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Trends in The Ongoing Research Regarding the Role of Xanthan Gum in Sustainable Geotechnical Engineering

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Abstract: *A biodegradable and eco-friendly biopolymer, xanthan gum, has gained attention as an alternative to traditional chemical soil stabilizers. This study presents a bibliometric analysis of global research trends on xanthan gum as a soil improvement additive, highlighting its growing role in sustainable geotechnical engineering. Data retrieval was collected through credible scientific databases, covering publications from 2000 to 2025. In addition, publication output, citation patterns, main contributors, and keyword co-occurrence were analyzed by using tools such as VOSviewer and Biblioshiny. During the overall research analysis, research activities on soil remediation issues have grown steadily. Among them, the main research topics include soil stabilization, erosion control, permeability reduction, and mechanical property enhancement. The analysis also revealed strong interactive network nodes and practical research focuses on sustainable development. This bibliometric map provides insights into the development of this sub-field, fills the gaps in knowledge gaps, and points out future directions for interdisciplinary research and practical applications.*

Keywords: Xanthan Gum; Bipolymer; Soil Stabilization; Sustainable Geotechnics; Soil Treatment

1. INTRODUCTION

1.1 Background

Soil stabilization is the primary concern in geotechnical engineering since soil strength, durability and bearing capacity are critical for the construction of buildings and public infrastructure projects as the most fundamental elements in the start [1]. In the conventional construction process and even today, chemical additives like cement and lime are still the mainstream and commonly used to enhance soil characteristics. With such chemical materials, pollution issues are almost inevitable, like carbon emissions, soil contamination and ecological injury [2]. Now, the more the economy thrives with growing infrastructure demands, the more pressing the need is for sustainable engineering solutions, especially with the United Nations' sustainable development goals looming [3, 4, 5]. Natural biopolymers have emerged in this aspect as effective alternatives for improving the soil in an environmentally-friendly manner.

A natural polysaccharide biopolymer, xanthan gum, which is produced by fermentation of sugars by a specific bacterium, Xanthomonas campestris, functions as a thickening and stabilizing agent, gaining attention due to its eco-friendly, biodegradable and non-toxic. With its excellent water retention, viscosity-enhancing and adhesive properties, xanthan gum can be considered as an ideal alternate solution to replace traditional harmful chemical medium in stabilizing soil, reducing permeability and controlling erosion. For instance, it is found to be able to form a gel-like matrix reducing the flow of water and stabilizing the structure between the soil particles, thereby improving unconfined compressive strength and reducing surface erosion. Its application also advocates green building and sustainable development processes.

With the establishment of the information age, the population is becoming increasingly conscious about environmental protection, which has driven interest in biopolymer-based soil additives as a subject. Among the biopolymers found naturally, xanthan gum has gained prominence because it is environmentally friendly and can successfully improve soil [6]. In the last decades, publication on xanthan gum applied to soil increased considerably. Nevertheless, with more research studies being conducted, there remains an insufficient amount of comprehensive bibliometric analysis to represent the growth, collaboration trends and thematic development of this sub-research field.

This research aims to bridge this gap through performing a bibliometric study on the international trends of research on xanthan gum as an additive for soil improvement. Through harvesting and analyzing journals between the years 2000 and 2025 from credible databases, this paper aims to determine prominent

contributors, regions or nations, institutions, significant keywords, and major research themes. As technology becomes increasingly advanced, software packages like VOSviewer and Biblioshiny are employed to create visual maps of co-authorship networks, keyword co-occurrence, and topic clusters in order to present a holistic figure of the make-up [7, 8].

1.2 Objectives

The main purpose of this study is to:

1. Exploring the growth and impact of xanthan gum on soil stabilization research.
2. Analyse and map thematic developments and trends in the field of xanthan gum and their regional distribution.
3. Present the gaps and future development directions in the field of xanthan gum.

2. METHODOLOGY

This study uses bibliometric methods to quantitatively and qualitatively analyze the current status of research on xanthan gum as a soil stabilizer worldwide. The research method is mainly divided into four parts: data source selection, retrieval strategy, data processing tools and analysis indicators.

2.1 Data Source

Scopus database, as the world's largest collection of literature data, will be used as the main data source in this paper because it covers a wide range of peer-reviewed scientific literature in engineering, environmental science and multidisciplinary fields [9]. Moreover, Scopus can provide rich and authentic citation information, author relationships and publication metadata, which is very suitable for bibliometric analysis.

2.2 Data Retrieval Strategy

A comprehensive search was conducted using the following key terms:

- Xanthan gum
- Soil stabilization
- Biopolymer-based soil improvement

The search covered titles, abstracts, and keywords to ensure inclusion of relevant literature. The filters for the search criteria were as follows:

- Document type: articles and reviews only
- Language: English
- Time range: 2000 to 2025
- Subject areas: engineering, environmental sciences, Earth and planetary sciences, materials sciences

Finally, download the dataset with citation information, bibliographic information, abstract and keyword in CSV format for further analysis.

2.3 Data processing tools

Bibliometric analysis and visualization will be conducted using two tools:

VOSviewer(version 1.6.20) is used for plotting co-authorship networks, keyword co-occurrences, and citation relationships.

Biblioshiny(Bibliometrix R package) is used for descriptive bibliometric statistics, trend analysis, and thematic mapping.

Preliminary data cleaning and basic tabulation will be performed using Microsoft Excel.

2.4 Data Analysis

The bibliometric indicators examined include:

- Author analysis, which is on the most prolific and influential authors (by citations and H-index)
- Keyword analysis, which includes the commonly used keywords and co-occurring keywords to identify research themes and emerging topics
- National and institutional contributions are the institutions with the largest contributions, and their geographical distribution
- Thematic analysis based on the most active topic relating xanthan gum soil-related research
- Citation analysis of highly cited papers and citation trends
- Collaboration networks are co-authorship relationships between researchers, institutions and countries

This structured approach provides a comprehensive perspective on the development and direction of research in this emerging field [10, 11].

3. RESULTS AND DISCUSSION

3.1 Author Analysis

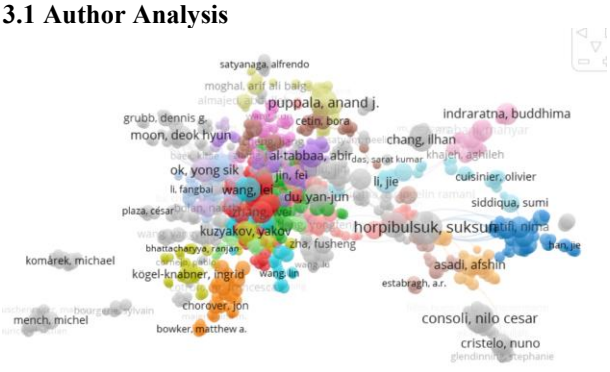

Fig. 1. Network Visualization of Contributors

The network of co-authors delivers information about the composition and the dynamics of peer interactions in research on xanthan gum soils. As demonstrated by the visual representation of the network (Figure 1), each node represents a single author, and node size is representative of the author's productivity or influence—tended to be measured in numbers of publications or

citations. Incidentally, writers such as Suksuntti Horpibulsuk, Buddhima Indraratna, Anand J. Puppala, and Yong Sik Ok are all marked by larger nodes, which signify their contributory significance and central roles in the discipline.

Color-coded clusters distinguish groups of authors who are often coauthors or write for particular thematic areas. For instance, a cluster could relate to geotechnical engineering applications of xanthan gum, and another could represent research in environmental soil stabilization or biopolymer interactions with soil systems. Authors in close proximity to each other often write more together because they have more similar kinds of research interests or because they coauthor more. Authors who are farther apart from each other are less likely connected or work on different subtopics.

The map also indicates robust co-authorship ties through the existence of thick diagonal lines among key players like Lei Wang, Yan-Jun Du, and Wei Zhang, who emerge in a highly connected area of the map. Conversely, writers like Michel Mench and Michael Komárek exist at the fringes, possibly indicating that they publish in niche or less integrated streams of research. Generally, the collaboration network emphasizes the existence of a number of dominant clusters and emphasizes the interdisciplinary and collaborative nature of research in this area.

3.2 Keyword Analysis

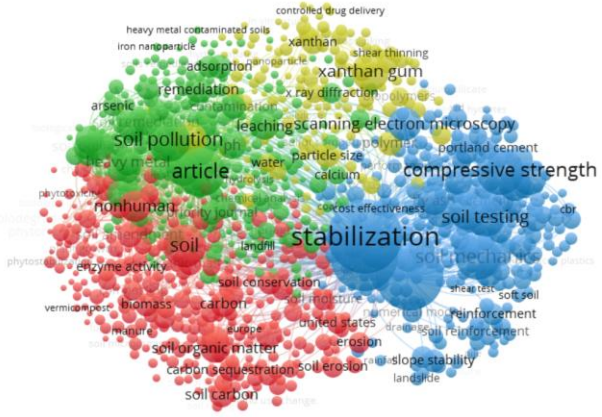

Fig. 2. Network Visualization of Keywords

Keyword co-occurrence network is giving us the bird's eye view of the xanthan gum horizon of literature on themes in soils. All nodes in this instance are keywords previously extracted from title, abstract, or author keywords, and node size is being represented by frequency of occurrence. Big nodes indicate key terms like "stabilization," "xanthan gum," "compressive strength," "soil pollution," and "soil" that register their highest-level salience in the literature. Color-coded clusters delineate clusters of keywords that co-occur and thus signal dominant streams of research and thematic specializations. The blue cluster in the lower-right is linked with geotechnical and civil engineering use, the most important key words being "stabilization," "compressive strength," "soil mechanics," "reinforcement," and "numerical modeling." The cluster is indicative of focus on the enhancement of the mechanical properties of the soil by xanthan gum, especially in use related to slope stability, soft ground improvement, and construction materials.

Top-center location has yellow cluster with keywords "xanthan gum," "polymer," "xanthan," "scanning electron microscopy," and "x-ray diffraction" and reflects high priority on material science and physicochemical characterization of xanthan gum in soil matrices. Green cluster at the left-center area of the network includes environmental remediation, which holds keywords "soil pollution," "heavy metal," "remediation," "adsorption," and "arsenic." The keywords target the use of xanthan gum in nature, i.e., immobilization and decontamination of contaminated soils. Finally, the red group found at bottom-left is filled with keywords like "soil carbon," "biomass," "enzyme activity," "carbon sequestration," and "soil organic matter." This indicates an increased number of research papers studying the environmental and biological effects of xanthan gum, especially on soil quality, microbial life, and the carbon cycle.

Lastly, the keyword network depicts four prevailing and superimposed thematic clusters in xanthan gum earth sciences: materials characterization, geotechnical engineering, environmental remediation, and soil ecology. The interstices between these clusters indicate xanthan gum's interdisciplinary application and is a proof of its rapidly impactful presence on both engineering and environmental sciences.

3.3 National and Institutional Contribution

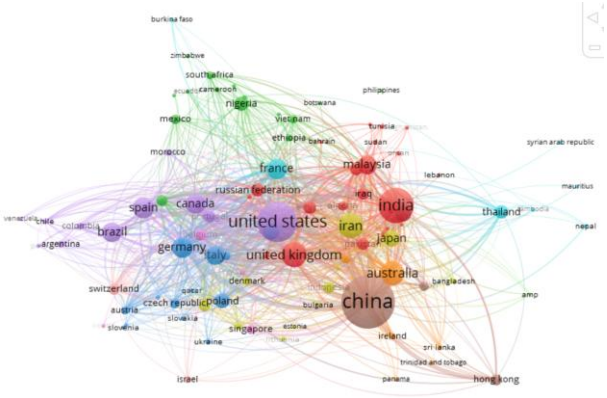

Fig. 3. Density Visualization of Countries

Country co-authorship network analysis detects several different geographical clusters, each of which forms regional research collaborations for xanthan gum as a soil conditioner. The core cluster of the purple group is found in the left-center of the map and consists of the United States. It is the biggest node in its cluster, working dynamically with countries such as Canada, Spain, Brazil, Argentina, Colombia, Venezuela, Portugal, and others, indicative of broad transcontinental research activity in the Americas and areas of Europe. China, conversely, is the biggest node on the entire map, at the bottom-right and brown. China's robust R&D performance is backed by its collaboration with Hong Kong, Bangladesh,

Bulgaria, and Estonia, with an expanding global outreach. Australia, forming the orange cluster in the top-right corner near China, has connections with Ireland, Panama, Sri Lanka, and Trinidad and Tobago, indicating its diverse global partnerships. India, also on the right-hand side as the red cluster, is also a major contributor, showing collaborations with Malaysia, Iraq, the Russian Federation, Sudan, Tunisia, the United Kingdom, Algeria, Egypt, Pakistan, and several others. A light blue cluster includes Thailand, connected to France—which is in the center—and extends to Nepal, Mauritius, and the Syrian Arab Republic at the left edge of the map. The dark blue cluster in the bottom-left has Germany, Italy, Poland, Austria, Czech Republic, Slovenia, Slovakia, and Ukraine as a tight European research community. Finally, there is a tiny green cluster in the top-left with emerging participants such as Nigeria, Vietnam, Cameroon, South Africa, and Mexico, denoting growing attention from African and Southeast Asian nations. These clusters together outline the international and multidisciplinary nature of research in biopolymer-based soil stabilization, with principal centers of attention in the developed and developing world.

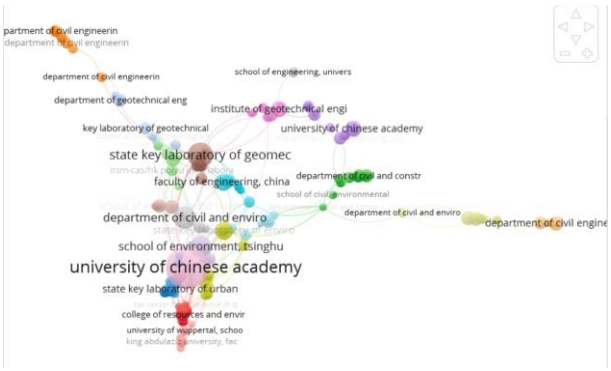

Fig. 4. Network Visualization of Organizations

Figure 4 is a visualization of a network of organizations with xanthan gum soil-related research engagement, highlighting institutional collaborative patterns. University of Chinese Academy of Sciences is the most central and dominating institution in the network, signifying its dominating position and close collaborative ties between the research community. Surrounding this focal point are some prominent departments and institutions, such as State Key Laboratory of Geomechanics, Department of Civil and Environmental Engineering, and some engineering schools, evidencing the convergence of research talent in civil, geotechnical, and environmental engineering domains.

Nodes of the same color grouped together indicate intensive working relationships between individual institutions or departments, and the proximity and density of edges indicate the extent of their collaborative publications or joint research work. Global players such as the University of Wuppertal and King Abdulaziz University also appear in the network but with sparse and less connectivity, indicating limited but imminent global partnerships.

Overall, the map illustrates the dominance of Chinese institutions in this area of study, and there are only a few leading organizations at the center of published work. The collaborative structure also reflects growing trends toward interdisciplinary and inter-institutional collaboration to advance the development of such biopolymers as xanthan gum in soil stabilization and related environmental issues.

3.4 Thematic Structure

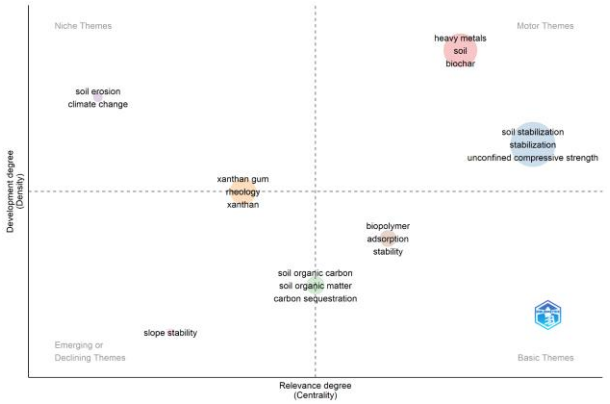

Fig. 5. Thematic Map of the Study

The thematic map also clarifies the intellectual layout of the field by classifying research themes into four quadrants in terms of their level of advancement (density) and pertinence (centrality).

Motor Themes (upper-right quadrant) like "soil," "biochar," "heavy metals," and "soil stabilization" are established, mature fields that are strongly applicable to current research. The fact that "unconfined compressive strength" occurs in this quadrant highlights the strong focus on the mechanical properties of treated soils.

Fundamental Themes (lower-right quadrant), such as "biopolymer," "adsorption," and "stability," are fundamental but still nascent ideas. The occurrence of "organic matter" and "carbon sequestration" indicates increasing overlap with environmental sustainability concerns, making these themes basic building blocks for directions of future research.

Niche Themes (upper-left quadrant) like "soil erosion" and "climate change" point to well-developed but less central themes. These themes might be specialized subfields or interdisciplinary intersections that can be better integrated into the main research.

Emerging or decreasing themes (lower-left quadrant), such as "slope stability," "xanthan gum," and "rheology," are less established and now have lower centrality. Yet their location indicates possible future development, especially as attention to the rheological characteristics and mechanical behavior of xanthan gum-treated soils grows.

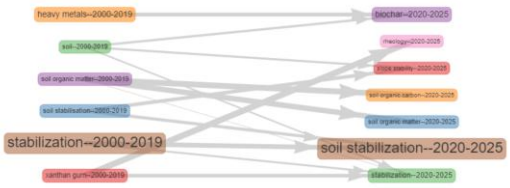

Fig. 6. Thematic Evolution

Figure 6 demonstrates the thematic development of study themes on xanthan gum-based soil research during two distinct periods: 2000–2019 and 2020–2025. The map signifies a discernable evolution from general foundation themes to more specialized and application-oriented studies. Dominant themes during the earlier period (2000–2019) were stabilization, soil, heavy metals, xanthan gum, soil organic matter, and soil stabilisation. These initial themes formed the foundation for creating biopolymer uses in soil improvement, environmental remediation, and the behavior of soils.

With maturation of research, the subject evolved towards more specific topics in the 2020–2025 decade. Most significantly, soil stabilization remains a core and ongoing theme, drawing inputs from previous concepts like stabilization, xanthan gum, and soil organic matter. The occurrence of new topics—biochar, rheology, slope stability, and soil organic carbon—testifies to the increasing focus on mechanical properties of stabilized soils, environmental sustainability, and organic amendment incorporation. The recurrence of soil organic matter during the second phase also attests to its continued relevance and future potential in the study of biopolymer-soil interactions.

This topical shift emphasizes the transition from broad soil treatment methods to multidisciplinary applications based on mechanical performance, environmental effect, and rheological behavior. The close interconnection between themes in the past and present reinforces the dynamic but integrated evolution of the field.

4. CONCLUSION

This bibliometric study has thoroughly examined global research trends, collaborative networks, and subject topics related to the use of xanthan gum as an additive for soil amendment. The results indicate an enduring rise in scientific interest from 2000 to 2025 that was driven by the urgent demand for sustainable and eco-friendly alternatives to conventional soil stabilizers. As a toxic-free and biodegradable biopolymer, xanthan gum is promising in stabilizing the soil strength, reducing erosion, and making environmental restoration easier, making it a vital material in the new sustainable geotechnical engineering design [12].

The study found several leading research streams, such as environmental remediation, soil stabilization, and rheological characterization. The top contributing countries were the United States, China, and India, supported by regional collaboration clusters and highly-ranked scholarly institutions. Visualization software such as VOSviewer and Biblioshiny were capable of representing these trends accurately, giving valuable insights into author collaborations, institutional collaborations, and keyword dynamics.

This study not only highlights the multidisciplinary use of xanthan gum in engineering and environmental sciences but also suggests directions for future research, such as biochar addition, slope stabilization, and carbon sequestration. The findings highlight the potential for future interdisciplinary studies that integrate material science, soil ecology, and sustainable construction. Through mapping the existing knowledge base, the current bibliometric review establishes a foundation for informing ongoing research and stimulating the pragmatic adoption of soil treatment with biopolymers worldwide.

5. REFERENCES

[1] C. Kanjanakul, Foundation design and slope failure protection for a large community building in Khanom, Nakhon Si Thammarat, Int. J. GEOMATE 18 (70) (2020) 88–93. https://doi.org/10.21660/2020.70.9287.

[2] M. K. J. Al-Khuwaildi, A review of environmental impacts of soil stabilization with cement and lime, *International Journal of Scientific Research and Engineering Development (IJSRED)*, vol. 2, no. 5, pp. 588–594, 2019.

[3] J.R. Dungca, J.G. Galupino, Artificial neural network permeability modeling of soil blended with fly ash, Int. J. GEOMATE 12 (2017) 76–83. https://doi.org/10.21660/2017.31.6549.

[4] J. Dungca, J. Galupino, C. Sy, A.S.F. Chiu, Linear optimization of soil mixes in the design of vertical cut-off walls, Int. J. GEOMATE 14 (2018) 159–165. https://doi.org/10.21660/2018.44.7146.

[5] E.E. Uy, M.A.Q. Adajar, Assessment of critical-state shear strength properties of copper tailings, Int. J. GEOMATE 12(32) (2017) 12–18. https://doi.org/10.21660/2017.32.6565.

[6] F. Garcia-Ochoa, V. E. Santos, J. A. Casas, and E. Gómez, Xanthan gum: Production, recovery, and properties, *Biotechnol. Adv.*, vol. 18, no. 7, pp. 549–579, 2000, https://doi.org/10.1016/S0734-9750(00)00050-1.

[7] N. J. van Eck and L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping, *Scientometrics*, vol. 84, no. 2, pp. 523–538, 2010, https://doi.org/10.1007/s11192-009-0146-3.

[8] M. Aria and C. Cuccurullo, bibliometrix: An R-tool for comprehensive science mapping analysis, *J. Informetr.*, vol. 11, no. 4, pp. 959–975, 2017, https://doi.org/10.1016/j.joi.2017.08.007.

[9] O. Ellegaard, and J. A. Wallin, The bibliometric analysis of scholarly production: How great is the impact?, *Scientometrics*, vol. 105, no. 3, pp. 1809–1831, 2015, https://doi.org/10.1007/s11192-015-1645-z.

[10] C.A. Fernandez, J. Galupino, L.E. Garciano, and R.L. Valdez, Evaluating seismic vulnerability and enhancing resilience of road infrastructure: A comprehensive bibliometric analysis, Proceedings of the International Exchange and Innovation Conference on Engineering & Sciences (IEICES), vol. 10, pp. 525–531, 2024, https://doi.org/10.5109/7323311.

[11] Sato, R., Recent use cases of bibliometric data and metrics in Japan to evaluate impact of scholarly output, Proc. Int. Exchange Innov. Conf. Eng. Sci. (IEICES), vol. 5, pp. 19–20, Kyushu University, Japan, Oct. 24, 2019. https://doi.org/10.15017/2552896.

[12] X. Rong, S. Deng, B. Liang, J. Zhuang, Y. Yu, and Z. Wu, Mechanical behavior and strengthening mechanism of loess stabilized with xanthan gum and guar gum biopolymers, *Construction and Building Materials*, vol. 390, p. 131786, 2023, https://doi.org/10.1088/2053-1591/ad832c.