

Bibliometric Analysis of Air Quality and Environmental Sustainability in Mining Sector

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ABSTRACT: This study explores the development of scientific publications on air quality and environmental sustainability from 2018 to 2026, employing a bibliometric approach. It examines trends in publications, keyword co-occurrence, scientific productivity, and key researchers involved in areas like mining, environmental management, and airborne pollutants. Data sourced from the Scopus database were analyzed using a descriptive bibliometric method, with visualization and network analysis conducted via VOSviewer and the Bibliometrix package in R Studio, based on Lotka's Law. The findings indicate an increasing scholarly focus on environmental sustainability, air quality, and resource management in recent years. The United States stands out as a main contributor, with robust collaboration networks and thematic development in environmental governance, sustainability, and regional growth. The study underscores that industrial activities, urbanization, and environmental change remain prominent themes in ongoing research. In summary, this work provides a comprehensive overview of publication trends and thematic advances in air quality and environmental sustainability, offering valuable insights for future research and policy development.

KEYWORDS: Air Quality, Environmental Sustainability, Bibliometric Analysis, Mining Sector

I. INTRODUCTION

Air quality and environmental sustainability have gained growing importance in environmental and development research, especially in areas with industrial expansion, urban growth, and mining operations. Past studies have examined how industrial emissions, land-use changes, and resource activities impact environmental health, ecosystem stability, and regional progress. Additionally, geographic and meteorological factors like rainfall, wind patterns, altitude, and terrain features are frequently linked to differences in environmental quality across various regions. (Lelieveld, 2015); (Burnett, 2018)

In South America, research on environmental and sustainability issues has increasingly concentrated on mining regions in countries like Peru, Colombia, and Bolivia. Notably, areas such as Madre de Dios and Pasco in Peru are known for extensive artisanal and small-scale mining (ASM) activities, which support local livelihoods and boost regional economies. Prior studies have examined how mining influences land-use change, environmental management, and sustainability challenges in these areas. Consequently, recent research stresses the importance of interdisciplinary approaches that combine environmental governance, sustainable resource management, and regional development strategies. (Diringer, 2020); (Sonter et al., 2018)

Recent studies highlight the vital role of community participation, environmental governance, and adaptive management in promoting sustainable development in mining regions. Discussions frequently include community-based environmental monitoring, sustainable mining practices, environmental planning, and cleaner production technologies as components of wider sustainability strategies. Furthermore, collaboration among governments, researchers, industry stakeholders, and local communities is deemed essential for enhancing environmental management and ensuring long-term regional sustainability. (Newig et al., 2018); (Reed, 2018)

Although there is an increasing body of research on environmental sustainability and mining, few studies have analyzed publication trends, scientific collaboration, and thematic development through bibliometric methods. Most prior research has concentrated on environmental impacts and regional management, leaving the evolution of scientific knowledge in this area less explored. Consequently, bibliometric approaches are valuable for examining research progress, publication patterns, and new themes in environmental sustainability and mining. (Husaini, 2022)

This study investigates the evolution of scientific publications on air quality and environmental sustainability within the mining sector from 2018 to 2026 through bibliometric analysis. It offers a thorough overview of publication trends, keyword

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relationships, international collaboration, and thematic progress based on data from the Scopus database. The results aim to guide future research efforts and inform policy discussions focused on sustainability, environmental management, and regional development.

II. METHODS

This study used a descriptive-retrospective bibliometric analysis to explore the growth of scientific publications on air quality, environmental sustainability, and mining activities from 2018 to 2026. Bibliometric analysis helps identify publication trends, thematic shifts, research productivity, and collaboration patterns in a specific field. Additionally, it is commonly employed to assess scientific contributions and emerging research themes through published literature.(Aria & Cuccurullo, 2017)

The study employed a systematic collection of scientific publications to guarantee a structured and comprehensive analysis. Data were sourced from the Scopus database due to its extensive coverage of peer-reviewed international publications across diverse scientific fields. The search targeted publications related to air quality, environmental management, sustainability, and mining activities. The strategy involved using specific keywords such as ("Air Quality", OR "Environmental Sustainability", OR "Bibliometric Analysis", OR "Mining Sector") and applying Boolean operators like AND and OR to refine results. Inclusion criteria were journal articles published in English from 2018 to 2026. Conference papers, book chapters, editorials, and non-English publications were excluded to ensure data relevance and consistency. The authors meticulously reviewed all titles and abstracts to confirm their relevance to the research focus.

The collected bibliographic data were exported in CSV format and analyzed using the Bibliometrix package in R Studio and VOSviewer software. Bibliometrix was used to analyze publication trends, scientific productivity, and collaboration patterns based on bibliometric indicators and Lotka's Law. Meanwhile, VOSviewer was utilized to visualize keyword co-occurrence, thematic structures, and relationships among publications (Van Eck & Waltman, 2010) The analysis process consisted of data collection, screening, bibliographic mapping, network visualization, and descriptive interpretation of publication trends. The key stages of the bibliometric analysis in this study are presented in the figure below, providing a clear overview of the research process.

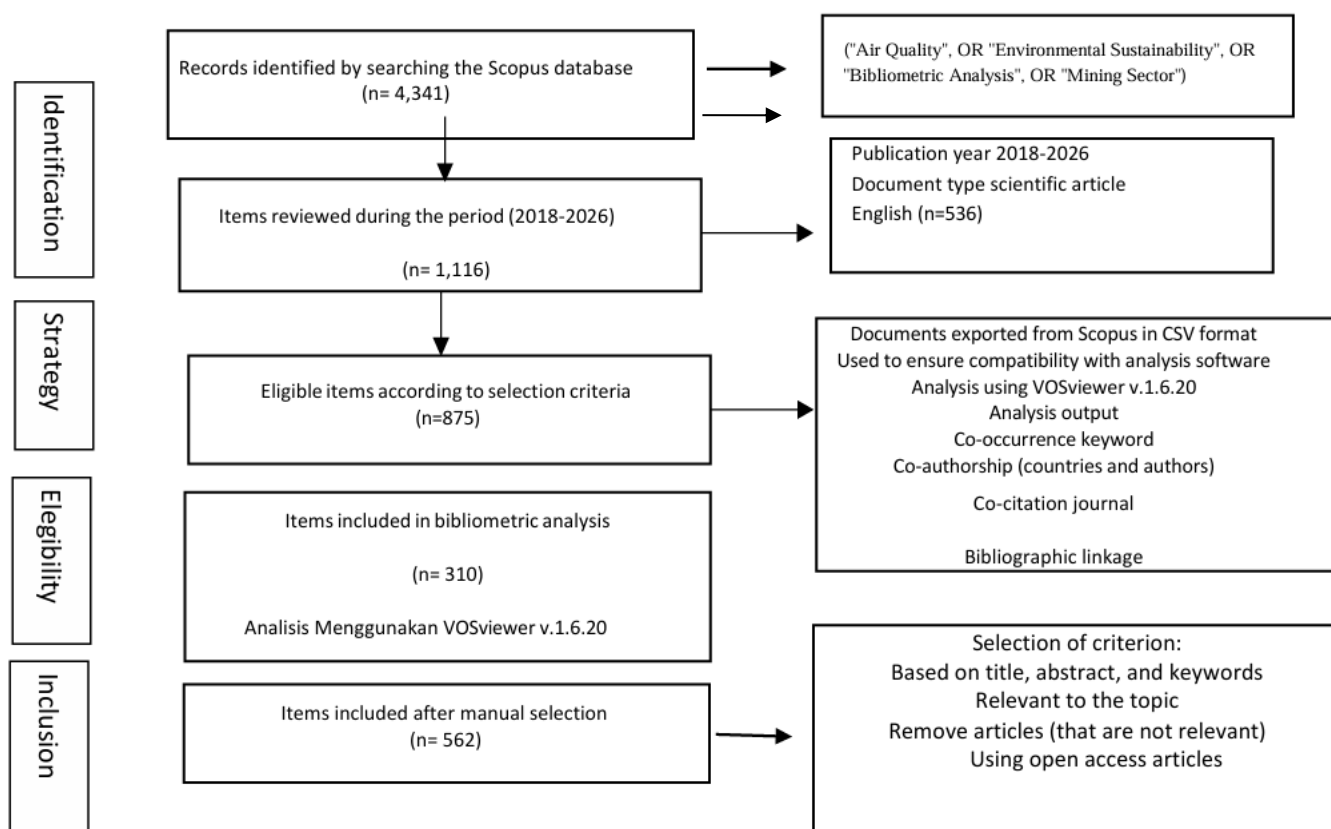


Figure 1. Stages of Bibliometric Analysis (Chen et al., 2016)

The data collection process was carried out through a systematic literature search using a combination of key terms, namely "Air Quality", OR "Environmental Sustainability", OR "Bibliometric Analysis", OR "Mining Sector" The search was limited to publications from 2018 to 2026, allowing the study to reflect research trends over the past decade.

In addition, a keyword filtering process was applied based on occurrence levels and term relevance to ensure that only significant and contextually appropriate keywords were included in the analysis. The results were then visualized through network

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visualization, co-authorship analysis, and density visualization, providing a more comprehensive understanding of the structure and dynamics of the research field. Keywords deemed irrelevant to the focus of the study were excluded from further analysis. The keyword filtering process in VOSviewer is illustrated in the following figure.

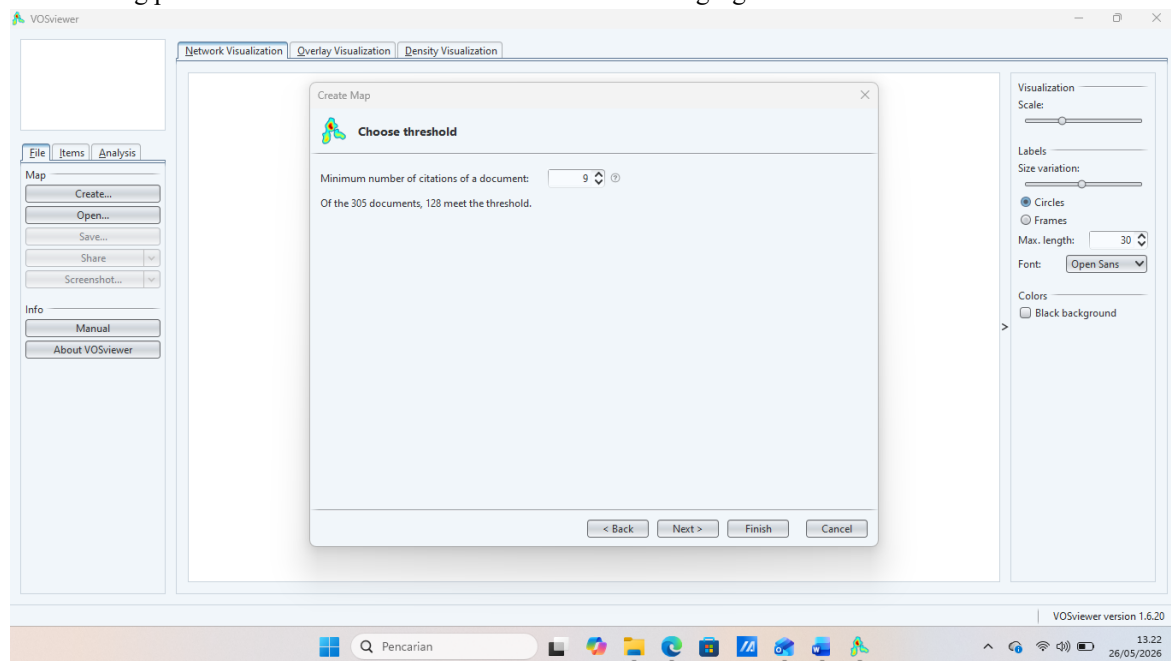


Figure 2. Minimum Keyword Occurrence Threshold

III. RESULT AND DISCUSSION

In this study, the bibliometric analysis was conducted using the Scopus database, with ("Air Quality", OR "Environmental Sustainability", OR "Bibliometric Analysis", OR "Mining Sector") as the primary keywords for literature retrieval. The collected data were then screened based on predefined inclusion criteria, including publications from 2018 to 2026, document types limited to articles and book chapters, and English-language publications. A summary of the retrieved data is presented in the following table.

Table 1 Comparison matrix

Data Matrix	Initial Search	Refinement Search
Keywords	High Tide Flooding	High Tide Flooding and Coastal Livelihood Injustice
Total Keywords	4,341	56
Article indexing	Scopus	Scopus
Article	1,116	875
Year	2018-2026	310

The data shows a rising trend in scientific publications focused on environmental sustainability, air quality, and mining studies from 2018 to 2026. This trend indicates a growing academic interest in environmental governance, sustainable resource use, and the socio-economic aspects of industrial and mining activities. The increasing scope of research also highlights how environmental issues are being explored through interdisciplinary lenses that incorporate sustainability, regional growth, and policy strategies. Prior research has noted that studies on industrialization, urbanization, and natural resource extraction are continuously expanding, driven by heightened global concerns about sustainable development and better environmental management. (Maconachie & Conteh, 2021); (Sonter et al., 2017)

The bibliometric analysis shows an increasing trend in scientific publications related to air quality and environmental sustainability in the mining sector from 2018 to 2026, as presented in Figure 3. Publication growth became more significant after 2022 and reached its highest point in 2024–2025. Citation trends also increased during the observed period, indicating growing academic interest and research development in this field.

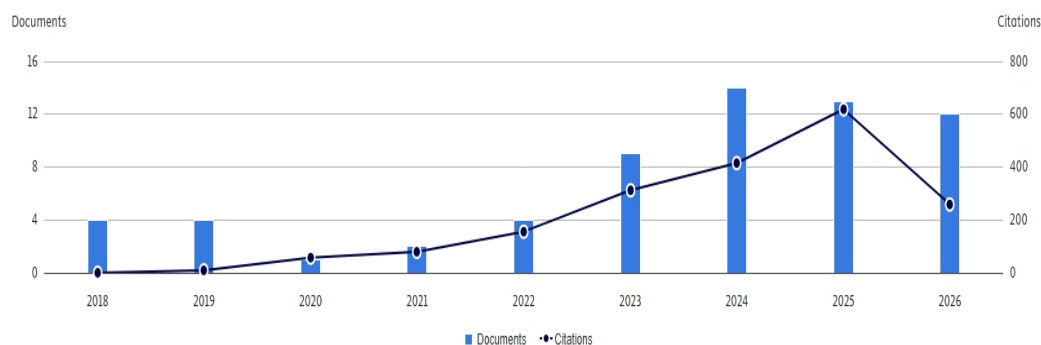


Figure 3. Average annual scientific production on air quality and mining sector Source: Scopus

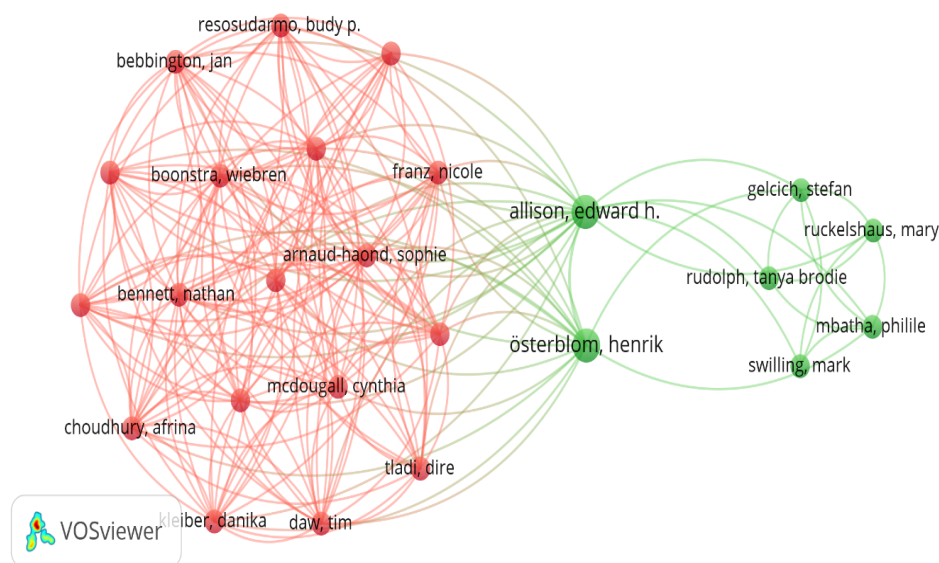


Figure 4. Map of co-authoring on air quality and mining themes over the last ten years (Van Eck & Waltman, 2010)

The data shows a steady rise in scholarly articles on air quality, environmental sustainability, and mining topics from 2018 to 2026. This pattern highlights the expanding academic focus on environmental governance, sustainable resource use, and regional growth within industry and mining fields. The growing publication count indicates that environmental research is increasingly approached from interdisciplinary angles, integrating sustainability, policy, and socio-economic factors. (Aria & Cuccurullo, 2017)

The co-authorship network analysis performed with VOSviewer identified 14 clusters, highlighting the variety of research themes and collaboration networks in the field. Figure 4 displays how researchers are connected through co-authorship, revealing interconnected scientific groups across multiple thematic areas. The visualization indicates that several authors hold central roles within the collaboration network, underlining their significant contributions to research on environmental sustainability and mining studies. (Van Eck & Waltman, 2010) (Giljum, 2025)

Among the identified authors, Allison, Edward H. appears as the most productive contributor with 11 publications, followed by Österblom, Henrik with 8 publications, Gelcich, Stefan with 6 publications, Rudolph, Tanya Brodie with 6 publications, and Ruckelshaus, Mary with 5 publications. The existence of these interconnected collaboration networks highlights the collaborative and interdisciplinary characteristics of research in this field. Furthermore, the presence of multiple clusters suggests that studies related to environmental management, sustainability, and mining activities continue to develop through diverse scientific approaches and international research collaboration.(Velasco, 2023)

The co-authorship analysis reveals not only the leading authors within the field, but also collaborative research networks involving multiple researchers and institutions, reflecting the collective and dynamic nature of scientific development in this area. The identified collaboration patterns demonstrate that studies related to environmental sustainability, air quality, and mining activities continue to evolve through interdisciplinary approaches and scientific cooperation. Table 2 demonstrates the distribution of author productivity based on Lotka's Law. A total of 86% of authors contributed only one publication, while 9% contributed two publications, 3% contributed three publications, and only 1% contributed four publications within the field of study.(Lotka, 1926)

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Environmental sustainability and resource management studies have increasingly expanded alongside the growth of industrialization, urban development, and extractive activities in various regions. Previous studies have emphasized that environmental governance, sustainable development, and industrial transformation remain important issues within contemporary environmental research, particularly in developing countries with intensive mining and industrial activities (Moran et al., 2014) (Sonter et al., 2020) Furthermore, the increasing complexity of environmental challenges has encouraged broader interdisciplinary collaboration involving environmental science, policy studies, and regional development perspectives.

Table 2. Lotka's law (processed with Bibliometric in (Aria & Cuccurullo, 2017), based on (Lotka, 1926)

Published documents	N° of authors	Proportion of authors
1	661	86%
2	72	9%
3	22	3%
4	5	1%
5	2	0%
6	2	0%
8	1	0%
11	1	0%

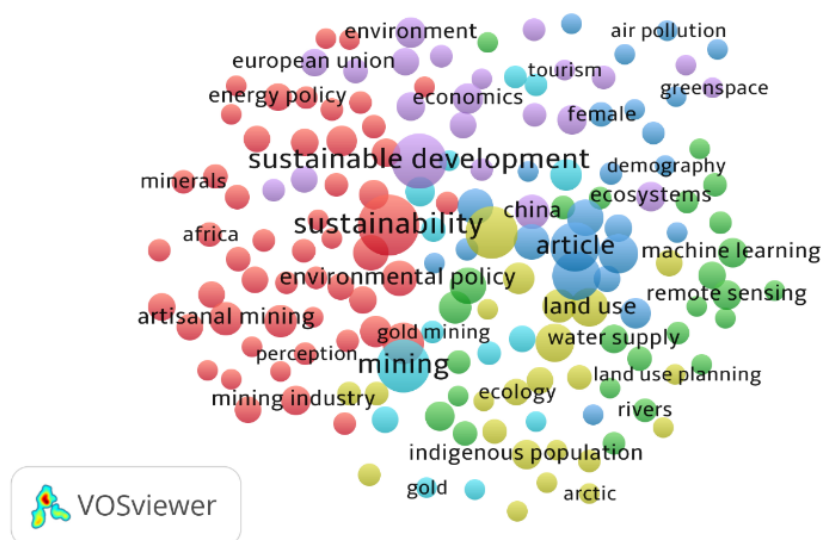


Figure 5. Network Visualization of Keyword Co-occurrence

Through term co-occurrence mapping, conceptual relationships among keywords can be identified to understand dominant themes within the research field. Figure 5 presents the most frequently occurring terms from the selected publications. The visualization indicates that themes such as sustainability, environmental policy, mining, land use, ecosystems, and air pollution are closely interconnected within environmental and sustainability studies. This pattern reflects the growing application of interdisciplinary approaches that integrate environmental governance, resource management, and regional development perspectives. The network visualization also shows that sustainability and environmental policy occupy central positions within the research structure, indicating their important role in discussions related to mining activities and environmental management. In addition, countries such as China, the United States, and India appear prominently in the collaboration network, reflecting their substantial contribution to scientific production and international collaboration in environmental and sustainability research (Bridge, n.d.);(Hilson, 2012)

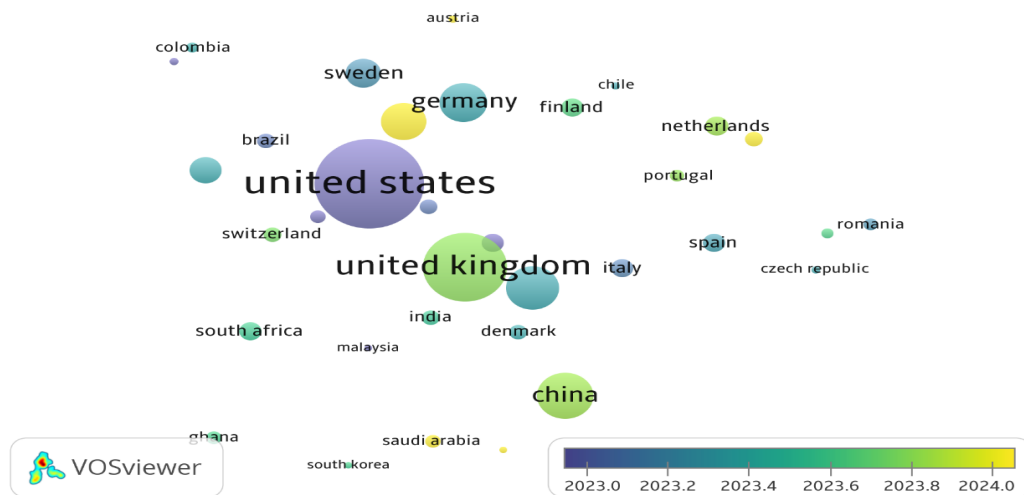


Figure 6. Map of co-authoring countries in air quality and mining sector articles over the last ten years (Van Eck & Waltman, 2010)

The relevance of the most frequently occurring keywords, as shown in Figure 7, includes terms such as air pollution, particulate matter, environmental monitoring, and sustainable development, as they influence research trends and scientific publications in air quality and mining sector. These keywords are grouped into four clusters: cluster 1 (10), cluster 2 (7), cluster 3 (4), and cluster 4 (2). The clusters are distinguished by different colors, reflecting the interconnectedness between research themes. The red cluster mainly focuses on environmental monitoring, risk assessment, and pollution sources such as soil and water contamination. The green cluster emphasizes sustainable development, population dynamics, and socio-economic aspects. The yellow cluster is associated with air quality and environmental exposure, while the blue cluster relates to urbanization, industrial activities, and environmental impacts. Overall, these clusters indicate that environmental and sustainability studies are interconnected across environmental, social, economic, and policy dimensions, reflecting the interdisciplinary nature of research within this field.(Liu, n.d.)

Frontiers in Ecology is a global open-access journal that publishes research on various ecological and environmental issues, including air pollution, climate change, and environmental sustainability. The leading authors in the citation network of this study are (Dwivedi & Hughes, 2022) (Shayan et al., 2022) (Mohajane & Costache, 2021) and (Montiel et al., 2021) as illustrated in Figure 8. This indicates that their publications are among the most frequently cited within the research network and contribute significantly to the development of studies related to environmental sustainability, air quality, and environmental management. Their central position within the citation network reflects their influence in shaping scientific discussions and research directions within the field. Furthermore, the high citation frequency suggests that their studies provide important theoretical and methodological contributions for subsequent research related to environmental governance, sustainability, and regional development.

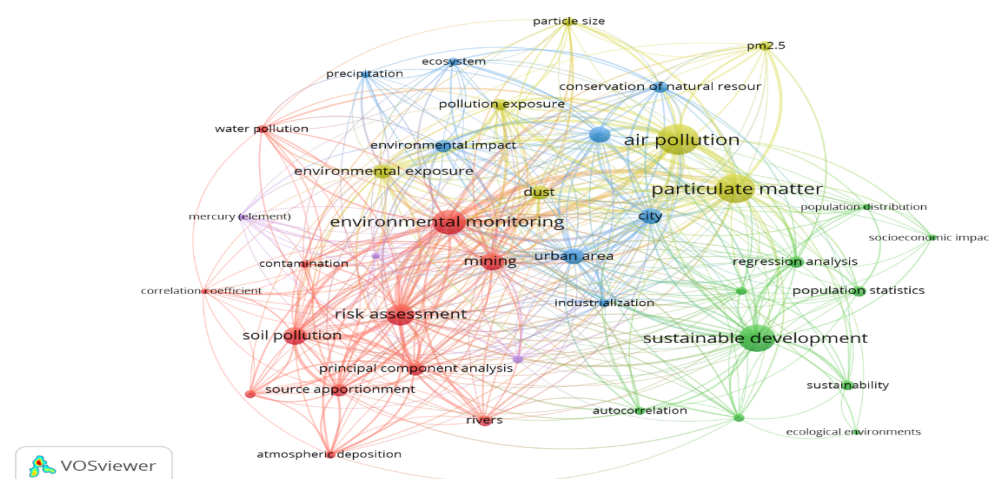


Figure 7. Map of bibliographic linkage by sources in air quality and mining sector articles of the last ten years (Van Eck & Waltman, 2010)

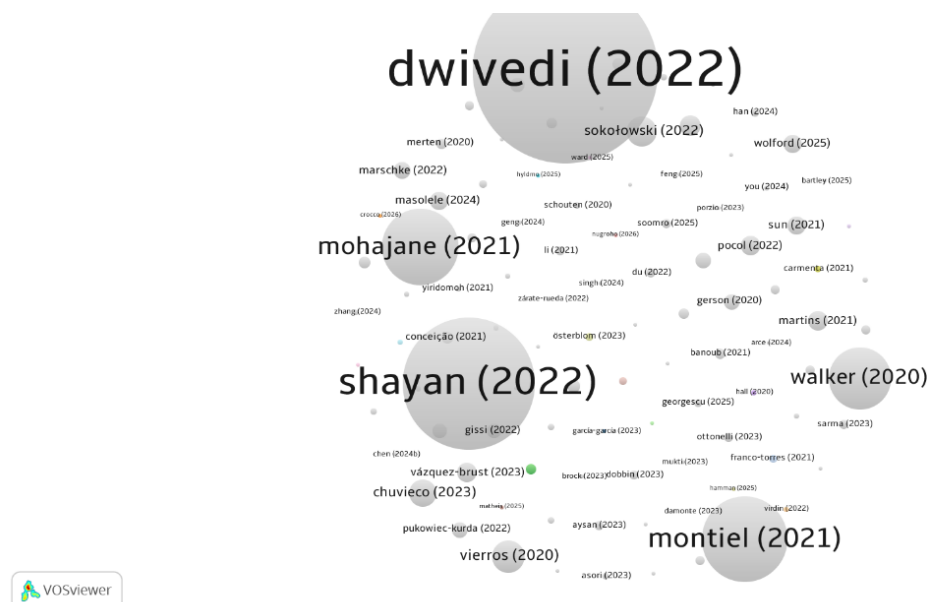


Figure 8. Author citation map by documents in air quality and mining sector articles 2018-2026 (Van Eck & Waltman, 2010)

The findings reveal that, although studies related to environmental sustainability, air quality, and mining activities have continued to develop, comprehensive bibliometric analyses within this field remain relatively limited. Based on the VOSviewer analysis, scientific production has shown a consistent increase over recent years, reflecting growing academic interest in environmental governance, sustainability, and resource management issues. This trend also indicates that environmental studies are increasingly examined through interdisciplinary perspectives involving environmental, social, and policy dimensions (Donthu et al., 2021); (Zupic & Čater, 2015)

In addition, the results demonstrate that countries such as China, the United States, and the United Kingdom occupy important positions within the scientific collaboration network, reflecting their significant contribution to global environmental and sustainability research. The increasing scientific output from these countries is associated with the expansion of industrial activities, urban development, and environmental policy discussions within international research agendas (Khan et al., 2021)

The co-occurrence analysis identified several dominant thematic areas, including environmental sustainability, air quality, environmental governance, industrial development, and resource management. These findings indicate that recent studies increasingly examine environmental issues through interdisciplinary perspectives integrating environmental, social, economic, and policy-related dimensions. The interconnected structure among keywords also demonstrates that environmental studies related to mining and industrial activities continue to develop alongside growing global concerns regarding sustainable development and environmental management (Geissdoerfer et al., 2017)

The results further show that industrial expansion, urban growth, transportation activities, and extractive industries remain closely associated with discussions on environmental quality and sustainability. In many developing regions, limited institutional capacity, environmental monitoring systems, and policy implementation continue to create challenges for effective environmental management. Consequently, recent studies increasingly emphasize the importance of integrated environmental governance, sustainable industrial practices, and long-term planning approaches to support environmental sustainability and regional development (Azapagic, 2004)

In addition, the co-authorship analysis reveals the existence of collaboration networks among researchers, institutions, and countries, reflecting the interdisciplinary character of environmental and sustainability studies. The productivity analysis based on Lotka's Law indicates that scientific production remains concentrated among a relatively small number of authors, while most researchers contribute only a limited number of publications. This pattern is commonly identified in bibliometric studies and highlights the importance of scientific collaboration in supporting the development of research networks and knowledge dissemination (Persson et al., n.d.)

Overall, these findings demonstrate the continuing development of research related to environmental sustainability, mining activities, and environmental governance. The application of bibliometric tools such as [VOSviewer](https://www.vosviewer.nl/) and Bibliometrix provides an effective approach for identifying publication trends, thematic structures, and scientific collaboration patterns within the field. Furthermore, this study contributes to the existing literature by providing a broader overview of research developments and emphasizing the importance of interdisciplinary approaches in environmental and sustainability studies. These findings also support the research objective of identifying publication trends, collaboration networks, and emerging themes related to environmental and mining studies, while providing useful insights for future research and environmental policy discussions.

Table 3 Knowledge Mapping

NO	Cluster	Main Theme	Research Focus	Dominant Keywords	Perspective	Limitations (Gap)
1	Environmental Sustainability Cluster	Air Quality & Environmental Governance	Air pollution, environmental management, sustainability in mining	air pollution, sustainability, governance, mining	Environmental / Governance	Still dominated by environmental-technical studies, limited legal integration
2	Mining Governance Cluster	Regulation & Resource Management	Mining regulation, sustainable resource use, institutional governance	regulation, resource management, policy, mining	Policy / Institutional	Weak focus on enforcement and environmental rights
3	Socio-Economic Cluster	Community & Livelihood Impacts	Community participation, livelihoods, socio-economic vulnerability	livelihood, participation, vulnerability, community	Socio-economic	Limited discussion on justice and inequality framework
4	Industrial Development Cluster	Urbanization & Industrial Expansion	Industrialization, urban growth, environmental degradation	urbanization, industry, pollution, development	Environmental / Economic	Insufficient analysis of long-term sustainability impacts
5	Scientific Collaboration Cluster	Research Productivity & Collaboration	Co-authorship networks, publication trends, citation mapping	collaboration, bibliometric, co-authorship, citation	Bibliometric / Interdisciplinary	Focus remains descriptive, lacks policy implementation linkage
6	Legal Gap Cluster	Environmental Justice & Rights-Based Approach	Environmental justice, public health rights, mining governance	justice, environmental rights, inequality, governance	Legal / Human Rights	Underdeveloped and not yet central in sustainability studies

From a legal perspective, this condition reveals a significant research gap in linking air quality issues, environmental sustainability, and mining governance within a rights-based framework. Mining activities not only contribute to environmental degradation and declining air quality but also potentially threaten public health and the right to a clean and healthy environment. Weak regulatory enforcement and unequal environmental impacts further create environmental injustice for communities surrounding mining areas.

Unlike previous studies that focus separately on environmental or economic aspects, this research offers an integrative approach by combining environmental, socio-economic, and legal dimensions. Using a bibliometric analysis based on Scopus-indexed publications, the study systematically maps research trends and emerging themes related to air quality and environmental sustainability in the mining sector. This research contributes to the development of environmental law and supports more equitable and sustainable mining governance frameworks.

CONCLUSIONS

This bibliometric study systematically mapped the development of research related to air quality, environmental sustainability, and mining activities for the period 2018–2026. The results confirm a steady increase in scientific output, with growing attention toward environmental governance, resource management, and the socio-economic impacts of extractive industries. Through visualization techniques, this research identified dominant themes, key contributing authors, leading countries, and international collaboration networks.

The study reveals that existing research integrates multiple disciplines, yet there is still an imbalance: technical and environmental studies dominate, while legal, institutional, and policy dimensions remain underrepresented. This finding highlights a critical need for future research to strengthen interdisciplinary approaches, combining environmental science, law, governance, and regional development perspectives.

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