science and Pollution Research	133	6.859%	5.19	Marine Pollution Bulletin	32	1.650%	7.001
Chemosphere	99	5.106%	8.943	Bulletin of Environmental Contamination and Toxicology	29	1.496%	2.807
Environmental Monitoring and Assessment	84	4.332%	3.307	Environmental Toxicology and Chemistry	27	1.392%	4.218
Environmental Pollution	74	3.816%	9.988	Water Air and Soil Pollution	27	1.392%	2.984
Environmental Earth Sciences	71	3.662%	3.119	Journal of Hazardous Materials	24	1.238%	14.224
Ecotoxicology and Environmental Safety	70	3.610%	7.129	Polish Journal of Environmental Studies	22	1.135%	1.871
Environmental Geochemistry and Health	57	2.940%	4.898	Archives of Environmental Contamination and Toxicology	21	1.083%	3.692
Journal of Soils and Sediments	48	2.476%	3.536	Ecological Indicators	19	0.980%	6.263
Human and Ecological Risk Assessment	40	2.063%	4.997	International Journal of Environmental Research and Public Health	19	0.980%	4.614

19 or more, and are closely related to Environmental Sciences Ecology, Public Environmental Occupational Health, Toxicology, Agriculture and Water Resources. As can be seen specifically from Table 3, Science of the Total Environment published the most relevant studies (194 papers, 10.005%), followed by Environmental Science and Pollution Research (133 papers, 6.859%), Chemosphere (99 papers, 5.106%) and Environmental Monitoring and Assessment (84 papers, 4.332%). In terms of overall distribution, there are only two journals with more than 100 papers and eight journals with more than 50 papers. More than half of the journals have an IF greater than 4.997, and two of them have an IF of more than 10, indicating that many leading academic journals are interested in research in the field of water ecological risk in mining areas.

#### Study Author Collaboration

Collaboration of research authors is a cornerstone of quality in the discipline. According to Price's Law, the number of papers by prolific authors accounts for half of the total number of papers, so the minimum number of documents of an author in VOSviewer is set to 3. Running the software to map the collaboration of research authors on water ecological risks in mining areas, starting with Network Visualization (Fig. 3a), the authors cited more than Zeng Guangming (575, TOP 1), Yang Zhaoguang (507, TOP 2), Pradhan Biswajeet (467, TOP 3), Perelra R. (465, TOP 4), Zhang Zengqiang (462, TOP 5), Wang Ying (460, TOP 6), Li Xiaodong (455, TOP 7) and Liang Jie (455, TOP 7) were cited more than 450 times. This is followed by Overlay Visualization (Fig. 3b), where a temporal

analysis of the collaborative publication volume of study authors shows that the research team has changed over time. Finally, Density Visualization, with 35 items (Fig. 3c), is divided into six clusters (Fig. 3d), particularly Tsang. Daniel C. W., Zhang Zengqiang and Xiao Tangfu. Many collaborative studies have been carried out between research teams within research teams, but the collaboration between research teams is still not close enough, and Chinese research teams are predominant.

#### Research Themes

It is assumed that the references of the same article adhere to the same theme and that an in-depth analysis of the research themes in the field is conducted. In this paper, a co-citation analysis was conducted to analyse the research themes in the field and the minimum number of citations of a cited reference was set to 20 in accordance with Price's Law. 98 eligible references were screened by VOSviewer software and plotted against Network Visualization (Fig. 4a) and Density Visualization (Fig. 4b and Fig. 4c). The field has 3 Clusters, 2703 Links and a Total link strength of 8730. The combined Citations and Total link strength of the co-cited literature were divided into Cluster 1 (35 items), Cluster 2 (33 items) and Cluster 3 (30 items). Cluster 1 focuses on Heavy metals, represented by Hakanson Lars (1980), Tomlinson D. L. (1980) and MacDonald D. D. (2000), and focuses on the relationship between heavy metals and water ecological risk in mining areas. Cluster 2 focuses on Health risk, represented by Li Zhiyuan (2014), Chen Haiyang (2015) and Rodriguez L. (2009), and focuses on the association between contaminants such as heavy

metals and health risk in mining areas. Cluster 3 focuses on Trace metals, represented by Tessier A. (1979), Sutherland R. A. (2000) and Loska Krzysztof (2004), and focuses on the link between heavy metals such as trace metals and water ecological risks in mining areas.

### High Frequency Keyword Characterisation

The cluster analysis of the co-cited literature could only be divided into three clusters, and the differences between the clusters were not very clear. In order to delve into the specific direction of the field of water

ecological risk in mining areas, this paper performs a cluster analysis of high-frequency keywords in the entire field and studies the differences in the characteristics of each cluster.

The 1939 documents were analysed with the help of CiteSpace software to draw a clustering map of high-frequency keywords (Fig. 5), with Modularity  $Q = 0.4053 > 0.3$  and Weighted Mean Silhouette  $S = 0.7245 > 0.7$ , indicating significant clustering effects and high confidence. The clustering profiles were divided into ten clusters, #0 Ecological risk assessment, #1 Heavy metals, #2 Trace elements, #3 Organic amendment, #4 Climate change, #5 Soil pollution, #6

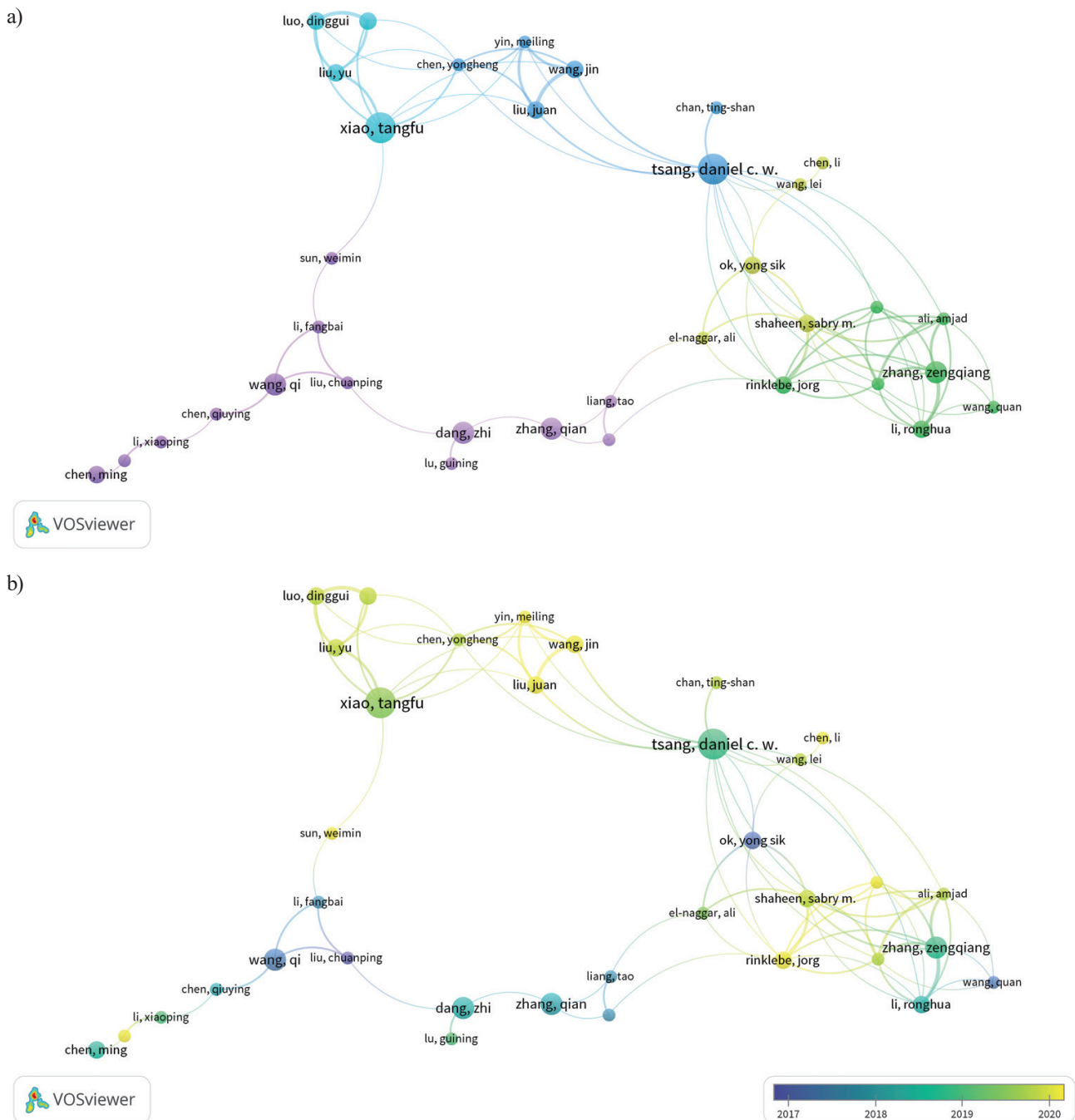


Fig. 3. Collaborative mapping of study authors.

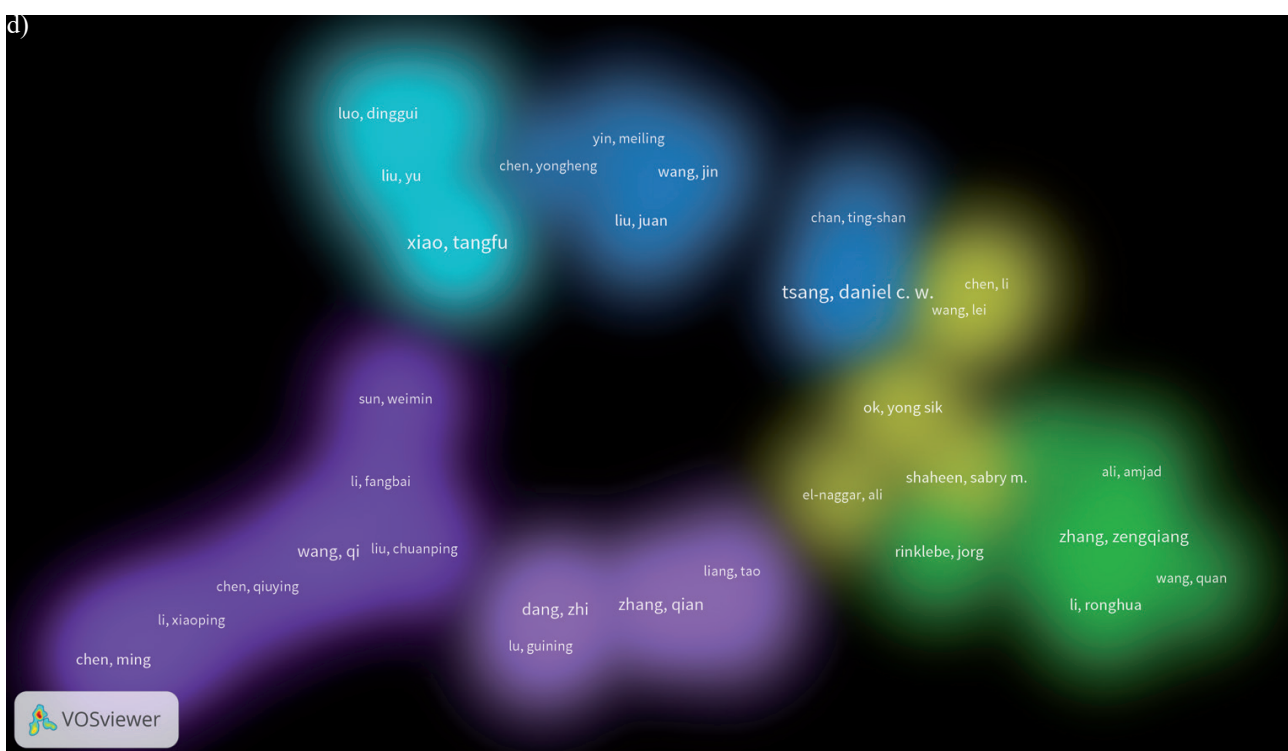
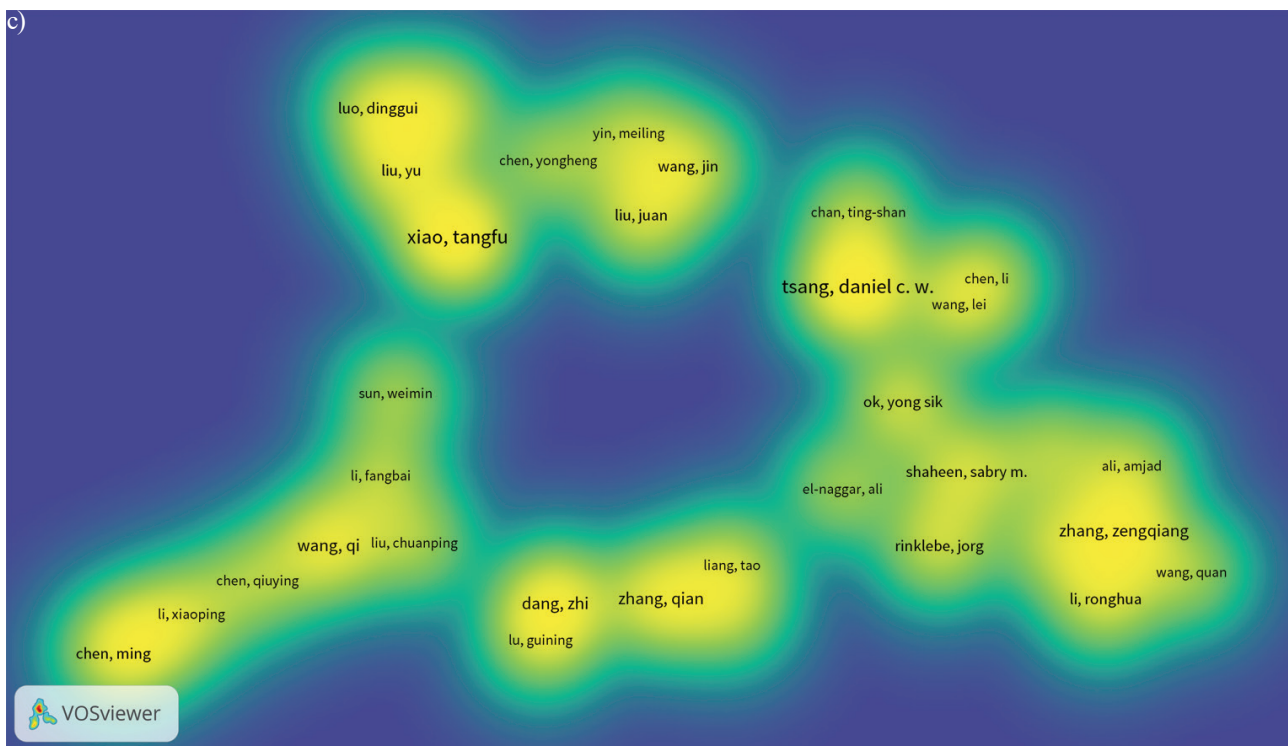


Fig. 3. Continued.

Methylmercury, #7 Heavy metal pollution, #8 Risk, #9 DNA damage.

Mine wastewater is caused by the presence of heavy metals and toxic elements in surface or groundwater caused by mining. Mine wastewater endangers the ecology of water sources and soil around the mining area, and even affects the normal use of water for human life. Many mines dump solid waste at will,

leading to river siltation and posing many water risks that affect social security. The open-pit mining has caused extensive land damage, affecting the normal development of agriculture and putting great pressure on human survival. The fine-grained substances and dust formed by the weathering of waste rocks during the mining process can generate dust storms in dry climates and strong winds, which can cause air pollution

in the regional environment and affect human life safety. So, the pollutants generated by mining directly affect the ecological environment and health and safety.

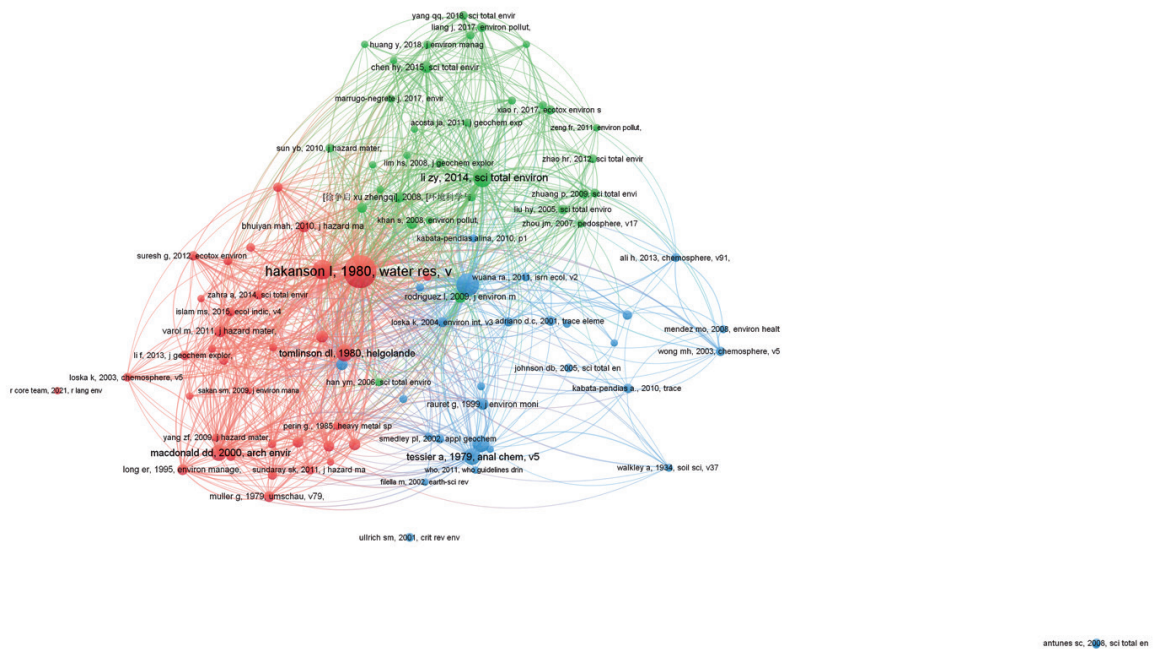
### Evolution of Research Hotspots

Timeline analysis of high-frequency keywords can better clarify the evolutionary path of the field in terms of the temporal dimension. At the same time,

the analysis of keyword emergence can reasonably predict the migration of research hotspots and derivative relationships in the field. The Timeline diagram of high frequency keywords (Fig. 6) and the emergence diagram of high frequency keywords (Fig. 7) were drawn with the help of CiteSpace software.

At the cluster level, the longest time span is #1 Heavy metals (2007-2021); the next longest time span is #0 Ecological risk assessment (2007-2019); the three

a)



b)

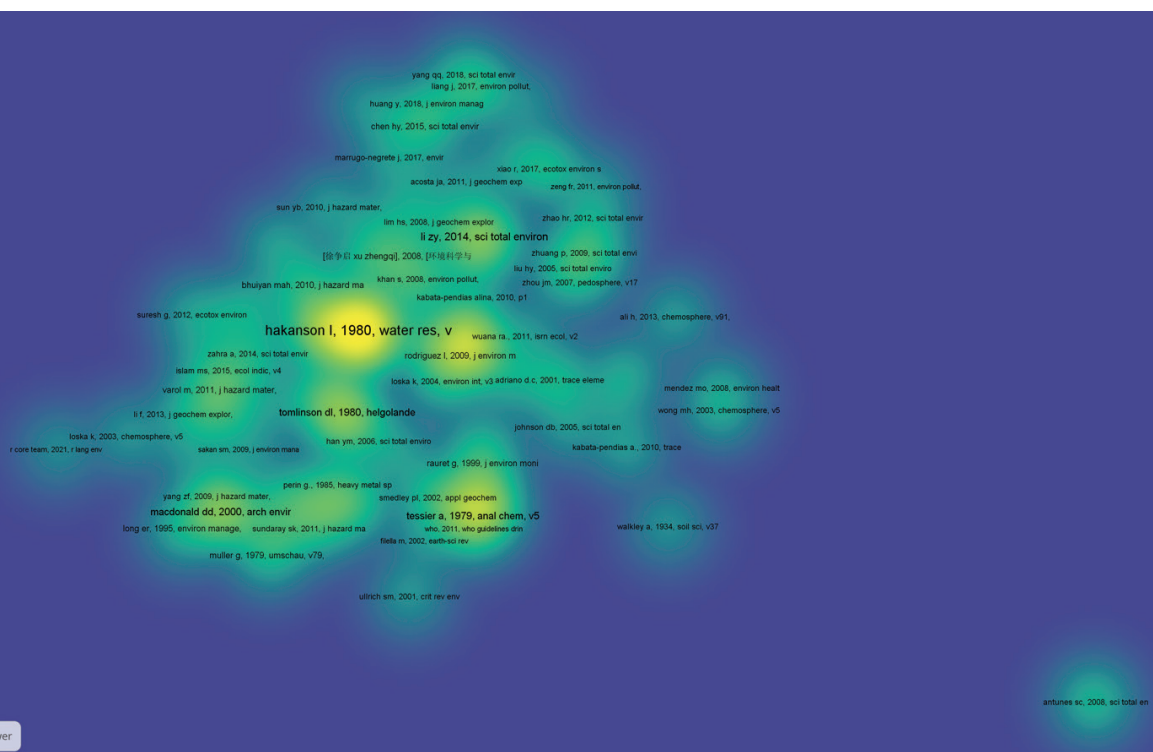


Fig. 4. Research themes - literature co-cited.



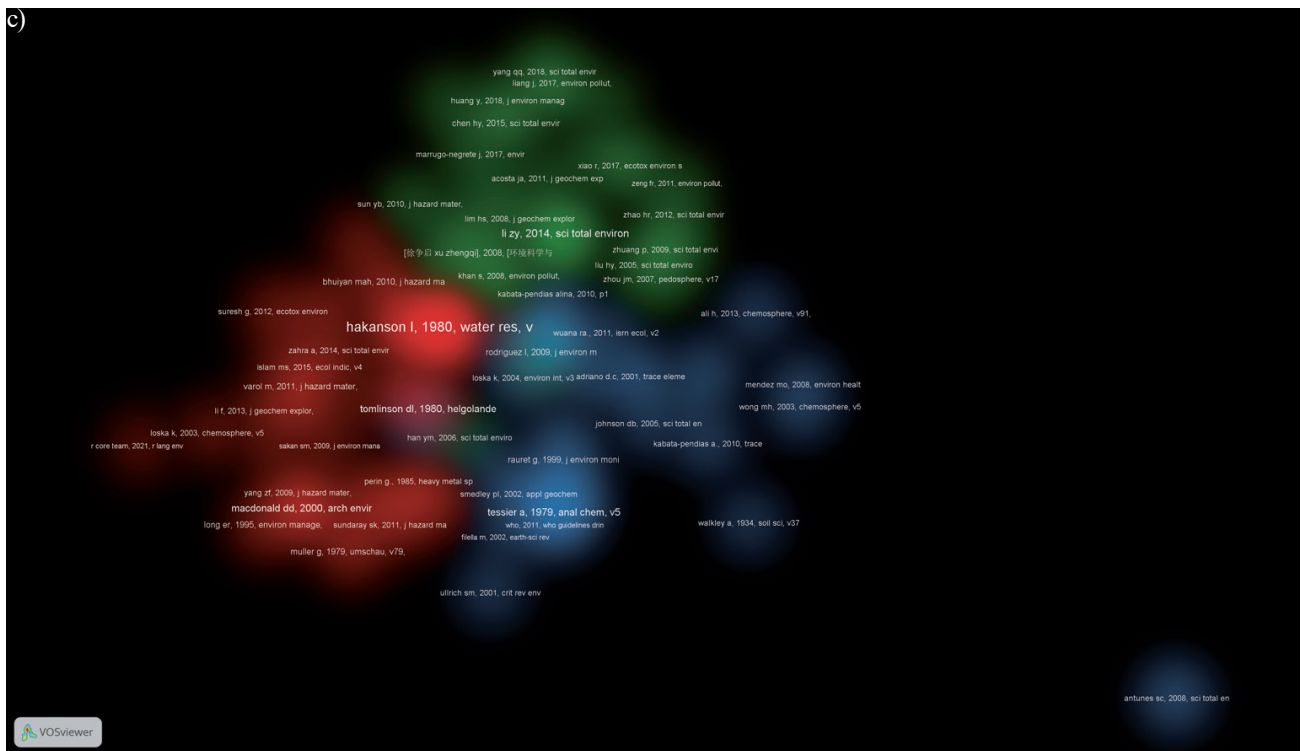


Fig. 4. Continued.

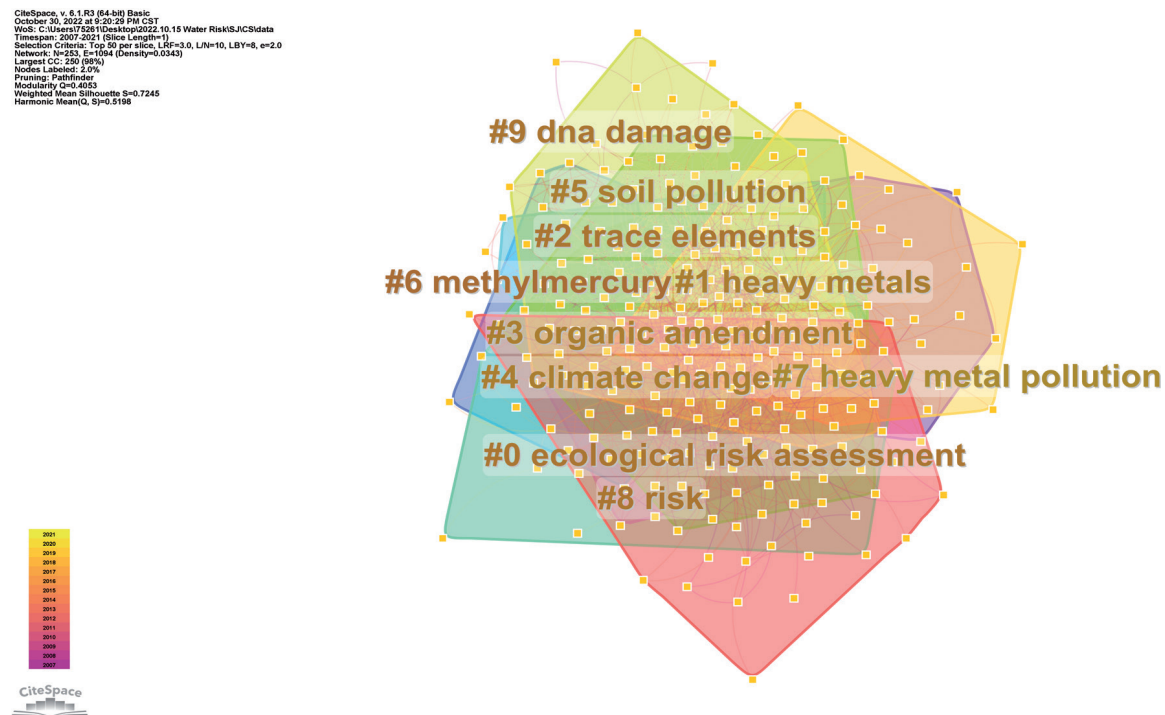


Fig. 5. High frequency keyword clustering mapping.

shortest time spans are #4 Climate change (2007-2014), #5 Soil pollution (2007-2014) and #8 Risk (2009-2016). Heavy metals has always been one of the sources of water ecological risk in the mining area, as Ecological risk assessment has also been conducted in parallel, so

Climate change, Soil pollution and Risk have improved. At the level of keyword emergence, the pre-study (2007-2012) focused on Fish, Environment, Response and Methylmercury; the mid-term studies (2014-2019) focused on Waste water, China, Potential ecological



Fig. 6. Timeline chart for high frequency keywords.

**Top 25 Keywords with the Strongest Citation Bursts**

Keywords	Year	Strength	Begin	End	2007 - 2021
fish	2007	9.76	2007	2015	[Red bar]
growth	2007	7.76	2007	2013	[Red bar]
environment	2007	6.16	2007	2014	[Red bar]
response	2007	5.64	2007	2015	[Red bar]
metal	2007	4.92	2007	2010	[Red bar]
methylmercury	2008	5.43	2008	2015	[Red bar]
uranium mine	2008	4.82	2008	2011	[Red bar]
iberian pyrite belt	2009	5.65	2009	2015	[Red bar]
marine sediment	2009	5.65	2009	2015	[Red bar]
environmental risk	2009	4.66	2009	2014	[Red bar]
ecosystem	2010	6.34	2010	2013	[Red bar]
fractionation	2011	7.41	2011	2016	[Red bar]
model	2012	7.77	2012	2017	[Red bar]
waste water	2014	6.98	2014	2017	[Red bar]
china	2015	11.22	2015	2018	[Red bar]
potential ecological risk	2015	7	2015	2018	[Red bar]
mining activity	2015	5.66	2015	2017	[Red bar]
multivariate analysis	2015	4.54	2015	2016	[Red bar]
tailing	2007	6.06	2016	2017	[Red bar]
mine tailing	2009	5.7	2017	2018	[Red bar]
pb	2008	6.53	2018	2019	[Red bar]
management	2012	5.46	2018	2019	[Red bar]
potentially toxic element	2019	7.55	2019	2021	[Red bar]
mining area	2010	6.77	2019	2021	[Red bar]
lake	2008	4.66	2019	2021	[Red bar]

Fig. 7. High frequency keyword emergence map.

risk and Mining activity; the later studies (2019-2021) focused on Potentially toxic element, Mining area and Lake.

The field of research has now shifted from initially considering individual substances as water-ecological risk points to exploring toxic substances from mining areas as sources of water-ecological risk, scientifically identifying water-ecological risk representations and effectively promoting the healthy and sustainable development of water ecosystems in mining areas.

**Discussion**

How to effectively reduce the water ecological risk under the premise of ensuring high-quality economic development should follow the anti-planning theory, give priority to the spatial planning of mining areas in non-construction areas, and emphasize the integrity of ecological resources and the authenticity of regional environment. In recent years, the research object has changed from the water ecological risk point composed of a single substance to the water ecological risk source of multiple substances, which can effectively control the uncertainty of water ecological risk in mining areas. Mining cities should jump out of the economy to see the economy, carry out economic-oriented transformation, realize the control of industrial structure and economic development direction through reasonable ecological layout of mining areas, and make the overall economy of mining cities develop towards an environmentally friendly situation. Heavy metals and Ecological risk assessment have become high-frequency keywords.

It can be seen that the economic guidance of mining cities should have the dual characteristics of optimal allocation of resources and environmental pollution control. Optimize the promotion of mining ecology, strengthen ecological environment planning, infiltrate economic planning and urban planning, emphasize the combination of physics-reason-human reason, implement binding and guiding measures, and apply diversified economic control means, so as to reduce the water ecological risks in mining areas in mining cities.

## Conclusions

Based on the Web of Science database, this paper uses CiteSpace and VOSviewer Knowledge graph to study the water ecological risk in the mining area. Through multidimensional analysis of the temporal distribution of publication volume, major research countries, major research institutions, major published journals, research author collaborations, research themes, high-frequency keyword feature analysis, and the evolution of research hotspots, the following conclusions can be drawn:

(1) The number of publications is steadily increasing, showing three stages of slow growth-steady growth-rapid growth, with an increasingly rapid growth rate. China is the research country with the highest number of publications, with seven research institutions ranked in the TOP 10; the second highest number of publications is the United States.

(2) There are 8 journals with more than 50 papers, and more than half of the TOP 20 journals have an IF greater than 4.997. Research teams are divided into 6 clusters, and many studies are carried out internally, but the cooperation between teams is not close enough.

(3) The research topics of water ecological risks in mining areas can be mainly divided into three clusters. Cluster 1 mainly focuses on Heavy metals, Cluster 2 mainly focuses on Health risks, and Cluster 3 mainly focuses on Trace metals.

(4) The high-frequency keyword feature analysis of water ecological risks in mining areas can be divided into ten clusters, namely # 0 Ecological risk assessment, # 1 Heavy metals, # 2 Trace elements, # 3 Organizational index, # 4 Climate change, # 5 Soil pollution, # 6 Metallmercury, # 7 Heavy metal pollution, # 8 Risk, and # 9 DNA damage.

(5) The evolution of research hotspots on water ecological risks in mining areas, from a clustering perspective, the longest time span is # 1 Heavy metals; The second longest time span is # 0 Ecological risk assessment. From the perspective of keyword emergence, it can be divided into three periods, namely early research (2007-2012), mid-term research (2014-2019), and later research (2019-2021).

At present, the research object in the field of mining area water ecological risk research has changed from the initial single substance as the water ecological risk point

to the coupling research of multiple substances produced by mining area as the water ecological risk source. The pollutants (dust, heavy metals, toxic elements, etc.) generated during mining directly affect the ecological environment and health safety. Therefore, it is necessary to strengthen resource optimization and environmental pollution control from the perspective of ecological layout in mining areas, in order to effectively ensure the safety of drinking water for residents.

## Acknowledgments

This work was supported by the following programs:

1. National Natural Science Foundation of China: Study on the spatial and temporal evolution, early warning and dynamic response mechanism of water ecological risks in the Huai River Basin (72271005).

2. Humanities and Social Sciences Planning Fund of the Education Ministry: Research on the priority assessment, amount measurement and cross-regional realization mechanism of ecological compensation in the Huai River Basin (22YJAZH025).

3. Philosophy and Social Science Planning Project in Anhui Province: Study on spatio-temporal evolution and early warning and response mechanism of water ecological environment risk in Huaihe River Basin (Anhui) (AHSKY2022D124).

4. Postgraduate Innovation Fund of AUST: Multidimensional measurement and prediction of water resources carrying capacity of mining cities (2021CX1013).

## Conflict of Interest

The authors declare no conflict of interest.

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