Visual Analysis of Bentonite Adsorption Research from January 2011 to July 2021

Ru Li\textsuperscript{1a}, Hui Huang\textsuperscript{1b}\textsuperscript{*}, Mengxin Zhang\textsuperscript{1c}, Changyong Jiang\textsuperscript{1d}

\textsuperscript{1}School of Materials and Chemical Engineering, Ningbo University of Technology, Ningbo, Zhejiang, 315211, P R China
\textsuperscript{a}540371323@qq.com, \textsuperscript{b}huihuang@nbut.edu.cn, \textsuperscript{c}2798143376@qq.com, \textsuperscript{d}2367362969@qq.com

Abstract. This paper takes "bentonite" as the theme and "adsorption" as the keyword, adopts the bibliometric method and visual analysis method, deeply analyzes the research status, keywords, authors and institutions of bentonite adsorption through CiteSpace software, and forecasts the future research and development trend, so as to better promote the research process of bentonite adsorption and provide reference for green sustainable development. The results show that researches on adsorption, sorption and bentonite are hot spots, and many scholars have published authoritative papers. Based on the whole, scholars and institutions mostly conduct independent research, and research forces are relatively scattered.

1. Introduction
At present, water pollution has become one of the most serious pollution in the world. International organizations attach great importance to the protection of ecological environment. Bentonite, as a new type of non-metallic mineral adsorbent, is rich in resources and known as "universal" clay. Bentonite is widely used in metallurgy, chemical industry, environmental protection and other fields because of its good adsorption, cation exchange and expansibility, which can be used as adsorbent, suspension agent and flocculant \cite{1}. To this end, the relevant literature was visually analyzed and the corresponding knowledge map was drawn, and the relationship between the research process and the knowledge structure system was accurately projected \cite{2}, which is of enlightening significance for promoting subsequent adsorption studies.

2. Data sources and methods
In order to ensure the scientificity and comprehensiveness of the data, this study was based on the DATABASE of China National Knowledge Network (CNKI). Through the retrieval of advanced retrieval journals, gas safety was set as the subject search term, and the publication time was limited to January 2011 to July 2021. After excluding irrelevant literatures, 2804 valid literatures were finally retrieved. At the same time, we cannot exclude the overlapping problem of a small part caused by different types of literature sources.

By analyzing the citation of literature, the visual knowledge map presents the development context and process of the knowledge domain, so as to mine the knowledge clustering and distribution contained in the citation space \cite{3}. In this study, the software CiteSpace 5.7.R3 was used to draw the corresponding knowledge graph, and the internal connection between the research and development process and the knowledge structure system was truthfully reflected in the form of representation. Set the time slice to
one year, Top N=50%, set keywords, institution and author respectively for Node types, draw the knowledge graph and carry out the detection of emergent words.

3. Quantitative Analysis of Communications
As an important indicator to measure the development of research in a certain field, the number of published papers can be used for reference to predict the development trend of future research. Figure 1 shows the statistics of bentonite emission. In the past decade, the number of published articles has been roughly flat, showing a small and stable growth trend. Initially, the study showed the largest increase in 2012, with a rapid increase in research interest, and reached the highest number of papers in 2020, with 329 papers.

![Fig.1 Statistical chart of documents issued on bentonite adsorption research from 2011 to July 2021](image)

3.1 Keywords and Emergent Words Analysis
Keywords, as the intersection of concepts and methods in academic communication, highly summarize the central trend or core method of academic development. Keywords co-occurrence map was drawn by CiteSpace, and the standard evaluation system was formed by the frequency and centrality of keywords, so as to directly analyze the overall framework of bentonite research hotspots. Cross nodes are set in Figure 2. The size of nodes represents the frequency of keywords. The figure contains a total of 741 nodes, 3336 lines, and the network density is 0.012. According to the analysis, adsorption, Montmorillonite, bentonite, and sorption are the main keywords, that is, the nature of bentonite is the core of the whole related academic system research. Based on the spatial crystal structure of bentonite, it has strong chemical and physical adsorption and efficient ion exchange, which is of great significance for the structural optimization and efficiency enhancement of the secondary industry. In the follow-up research process, it will be the top priority to optimize the output ratio and cost performance of bentonite to make it serve for the upgrading of China's industrial structure.
Emergent words, as the strength of keyword nodes in the time span, represent the dynamic changes in the time dimension of the research field in the past decade. To a certain extent, partial effective data fitting can be carried out, which is beneficial to present some potential research frontiers. Based on the emergent words, the span in the sense of time is analyzed in depth. Combined with Kleinberg's emergent words detection algorithm in CiteSpace, the top 10 keywords in the emergent information table are truncated to obtain Figure 3. "Strength" refers to the burst rate, which represents the burst strength of keywords. Keywords such as organobentonite, organoclay and chitosan have high emergence intensity, which lasts for three years or more. "Keywords" represent the hot Keywords studied within the time range of the beginning and the end of the emergence. The analysis shows that the emerging liability Ant, Cationic dye and Adsorption models have continued to be paid attention to during 2019-2021, highlighting the dual central core. On the one hand, the chemical properties of bentonite, that is, the use of modern technology for bentonite properties detection and application analysis. On the other hand is the bentonite modification scheme, which is modified based on chemical properties with the help of academic literacy and suitable for production.

**Top 10 Keywords with the Strongest Citation Bursts**

| Keywords               | Year | Strength Begin End 2011 - 2021 |
|------------------------|------|---------------------------------|
| organoclay             | 2011 | 5.07 2011 2015                  |
| modified bentonite     | 2011 | 4.29 2011 2012                  |
| organic bentonite      | 2011 | 4.02 2011 2016                  |
| chitosan               | 2011 | 4.67 2012 2015                  |
| nanoclay               | 2011 | 3.70 2015 2018                  |
| response surface method | 2011 | 3.73 2018 2019                  |
| emerging contaminant   | 2011 | 4.06 2019 2021                  |
| montmorillonite clay   | 2011 | 4.52 2019 2021                  |
| cationic dye           | 2011 | 3.66 2019 2021                  |
| adsorption model       | 2011 | 3.66 2019 2021                  |

3.2 **Core Author Analysis**  
The researcher is a very important factor in the process of the development and evolution of the discipline, and is the main force to promote the development of the discipline. As a basis for judging the level of researchers, the ability of researchers is positively correlated with the number of papers published in important academic journals, that is, the number of high-quality academic papers represents
the research ability [5]. Run the CiteSpace software, set Node Types to "Author", and Thresholds to 5 (When the number of outgoing posts exceeds 5, the Node marker is displayed), and you need to Thresholds for the co-occurrence graph of outgoing authors. There are 597 nodes in FIG. 4, and the network density is only 0.001, indicating that the research system in the field is relatively loose. From the figure, we can see intuitively that there are many scholars engaged in research in this field, but a large cooperation network has not been formed yet, mostly in a group mode of 3-5 people. Although Mingzhu Xia and Fengyun Wang only published articles since 2019, they have published 18 related articles in the past two years, tying for the first place. Zhaohui Li ranked third with 16 articles, and at least 8 articles.

Fig.4 Contribution of authors in bentonite adsorption field from 2011 to July 2021

3.3 Analysis of Posting Mechanism

The map of institutional cooperation knowledge for bentonite adsorption studies is shown in Figure 5. There are 433 nodes in the figure, and each node represents an institution. The density of cooperation among institutions is lower than that of authors, which is only 0.0009. Scientific research results in the corresponding period in a certain field are published to the world through scientific literature and invention patents, while scientific cooperation is usually reflected in the publication of academic papers jointly signed by researchers and their cooperative institutions in academic journals. Cooperation in academic papers is an important way to understand the situation of scientific cooperation [6]. As can be seen from Figure 5, the authors with a large number of publications are all in cooperation with universities, and these authors often work in corresponding universities. Based on the above analysis, the main force of bentonite adsorption research institutions in China is still colleges and universities, and they have not established a close cooperation relationship with enterprises, which is not in line with the current trend of "industry-university-research" and "R&D OEM", and is not conducive to the market-oriented transformation of scientific research results.
4. Conclusions
From the point of view of research hotspots, the research on bentonite adsorption will focus on chemisorption properties and bentonite modification. By further developing the accumulation of bentonite natural science and absorbing the foundation of bentonite natural science, the optimization of bentonite adsorption property will become the focus of future research.

From the perspective of spatial distribution, China has a large number of talents in the field of bentonite adsorption. In the past decade, MINGZHU XIA and FENGYUN WANG published the most papers. However, there is a lack of close cooperation between authors and institutions, and the research system in this field is loose. In future research, universities can strengthen communication and exchanges with related enterprises, so as to form a virtuous cycle of theory guiding practice and practice testing truth, so as to explore a road of collaborative innovation and accelerate the transformation of scientific research results.

Acknowledgment
This work was the initial result of the Student Innovation and Entrepreneurship Training Program of China with the project name of preparation and adsorption properties of modified attapulgite.

References
[1] Zhang, W. (2018) Application progress of bentonite for adsorption of organic pollutants in water. Envi. Protec. Chem. Indu., 38: 267-274.
[2] Li, R., Huang, H., Zhang, J., Zhang, M.X. (2021) Research status and hot spot visualization analysis of “gas safety” based on CiteSpace. E3S Web of Conferences, 228.
[3] Zhang, J., Li, R., Zhang, M.X., Jiang, L.Y., Huang, H. (2020) Visual Analysis of Set pair Analysis Theory Based on CiteSpace. J. Ningbo Insti. Tech., 201:71-76.
[4] Li, M.N. (2016) Frontier analysis of competitive intelligence mining based on association rules. J. Intell., 35:54-60.
[5] Du, W.B. (2020) Research on THE Development of STEM Education in the United States. East China Normal U.
[6] Lu, C.W., Liu, X.Q., Jiang, S., Zhang, S. (2021) Visualization analysis of deep well mining research based on CiteSpace. Mining Tech., 21:137-142.