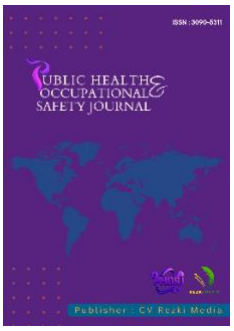

Mapping the intellectual structure of lead exposure and occupational health research in mining: A bibliometric analysis (2015–2025)

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B – Collection and/or assembly of data
C – Data analysis and interpretation
D – Writing the article
E – Critical revision of the article
F – Final approval of article

ABSTRACT

Background: Lead exposure remains a significant occupational health issue in the mining industry, where workers are frequently exposed to dust, particulate matter, and contaminated environments. While research has increased, the literature often develops in separate thematic streams, making it difficult to capture the overall structure and relationships between key areas of study.

Objectives: This study aims to map research trends and thematic developments related to lead exposure and occupational health in the mining industry from 2015 to 2025. The goal is to provide a comprehensive bibliometric overview of the field and identify dominant and emerging themes.

Methods: A bibliometric approach was applied using Scopus-indexed publications. Peer-reviewed articles and review papers published between 2015 and 2025 were screened for relevance, resulting in a dataset of 133 documents. Descriptive analyses examined publication trends, subject areas, document types, leading journals, authors, affiliations, and contributing countries. Keyword co-occurrence analysis was performed using VOSviewer to map thematic patterns.

Results: The volume of publications increased significantly after 2020, peaking in the early 2020s. Research predominantly focused on environmental and health-related topics, driven by empirical studies. The thematic mapping revealed three major clusters: (1) mining assessment, (2) epidemiological outcomes, and (3) occupational health risks. Although connections between exposure assessment and health outcomes were observed, these relationships remain weak.

Conclusions: Research on lead exposure and occupational health in mining has shown sustained growth and thematic maturity. However, there is limited integration between exposure monitoring and health outcome studies. Future research should focus on integrating exposure monitoring with health outcomes, particularly in high-risk mining sectors.

Keywords: bibliometric analysis, lead exposure, mining industry, occupational health.

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INTRODUCTION

Lead exposure remains a persistent occupational health concern in mining, particularly because workers are repeatedly exposed to contaminated dust, particulate matter, and mining-related materials. Recent literature continues to underline the public health relevance of mining activities, with lead frequently discussed alongside other hazardous agents that may contribute to adverse outcomes in populations affected by mining (Cortes-Ramirez et al., 2025). Importantly, the occupational risk profile in mining is multifactorial, involving multiple exposures such as respirable crystalline silica and elemental carbon. These exposures require ongoing surveillance and effective control strategies within mining operations (Arrandale et al., 2025). Beyond direct workplace exposure, mining and mineral processing can drive pollution pathways through soil, water, and air contamination, particularly around lead- and zinc-related mining and processing areas. These contamination pathways may further influence exposure profiles and amplify health risks for both workers and surrounding communities (Sharifi et al., 2023). Taken together, these findings indicate the need for integrated approaches that link exposure assessment, hazard control, and prevention strategies. These complex and interconnected risk factors call for comprehensive approaches to mitigate occupational and environmental health impacts (Arrandale et al., 2025; Cortes-Ramirez et al., 2025; Sharifi et al., 2023).

Over the past decade, research attention has increasingly focused on mining-related health outcomes, including long-term conditions and mortality within mining workforces. Surveillance evidence on coal workers' pneumoconiosis-associated deaths, for instance, demonstrates the continuing burden of occupational respiratory disease and the sustained need for prevention in high-risk mining sectors (Mazurek et al., 2025). At the same time, occupational health studies in mining settings address broader disease risks and work-related health impacts across diverse contexts, including industrial zones with distinctive occupational hazards (Goryaev et al., 2023). Evidence from mining worker populations suggests that health impacts can emerge in complex exposure settings involving multiple metals. For example, research on mercury mining workers explicitly includes lead as a relevant co-exposure, emphasizing worker-centered assessment under precarious employment conditions (Saldaña-Villanueva et al., 2022). In parallel, mining-related contamination pathways, such as metal contamination in sediments and heavy-metal contamination in mining-impacted soils, may indirectly influence both occupational and community health risk profiles (Galgani et al., 2025; Rajput et al., 2025).

Despite the growing body of empirical studies and thematic reviews, an important gap persists: the field lacks an integrated, quantitative map of how the literature has developed over time, which themes are most dominant, and which themes remain under-connected. Many studies concentrate on specific exposure types, locations, or health endpoints, from artisanal mining risk assessments to occupational impacts in historically lead-affected settings. Yet, fewer efforts have systematically consolidated the intellectual structure of the field, patterns of collaboration, and thematic evolution within a single analytical framework (Miranda & Anjos, 2018; Obiri et al., 2016). Research examining long-term health endpoints among mining worker cohorts, such as lung cancer risk, often progresses as outcome-focused evidence streams without strong integration with the wider exposure monitoring and risk assessment literature (Allen et al., 2015).

This gap is practically consequential because clearer mapping of the research landscape can support more targeted future studies and strengthen translation into occupational health and safety priorities. Bibliometric analysis offers a structured way to address this gap by examining patterns in scientific production, identifying major thematic clusters, and tracing how research directions shift over time. In mining-related occupational health and lead exposure research, bibliometric mapping can clarify the balance between exposure surveillance (e.g., industrial hygiene and occupational monitoring), health outcomes (e.g., occupational diseases and mortality), and contamination-related themes that may influence risk profiles (Arrandale et al., 2025; Cortes-Ramirez et al., 2025; Mazurek et al., 2025). This approach is particularly relevant because the literature includes both worker-focused evidence and risk assessment frameworks—such as modeling-based approaches to characterizing lead-related risks in contaminated mining-impacted areas—alongside increasingly visible remediation perspectives for mining-contaminated soils (Delgado-Caballero et al., 2018; Rajput et al., 2025). By quantifying thematic relationships and temporal dynamics, bibliometric analysis can help determine whether the field remains concentrated on assessment and monitoring, whether it is moving toward stronger emphasis on worker health endpoints, and where conceptual bridges between these streams remain insufficient (Goryaev et al., 2023; Saldaña-Villanueva et al., 2022; Sharifi et al., 2023).

This study conducts a Bibliometric Analysis of Research Trends in Lead Exposure and Occupational Health in the Mining Industry (2015–2025) using Scopus as the primary database. The study aims to: (1) examine annual publication trends; (2) describe subject areas and document types; (3) identify leading journals, authors, affiliations, and contributing countries; and (4) map thematic structures using keyword co-occurrence through network, overlay, and density visualizations. The expected contribution is to provide a consolidated overview of the research landscape, highlight dominant and emerging themes, and outline evidence-informed directions for future research and practice, especially the need to better integrate exposure monitoring, risk assessment, and worker health outcomes (Allen et al., 2015; Arrandale et al., 2025; Mazurek et al., 2025).

METHODS

Study Design

This study adopted a bibliometric research design to map and analyze scientific publications addressing lead exposure and occupational health in the mining industry. Bibliometric analysis was chosen because it allows systematic and quantitative examination of publication trends, collaboration patterns, and thematic development within a research field over a defined period (Donthu et al., 2021; Aria & Cuccurullo, 2017). The analysis focused on literature indexed in the Scopus database, which was selected due to its broad and multidisciplinary coverage of peer-reviewed journals in environmental science, occupational health, engineering, and related fields relevant to mining research.

Eligibility Criteria and Search Strategy

The dataset comprised peer-reviewed research articles and review papers published between 2015 - 2025 that explicitly addressed lead exposure or heavy metal exposure in relation to occupational health, occupational diseases, or health risks

within mining settings. Publications were excluded if they focused primarily on non-mining sectors or discussed environmental contamination without a clear connection to occupational or worker health.

To ensure adequate coverage while maintaining relevance, a structured search strategy was developed iteratively. The final search query used was: ("heavy metals" OR "lead" OR "mining exposure") AND ("health risks" OR "occupational diseases" OR "health impact") AND ("mining workers" OR "mining industry" OR "worker safety"). No language restrictions were applied at the search stage. All eligible records were exported in CSV format, including complete bibliographic metadata required for bibliometric analysis.

Study Selection and Data Curation

After data retrieval, a transparent data curation process was undertaken to ensure the relevance and consistency of the dataset. The selection process followed these steps:

1. Data Retrieval: Scopus-indexed publications between 2015 and 2025 were retrieved;
2. Relevance Screening: Titles, abstracts, and keywords were screened to ensure relevance to lead exposure and occupational health in mining contexts; and
3. Final Dataset: After screening, 133 relevant documents were included for analysis.

This selection process was designed to support reproducibility and clarity in bibliometric mapping. The evaluation of the methodological quality of individual studies falls outside the scope of this bibliometric analysis (Zupic & Čater, 2015).

Data Analysis and Bibliometric Mapping

Bibliographic data were analyzed using descriptive approaches to examine publication trends over time, subject area distribution, document types, leading journals, authors, institutional affiliations, and contributing countries. To explore the thematic structure of the field, keyword co-occurrence analysis was performed using VOSviewer software (van Eck & Waltman, 2010). Network visualization was applied to identify relationships among keywords, overlay visualization to examine the temporal dynamics of research themes, and density visualization to highlight areas of thematic concentration. These bibliometric techniques are widely used to uncover the intellectual structure and developmental patterns of scientific research domains (Aria & Cuccurullo, 2017; Donthu et al., 2021).

RESULTS

Publication output on lead exposure and occupational health in the mining industry shows a clear growth trajectory over the 2015–2025 period based on a Scopus dataset comprising 133 documents. As shown in Figure 1, publication numbers remained relatively low during the earlier years and increased gradually until 2019. A more pronounced rise occurred after 2020, coinciding with the growing global awareness and regulatory scrutiny surrounding mining-related occupational hazards. This trend highlights that the mining sector's occupational health issues, particularly those related to lead exposure, have gained significant scholarly attention as concerns over environmental health risks and worker safety continue to escalate. The peak in publication output from 2021 to 2023 reflects the industry's response to

increasing health-related challenges and advancements in exposure monitoring techniques. However, the slight decline observed towards 2025 may be attributed to publication lag or the completion of major studies rather than a true decrease in research activity.

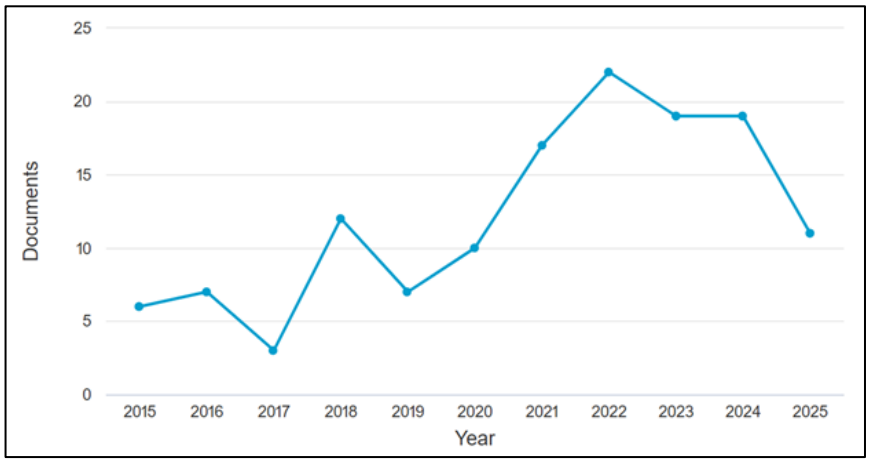

Figure 1. Documents by Year (2015–2025)

The distribution of subject areas confirms the strongly multidisciplinary character of the literature (Figure 2). Environmental Science accounts for the largest share of publications, followed by Medicine, Earth and Planetary Sciences, and Engineering. Contributions from Social Sciences and Agricultural and Biological Sciences further indicate increasing attention to socio-environmental impacts and biological consequences of mining-related exposures. Smaller shares are represented by Chemistry, Pharmacology and Toxicology, Energy, and other related fields. Taken together, this distribution positions research on lead exposure in mining at the intersection of environmental monitoring, toxicological assessment, and occupational and public health, consistent with empirical studies within the dataset.

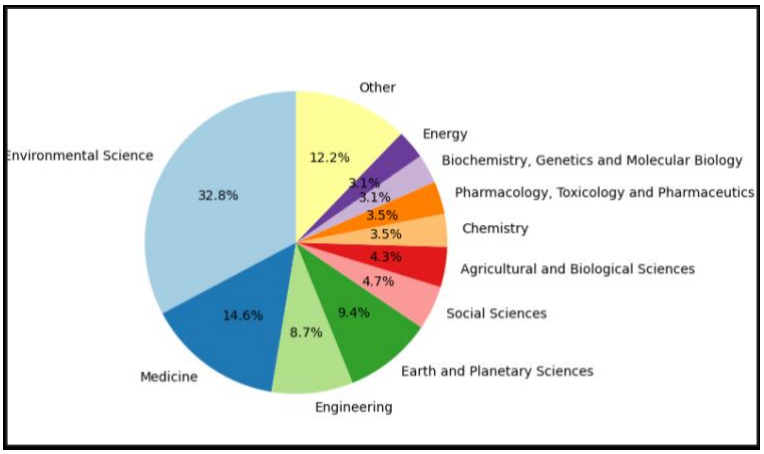

Figure 2. Documents by Subject Area

Original research articles dominate the dataset, comprising the bulk of publications as seen in Figure 3. This indicates that the field is primarily driven by empirical investigations rather than by synthesis-oriented or theoretical studies. While review articles, conference papers, and book chapters account for a smaller portion, their presence highlights the growing effort to consolidate knowledge and synthesize findings from primary studies. This underscores the importance of bibliometric analysis in organizing the substantial body of empirical work and identifying gaps for future research.

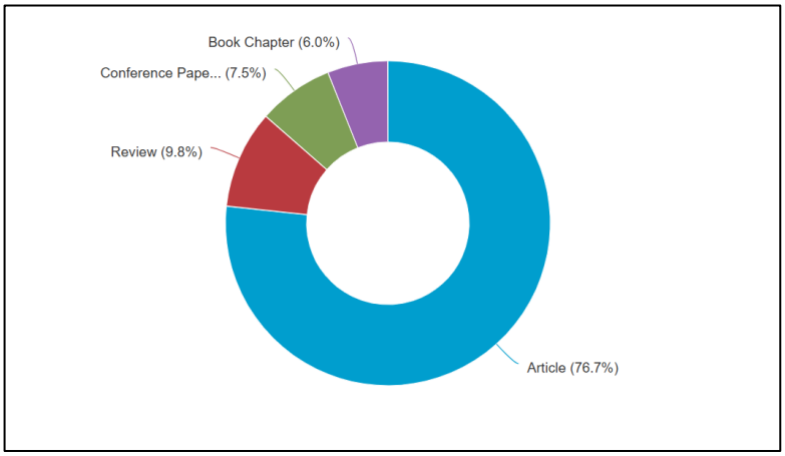

Figure 3. Documents by Type

Source analysis highlights a group of journals that consistently publish research on mining, lead exposure, and occupational health (Figure 4). Key outlets include Environmental Geochemistry and Health, Environmental Science and Pollution Research, Ecotoxicology and Environmental Safety, International Journal of Environmental Research and Public Health, and Science of the Total Environment. Publication activity in these journals increased notably after 2020, mirroring the overall growth trend and indicating that expansion of the field is primarily disseminated through environmentally and public health–oriented journals rather than a single dominant source.

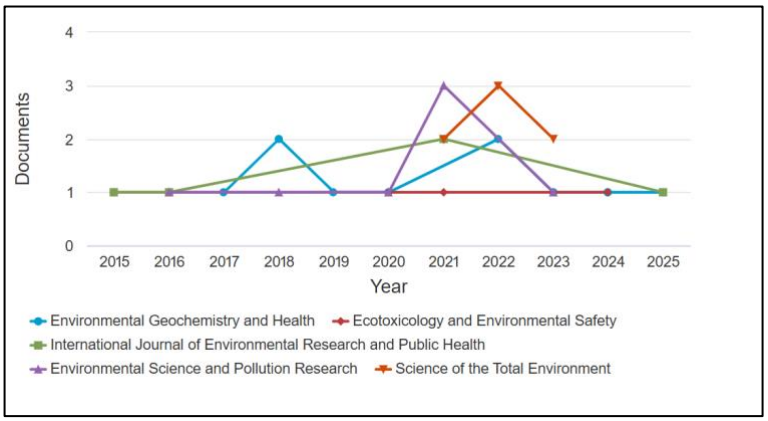

Figure 4. Leading Source Titles Over Time

Geographically, research output is concentrated in a limited number of countries (Figure 5). China emerges as the most prolific contributor, followed by the United States, with additional contributions from Russia, Canada, India, and several European countries. Contributions from Russia, Canada, and several European countries further reinforce the geographical pattern of mining activity and occupational health research. Although publications from Africa and South America are present, they remain limited, possibly due to fewer research resources or mining activities in these regions. This unequal distribution suggests a global imbalance in research output, with high-contribution countries taking the lead in setting the research agenda.

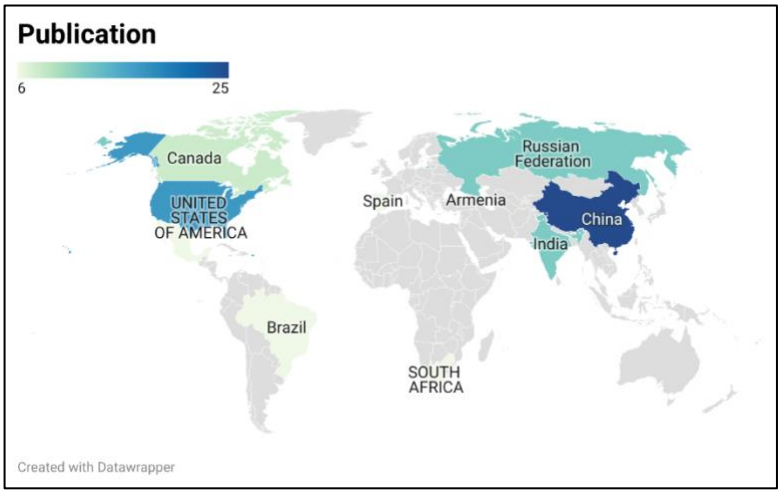

Figure 5. Publication by Country

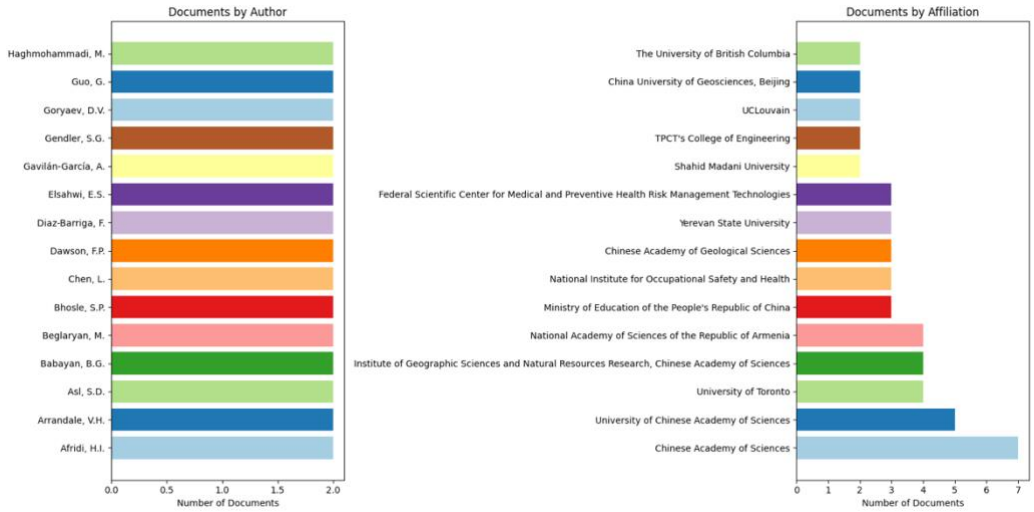

Figure 6. Leading Authors and Affiliations
(compare the document counts for up to 15 authors and 15 afiliations)

At the author and institutional levels (Figure 6), the findings indicate a dispersed authorship structure. No single author or institution dominates the field; instead, research output is distributed across multiple contributors and affiliations. Several Chinese research institutions appear prominently, alongside universities and research centers from North America and Europe. This pattern reflects a decentralized research landscape characterized by identifiable institutional hubs rather than concentrated authorship.

Keyword co-occurrence analysis using VOSviewer reveals the thematic organization of research on lead exposure and occupational health in mining (Figures 7A, 7B, and 7C). Network visualization (Figure 7A) identifies three major thematic clusters. The first cluster focuses on mining operations and assessment-oriented approaches, linking mining, mining industry, risk assessment, environmental monitoring, and toxicity. The second cluster emphasizes exposure and epidemiological outcomes, connecting lead with epidemiology, coal mining, and mortality. The third cluster reflects occupational health framing, characterized by strong associations among occupational diseases, occupational risks, and health risks. The prominence of assessment-related terms indicates that hazard identification and risk evaluation remain central research priorities, while the

epidemiological cluster highlights continued attention to health outcomes in specific mining contexts, particularly coal mining.

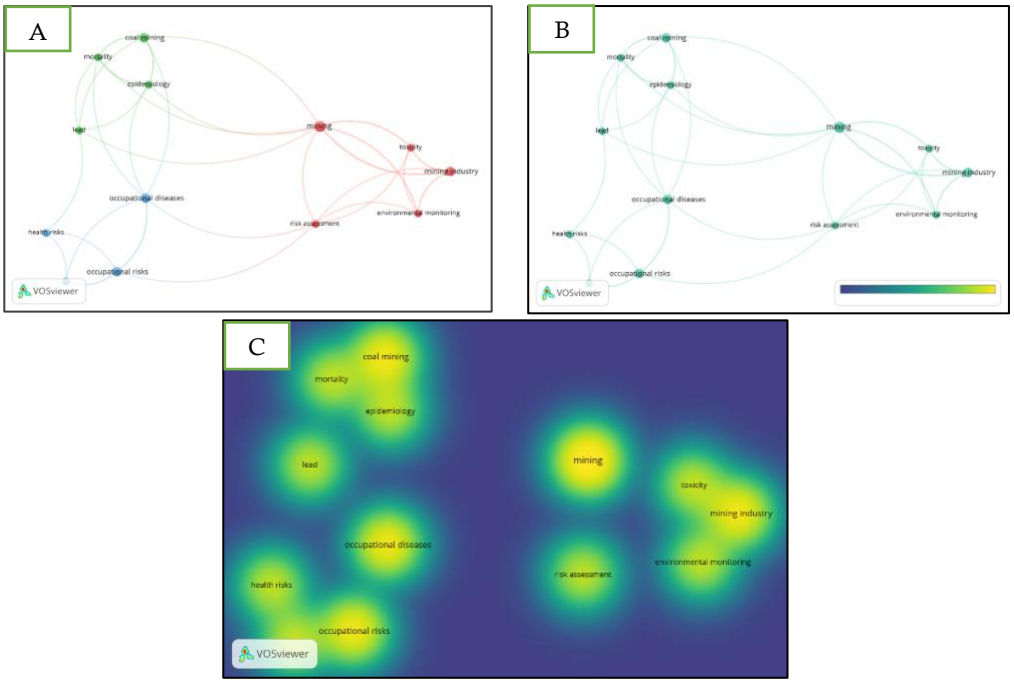

Figure 7. Network (A), Overlay (B), and Density Visualizations (C) of Author Keywords

Overlay visualization (Figure 7B) shows that core research themes remain active throughout the study period rather than becoming obsolete. Assessment and monitoring-related keywords remain temporally integrated with mining-related terms, suggesting sustained relevance. Density visualization (Figure 7C) further demonstrates that thematic hotspots are concentrated around mining and the mining industry, with additional high-density areas associated with risk assessment and occupational diseases. In contrast, mortality and coal mining appear as more specialized thematic pockets, indicating narrower but distinct lines of inquiry.

The keyword co-occurrence analysis conducted through VOSviewer revealed three primary thematic clusters:

1. Risk assessment and environmental monitoring: This cluster remains highly central, underlining the focus on hazard identification and exposure assessment in mining operations;
2. Epidemiological outcomes: This cluster links lead exposure with health risks such as mortality and disease, particularly within coal mining contexts. However, this cluster is less integrated with the first, indicating that exposure assessments and health outcome research are often pursued in parallel; and
3. Occupational health: This cluster focuses on the risks to workers' health due to mining activities, including occupational diseases, injury risks, and overall health risks.

The separation between exposure monitoring and health outcomes is particularly notable, highlighting a gap in research integration. Figure 7 show that, while the assessment and monitoring keywords maintain sustained relevance throughout the study period, the epidemiological cluster remains specialized, indicating that these two research streams (exposure assessment and health outcomes) have not been thoroughly integrated into a cohesive analytical framework. This conceptual gap underscores the need for more holistic research approaches that link exposure data

directly to long-term health outcomes, particularly in high-risk sectors such as coal mining.

DISCUSSION

The sharp increase in publications during the early 2020s reflects intensified scientific attention to occupational exposure risks, likely driven by growing awareness of long-term health impacts, advances in exposure monitoring, and heightened regulatory and public health concern. This trend is consistent with recent empirical and surveillance-based studies documenting persistent occupational disease burdens among mining workers (Arrandale et al., 2025; Mazurek et al., 2025). However, the slight decline observed toward 2025 should be interpreted cautiously, as it may reflect publication lag or incomplete indexing rather than a true reduction in research activity.

This increase in research output highlights the importance of Environmental Science and Medicine, which continue to dominate the literature. These fields play a central role in understanding environmental hazards and health outcomes in the mining industry. As seen in the growing contribution from Earth and Planetary Sciences and Engineering, there is also significant focus on the geochemical analysis and technical monitoring of mining areas, particularly in relation to contamination in soil, water, and air (Sharifi et al., 2023; Galgani et al., 2025). However, while this multidisciplinary approach strengthens the field, it also reveals a degree of fragmentation, with environmental monitoring studies often progressing independently of studies on occupational health outcomes (Goryaev et al., 2023).

This fragmentation becomes particularly evident in the analysis of the thematic clusters identified through keyword co-occurrence. The cluster focused on risk assessment and environmental monitoring remains highly central, reflecting the ongoing emphasis on exposure assessment as a critical priority in mining research. In contrast, the cluster emphasizing epidemiological outcomes, which links lead exposure with health risks such as mortality, is less integrated with the assessment-oriented cluster. This separation between exposure assessment and health outcomes mirrors empirical trends in which detailed exposure characterization is not consistently connected with long-term disease surveillance or mortality outcomes among mining workers (Mazurek et al., 2025; Saldaña-Villanueva et al., 2022). Consequently, this gap underscores the need for more integrated research that connects these two streams—exposure monitoring and health outcomes in a more cohesive and comprehensive manner.

From a bibliometric perspective, the overlay visualization reinforces the notion that the field is not outdated, but rather evolving. This maturity is beneficial for bibliometric analysis, as it allows for identifying key thematic pillars and underexplored connections. As such, future research should aim to bridge the gap between environmental monitoring, risk assessment, and occupational disease outcomes, particularly in high-risk sectors such as coal mining. Expanding international collaboration and incorporating a broader range of perspectives will also enhance the global relevance of research on occupational health in mining, addressing gaps in current evidence and strengthening international standards (Cortes-Ramirez et al., 2025).

Limitations of the study

However, several limitations of this study must be acknowledged. The analysis is based solely on Scopus-indexed publications, which means relevant studies indexed in other databases may have been excluded. Additionally, the reliance on author-provided keywords for the keyword co-occurrence analysis may have introduced some inconsistencies in terminology, affecting the formation of clusters. Finally, this study focused on publication patterns and thematic structures, rather than the quality of the methodologies or causal inferences made in the studies. Future research can address these limitations by expanding the search to include other databases, harmonizing keywords, and combining bibliometric analysis with systematic or scoping reviews to enhance the synthesis of evidence across the field.

CONCLUSIONS

This bibliometric analysis reveals that research on lead exposure and occupational health in the mining industry has experienced significant growth between 2015 and 2025, with a notable increase in publications after 2020. The findings indicate that the literature is distinctly multidisciplinary, integrating fields such as environmental science, medicine, engineering, and occupational health, all of which interact to address risks related to exposure in the mining sector.

Thematic mapping identifies three main research orientations: first, risk assessment and environmental monitoring; second, epidemiological research linking lead exposure to health impacts; and third, occupational health research focusing on diseases and health risks in mining. While these thematic cores are well-established, the analysis reveals a conceptual gap between exposure assessment and health outcomes, indicating that these research streams often progress in parallel rather than within integrated analytical frameworks.

These findings are important as they highlight the knowledge gap between exposure measurement and the long-term health impacts in the mining sector. Future research should focus on bridging this gap by explicitly connecting exposure monitoring, risk assessment, and occupational disease surveillance, especially in high-risk sectors such as coal mining.

Suggestions for Future Research:

1. More integrative research that links exposure monitoring with long-term health outcomes is essential to deepen our understanding of the impact of lead exposure on mining workers; and
2. Strengthening international collaborations and exploring differences and similarities in findings across countries can enhance the global relevance of this research and provide a foundation for more effective health mitigation strategies in the mining sector

AI DISCLOSURE STATEMENT

Artificial intelligence tools were used to support language refinement and manuscript editing. All analyses, interpretations, and conclusions were developed by the authors, who take full responsibility for the content and integrity of the study.

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We want to thank all participants who participated in this study.

DATA AVAILABILITY

The data supporting the results of this study were gathered through field-based observations and have been recorded by the researcher. Although the dataset is not openly accessible, it can be shared by the corresponding author upon reasonable and well-justified request.

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This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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