SEMARAK ILMU PUBLISHING

Semarak International Journal of Design, Built Environment and Sustainability

Journal homepage: https://semarakilmu.my/index.php/sijdbes/index
ISSN: 3083-9025

Challenges and Opportunities for Sustainable Tin Mining Activities: a Systematic Literature Review

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ARTICLE INFO

Article history:
Received 19 July 2025
Received in revised form 16 August 2025
Accepted 31 August 2025
Available online 18 September 2025

ABSTRACT

Tin mining contributes significantly to the world economy, particularly in the creation of electronics and construction materials, but it frequently has a negative influence on the environment and the health of those living near mines. These effects include deforestation, habitat damage, water contamination, and radiation exposure from mining waste. The main issue is environmental devastation and substantial health risks caused by uncontrolled mining activities. The goal of this research is to investigate the ecological and health effects of tin mining and to develop appropriate mitigation strategies. The approach employed is Systematic Literature Review (SLR) with a data search strategy based on PICOS, and databases used include Google Scholar, Publish or Perish, and Scopus. Relevant publications were identified using the PRISMA technique and examined using Covidence and VOSviewer software. Based on inclusion criteria, 54 articles were chosen for the systematic literature review out of 608 total. The bibliometric study revealed 52 distinct terms connected to the impact of tin mining, including "natural radioactivity," "radiation hazards," "heavy metals," and "environmental monitoring." Chemical and radioactive contamination cause environmental damage by contaminating soil and water and threatening biodiversity. Tin mining emits heavy metals into the environment, including arsenic and lead, which harms human health and ecosystems. Radiation exposure from mining waste, such as NORM and TENORM, raises the risk of cancer and other disorders. Mining waste also pollutes water sources, affects aquatic ecosystems, and endangers the health of those who rely on water. Some of the proposed solutions include regular monitoring of environmental quality, improved waste management, and stringent regulatory enforcement to mitigate the harmful effects of tin mining. This study highlights the need for a holistic approach to tin mining management to reduce negative environmental and human health impacts, including radiation monitoring systems, improved waste management, and legislation that promote sustainable mining practices. Furthermore, in order to manage tin mining responsibly, greater legislation, improved oversight, and coordination among the government, industry, and society

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https://doi.org/10.37934/sijdebs.4.1.117

are required. The research is also useful in informing government, industry, and the general public on the consequences of tin mining and encouraging more sustainable methods.

Keywords:
Tin mining; environmental; social; health; impact; sustainability

1. Introduction

Mineral mining has a substantial impact on economic growth, infrastructural development, industrial expansion, job creation, and poverty alleviation in numerous nations [1,2]. Tin mining, in particular, is crucial to the world economy, particularly in the production of electronics and construction materials. Many countries have boosted mineral resource use to meet local and export demand, thereby improving their economies [3].

However, the tin mining process frequently has a severe influence on the environment, including deforestation, habitat damage, and water pollution [2,4]. Furthermore, this action has an impact on the health of the community residing near the mining site [5]. Mining waste, particularly tailings, is typically released into the open air without proper oversight, allowing hazardous particles to be distributed by the wind and impact the health of the local community [2]. Furthermore, the tin ore processing process produces dust, gas, slag, and tin slag, which contributes to environmental pollution [6].

Overall, mining's harmful impact on human health and the environment cannot be disregarded. Tin mining can generate pollution and substantial landscape changes, endangering ecosystems and polluting the surrounding environment [7]. Because tin mining waste contains a high concentration of radionuclides from naturally occurring radioactive materials (NORMs) such as rutile, monasite, zircon, and ilmenite [8]. Workers at mining sites and neighboring populations may be exposed to TENORM (Technologically Enhanced Naturally Occurring Radioactive Material) through inhalation, absorption, and ingestion/ingestion of wind-borne radionuclide particles or water via the food chain [9,10].

Tin mining has left soil with a number of naturally occurring radionuclides. The high radioactivity concerns associated with exposure to ionizing radiation from decay nuclides ^{238}U and ^{232}Th can reach 200,000 and 400,000 Bq.kg-1, respectively, leading in gamma radiation exposure of over 30,000 nGy.h-1 [10]. Workers in tailings processing plants can inhale alpha-emitting particles like radon (^{222}Rn) and thoron (^{220}Rn), which can cause radioactive accumulation in body tissues and raise the risk of cancer [6,11]. Furthermore, the transfer of Potentially Toxic Elements (PTEs) from soil to plants through the food chain can endanger human and animal health [12].

Furthermore, the use of these natural resources results in land degradation, habitat loss, biodiversity, and water and air pollution. Tin mining causes social disputes among industry, local communities, governments, fishers, tourism entrepreneurs, and illegal miners [13]. As a result, the purpose of this study is to examine the environmental impact of tin mining activities. This research is especially useful for teaching politicians, industry, and the general public on the consequences of tin mining and advocating more environmentally friendly practices.

2. Methodology

This study's design is based on a Systematic Literature Review (SLR). A systematic literature review is a systematic and planned literature review that uses rigorous procedures to identify, assess, and synthesize all relevant research related to a question or topic, as well as bias-reduction strategies, and is regarded as the "gold standard" for gathering and understanding research [14].

The data search technique employs the PICOS (Population, Intervention, Comparison, Outcome, Study type) [15], specifically: Population: Tin mining, Intervention refers to acts performed by stakeholders. There is no comparison, Outcomes: effects induced The study kind is experiment. Based on the definition of PICOS, the study topic is: what is the impact of tin mining activities?.

Systematic literature searches are conducted utilizing electronic bibliographic databases such as Google Scholar, Publish or Perish, and Scopus. Keyword indexes are used in literature searches to find information about the effects of tin mining. The search is based on the keywords appearing in the title and abstract as follows: category #1: ("tin mining" OR "mine" OR "mineral mines" OR "exploitation" OR "exploration" OR "solid minerals" OR "mine legacies") AND ("radiological" OR "NORM" OR "TENORM" OR "radiation" OR "Radioact*" OR "radionuclides") AND ("environmental impact" OR "ecological impact" OR "pollution" OR "contamination"); Category #2: ("tin mining" OR "tin mine") AND ("impact" OR "effect" OR "affect" OR "influence") AND ("environment" OR "ecology"); Category #3: ("Impact" OR "effect") AND ("tin mining" OR "tin mine").

Following a literature search, all data is entered into Mendeley as a reference manager, which is subsequently exported to the research information system format (*.ris). Furthermore, the researcher employs covidence web-based software as a systematic review manager to assist with literature study selection. Data is reviewed by titles, abstracts, and full text to guarantee the relevance and quality of the research.

Data analysis was carried out by creating a review protocol utilizing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) methodology. The PRISMA method is useful for clearly and methodically describing the process and findings of a literature review [16]The inclusion criteria utilized in this study are papers describing the environmental/health implications of tin mining, published in the recent three years (2021-2024), available in full-text pdf format, and written in English.

3. Result

3.1 Article Search

When selecting articles for a systematic literature review, authors look for articles that meet inclusion criteria. Searches are carried out on Google Scholar, Publish or Perish, and Scopus utilizing the boolean operators AND and OR. Initially, 608 publications were identified and subsequently removed using the PRISMA chart, leaving 53 articles for systematic literature review.

The methodical processes in reviewing publications based on PRISMA published on the Covidence website are as follows: a. Identification: Using a covidence systematic review, the author removed 120 duplicate papers from the Google Scholar, Publish or Perish, and Scopus databases, leaving 488 articles. Screening: 292 of the 488 items filtered were eliminated, leaving 196 papers for assessment. Eligibility: After examining the viability of 196 articles, 142 further articles were removed, leaving 54 articles that meet the inclusion criteria. d. Included: 53 publications chosen for systematic literature review. Fig. 1 shows the course of an article search using the PRISMA approach.

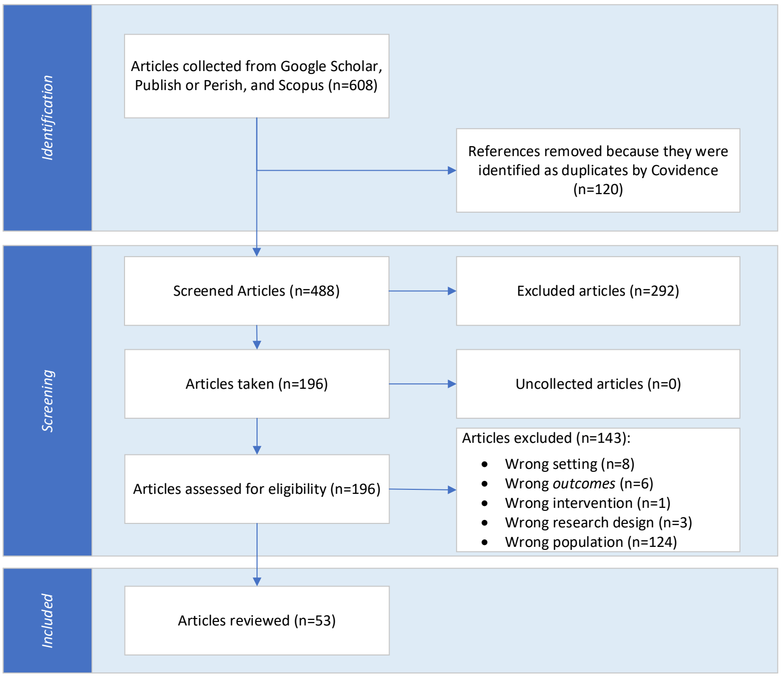

Fig. 1. Article search flow based on the PRISMA method

3.2 Mapping the Position of Research Topics

Bibliometric analysis is used to identify the most recent research on current positions and trends. As a result, the bibliometric analysis method adopted is co-occurrence analysis with author-derived keywords. We discovered 488 publications through searches on Google Scholar, Publish or Perish, and Scopus. The author's keyword-based co-occurrence analysis method yielded 1459 unique keywords. Then, a minimum of three occurrences are chosen, resulting in 52 distinct keywords that will be further evaluated in VOSviewer. **Table** 1 shows keywords connected to the impact of tin management, as well as their frequency and degree of relationship with other keywords.

Table 1
List of keywords related to this study

No	Keywords	Occurrences	Total Link Strength
1	activity concentration	6	10
2	animals	4	12
3	annual effective dose	3	5
4	arsenic	7	18
5	assessment	3	9
6	bangka	3	3
7	building materials	5	5
8	cancer risk	6	7
9	chemistry	3	14
10	clearance level	3	4
11	decommissioning	4	2
12	dose assessment	3	1
13	dose rate	3	5
14	ecosystem	3	12
15	environment	5	22

Table 2 ***(Continued)***

16	environmental monitoring	11	53
17	gamma rays	3	18
18	gamma-ray spectrometry	3	9
19	Genetics	3	11
20	health impact	3	9
21	heavy metals	17	62
22	Humans	18	87
23	knowledge management	3	11
24	lifetime cancer risk	4	9
25	Mining	22	74
26	Modelling	3	9
27	natural radioactivity	36	60
28	occupational exposure	5	24
29	ore processing	5	20
30	Pathway	3	9
31	quality of life	3	10
32	radiation dose	8	29
33	radiation exposure	3	7
34	radiation hazards	30	64
35	radiation monitoring	16	72
36	radioactive materials	3	7
37	radioactive waste	3	5
38	radioactivity	6	6
39	radium equivalent activity	7	10
40	Radon	4	5
41	Regulation	8	26
42	Resrad	15	21
43	rural population	3	24
44	Soil	14	62
45	sustainability	3	10
46	Tailing	10	26
47	Tenorm	15	19
48	Tin	14	61
49	tin mining	7	2
50	transfer factor	7	21
51	vegetables	6	42
52	Water	4	25

Table 1 displays a list of keywords connected to lead management effect studies based on their frequency and overall link strength. The keyword "natural radioactivity" was mentioned the most (36 times), with a total relationship strength of 60, showing that it is the most often discussed topic and is highly related to the other topics in the study. Furthermore, the keywords "humans" and "mining" appear frequently (18 and 22 times, respectively) and have a relatively high overall relationship strength (87 and 74), indicating widespread worry about the impact of tin mining activities on humans and the mining process itself.

Other terms like as "radiation hazards," "heavy metals," "environmental monitoring," and "soil" appear frequently and have substantial connections, implying that these factors are equally essential to tin management effect studies. For example, the phrase "radiation hazards" appears 30 times with a total relationship strength of 64, whereas "heavy metals" appears 17 times with a total association strength of 62. This data suggests that radiation risk and heavy metal contaminants are the primary topics addressed in this study.

VOSviewer generates three visual outputs: network visualization, overlay visualization, and density visualization. Each graphic conveys distinct information or insights. The three representations allow for the evaluation of the research's trends and positions. Fig. 2 to Fig. 4depict the three visualizations generated by VOSviewer.

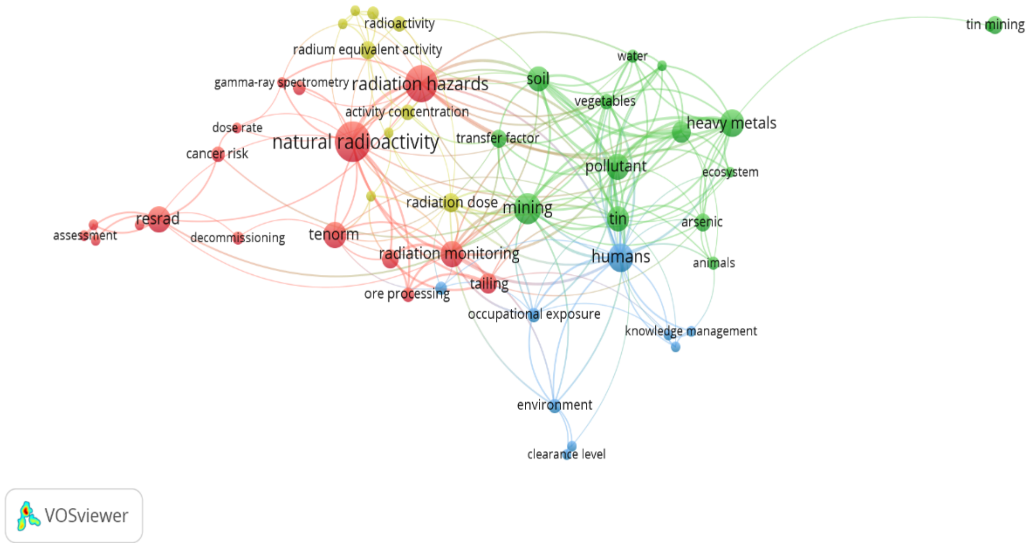

Fig. 2. Network visualization

Fig. 2 depicts the grouping of several variables related to the influence of tin management, with the four main clusters distinguished by color. This research identifies numerous major clusters. Natural radioactivity, radiation hazards, radiation monitoring, radiation dose, cancer risk, and dose rate are all in the Red Cluster; heavy metals, tin, pollutants, soil, ecosystem, arsenic, and animals are in the Green Cluster; humans, occupational exposure, environment, and clearance level are in the Blue Cluster; and radioactivity, radium equivalent activity, and gamma-ray spectrometry are in the Yellow Cluster. Furthermore, the term "tin mining" is distinct but connected to the green cluster. These categories represent the primary emphasis of the studies done, illustrating the complexity and breadth of the implications of tin management, including environmental, health, and monitoring technology components.

According to network visualization using VOSviewer, lead management is strongly related to natural radiation exposure and radiation dangers. Major clusters like "natural radioactivity" and "radiation hazards" highlight the significance of radiation monitoring in the tin management process. The terms "radiation monitoring," "radiation dose," and "cancer risk" demonstrate that in this setting, substantial emphasis is placed on monitoring the radiation doses received by workers and the environment, as well as potential long-term health hazards such as cancer.

In addition to radioactivity, the study found that tin management has a major impact on soil and ecosystem quality, as evidenced by clusters like "heavy metals," "pollutants," and "soil." Heavy metal contamination, especially arsenic, demonstrates that tin mining and processing activities not only affect radioactivity, but also generate dangerous chemical pollution. The close link with phrases like "humans," "occupational exposure," and "environment" indicates that the study also takes into account the impact of workplace exposure and environmental contamination on the health of workers and the surrounding communities. These findings support the necessity for a comprehensive strategy to tin management in order to reduce harmful effects on health and the environment.

From 2018 to 2022, extensive research on the impact of tin management on the environment and human health will be conducted. According to the color scale depicting the temporal dimension in **Fig.** 3,the study concentrated more on the natural aspect of radioactivity in 2018, as evidenced by dark blue clusters with phrases such as "natural radioactivity" and "resrad." In 2019-2020, scientific attention switched to radiation dangers and monitoring, with phrases like "radiation hazards" and "radiation monitoring" highlighted in green. This period also focuses on mining activities and the effects of pollution and heavy metals.

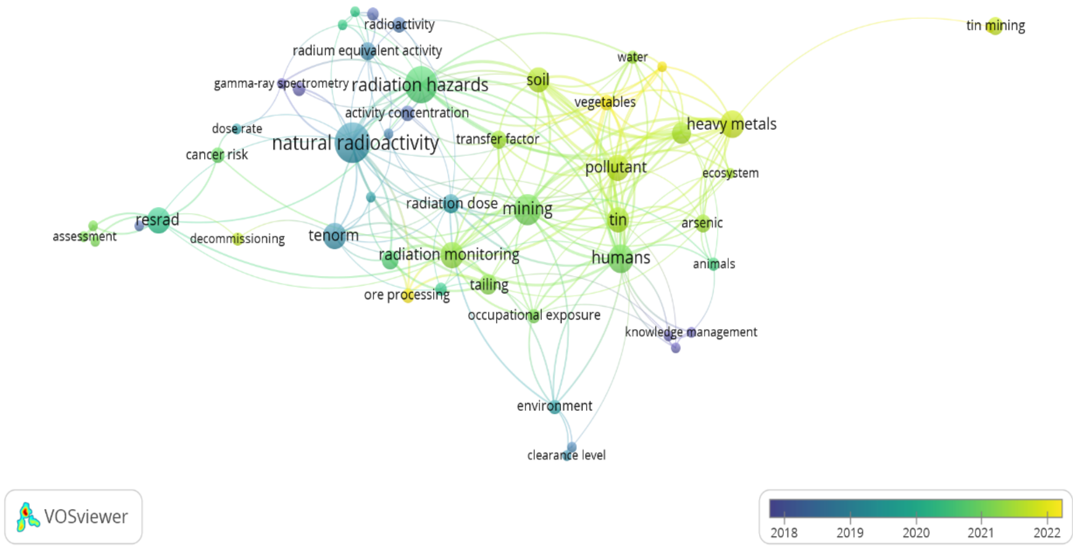

Fig. 3. Overlay visualization

According to **Fig.** 3, research in 2021-2022 is increasingly focused on the specific impacts of tin mining on ecosystems and soil quality, as evidenced by yellow phrases such as "tin mining," "pollutant," "ecosystem," and "soil." This reflects a greater emphasis on the direct environmental consequences of tin mining activities, as well as the significance of monitoring and controlling contaminants in ecosystems. According to the most recent study, contemporary issues with the environmental impact of tin mining are becoming increasingly important and urgent, necessitating a comprehensive and sustainable strategy to tin management in order to avoid negative environmental and human health implications.

Fig. 4 depicts the density distribution of important phrases from the research on the impact of tin management on the environment and human health. Bright yellow shows places with a high density of phrases, such as "natural radioactivity," "radiation hazards," "pollutants," "mining," "heavy metals," "tin," and "humans." The high density of these terms suggests that research during the analyzed period was heavily focused on the health and environmental impacts of tin mining activities, such as the risks of natural and man-made radiation, as well as the distribution of pollutants and heavy metals in ecosystems and human exposure. This emphasis indicates significant scientific attention to the potential dangers and hazards associated with the tin mining process.

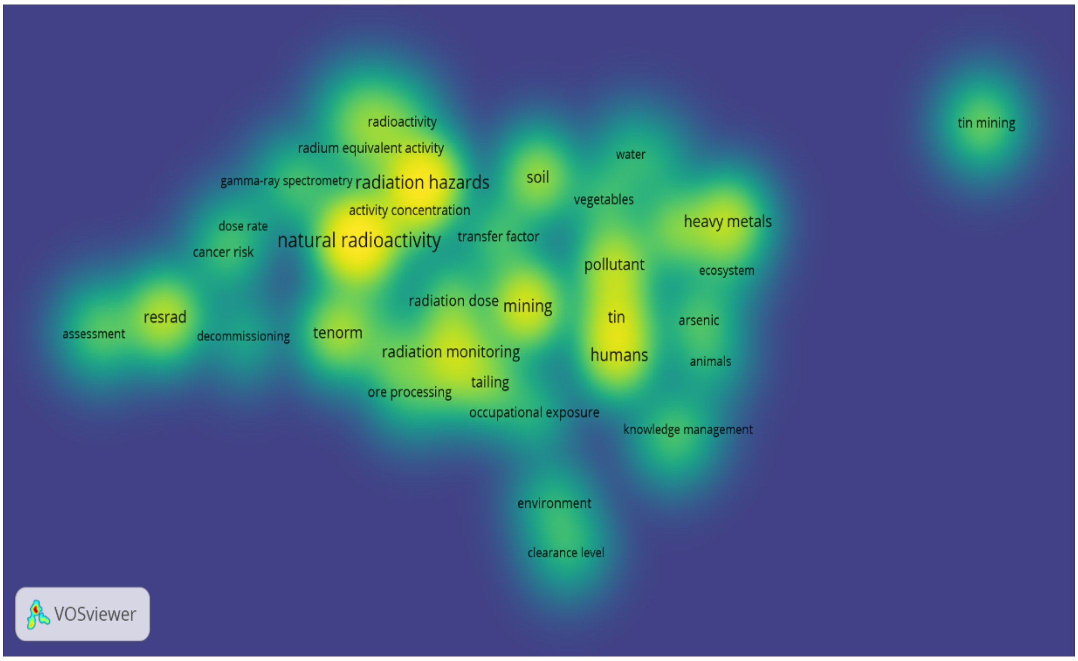

Fig. 4. Density visualization

Medium-density terminology, such as "resrad," "radiation monitoring," "tailings," "occupational exposure," "soil," and "ecosystem," emphasize the technical features and specific environmental implications of tin mining. Low-density phrases like "environment," "clearance level," and "knowledge management" represent issues that, while significant, have not yet received much consideration in the study. This demonstrates how the research focus has shifted over time, highlighting the most recent trends in the study of the impact of tin management. It also enables the identification of the most relevant areas of research and provides guidance for future studies in efforts to alleviate the harmful effects of tin mining. This visualization has the potential to help shape better environmental management policies and risk mitigation techniques in the future.

Based on the previously described bibliometric analysis, this literature review seeks to provide comprehensive information that there are still shortcomings in the impact study of tin management that combines economic analysis and social welfare of local communities, which has been underpaid thus far. The study takes a comprehensive approach to sustainability, taking into account not only environmental and health concerns, but also practical solutions. This study is likely to help improve sustainable tin management policies and practices.

3.3 Scope of the Study

The researchers' publications cover several countries as research locusts, with each focusing on distinct difficulties within that country. Quynh *et al.*, [3] conducted research in Vietnam on social, economic, and environmental issues. González-Sánchez *et al.*, [2] researched obstacles and developments in Mexico, whereas Rafique *et al.*, [17] investigated technology and social policy in Germany. Lima *et al.*, [18] conducted research in Brazil on environmental and climate change issues. In China, H. Yang *et al.*, [19] and Y. Yang *et al.*, [20] looked into economic development and urbanization.

Sanusi *et al.*, [10] Sibuar *et al.*, [21] Abdulah *et al.*, [22] Palanimally *et al.*, [23] and Rahmat *et al.*, [8] have conducted research in Malaysia on technological innovation and public policy issues. In Nigeria, different studies by Bwede *et al.*, [24] Onyeka *et al.*, [25] Muhammad *et al.,* [5,9,26], Mafulul *et al.*, [12] Kwaghe *et al.*, [27] Agbalagba *et al.*, [28] and Sati *et al.*, [7] focus on social and economic difficulties. Indonesia has the most articles, with research by Yazid *et al.*, [29] Darwance *et al.*, [30] Sukarman *et al.*, [31], and others covering environmental issues, public policy, and technological innovation, providing in-depth insights into the challenges and solutions in the country. This paper not only contributes to the academic literature, but it also contains valuable information for policymakers, practitioners, and researchers. **Fig.** 5 depicts statistics from the country where the research is being conducted.

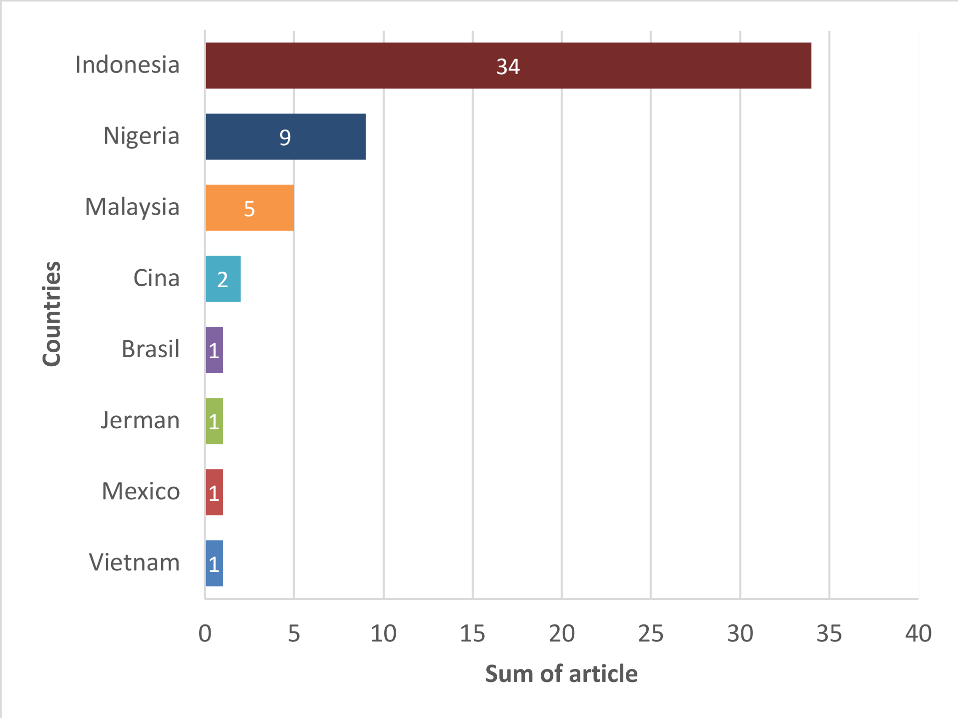

Fig. 5. Countries with research loci

These articles' research methodologies include quantitative, qualitative, and mixed-method approaches. The quantitative approach entails the collecting and analysis of numerical data, as demonstrated by Bwede *et al.*, [24], Yazid *et al.*, [29] and Rafique *et al.*, [17]. Articles H. Yang *et al.*, [19], Sanusi *et al.*, [10] and others use statistical measurements to describe specific events. In contrast, qualitative research, such as that undertaken by Darwance *et al.*, [32] and Quynh *et al.*, [3], aims to develop an understanding of the phenomenon by direct observation, interviews, and content analysis.

Qualitative research allows for a more in-depth understanding of an individual's or group's perceptions and experiences. Furthermore, Onyeka *et al.*, [25] adopted the blended method, which integrates elements from both methodologies to provide a deeper knowledge of the subject under investigation. The mixed technique enables researchers to comprehensively investigate data while quantitatively assessing certain elements. **Fig.** 6 shows the data for the study approach used.

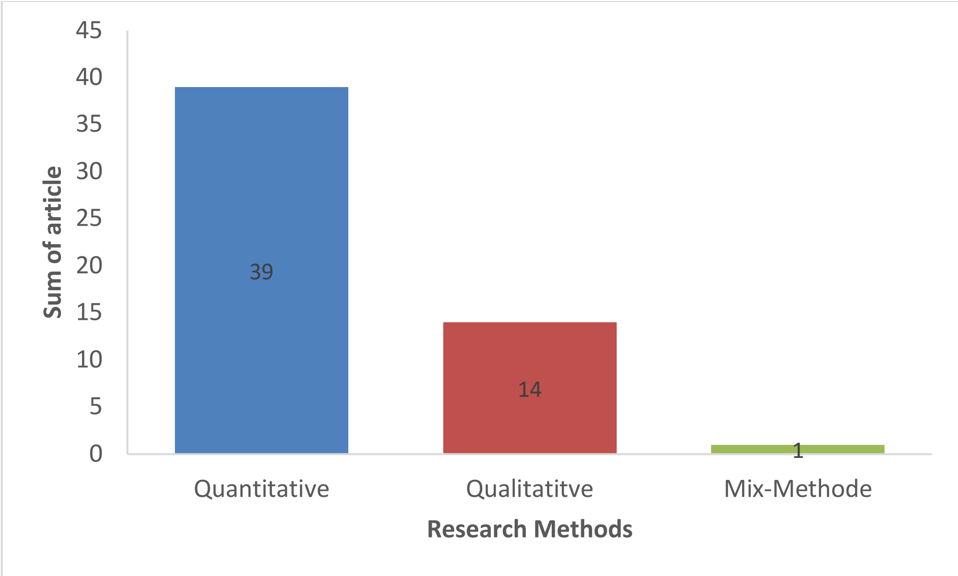

Fig. 6. Research methods used

3.4 Environmental Damage

The history of tin mining reveals economic injustice, social conflict, and environmental devastation. Tin mining frequently causes deforestation, soil erosion, and pollution, affecting agricultural production and local ecosystems. Competition for resources causes societal unrest, while foreign corporations and local elites reap more economic gains [25].

Tin mining has a wide range of severe environmental consequences, including soil degradation, ecosystem disruption, radionuclide and heavy metal contamination, and health concerns to humans and wildlife [13,33,34]. Land deformation, soil degradation, water pollution, and biodiversity loss are some of the impairments that render productive land unproductive and prone to landslides [35-40].

After mining, the terrain frequently becomes sterile due to high levels of harmful metals and low pH. This poses a threat to local agriculture and food security, as agriculture is the primary source of income for many rural families [25,30,32,41,42].

This environmental harm also includes deterioration of water quality, landscape damage from residual tailings and waste, and pollution of coastal habitats such as mangroves and coral reefs [19,23,42]. To mitigate such harmful consequences, rehabilitation and improved management measures are required.

Tin mining, both on land and at sea, has severe environmental consequences. Mining on land degrades soil structure and texture, depletes organic matter, reduces soil fertility, and creates enormous holes and ponds without reclamation [31,43]. Mining in the sea with boats or pontoons in shallow waters harms the coastal tourism economy by creating sedimentation that harms coral reefs and lowers plankton populations, both of which are key components of marine ecosystems [44].

3.5 Heavy Metal Pollution

Tin mining releases heavy metals into the environment, including lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel. This pollution lowers microbial activity, fertility, and soil quality. When toxic metals enter the bodies of organisms via the food chain, they can induce a variety of deadly diseases that jeopardize human life. As a result, rehabilitation and sustainable management activities are critical to mitigating these detrimental impacts [3,5,10,19,20,23,31,40,45-58]

According to studies, high levels of potentially hazardous elements (PTEs) in soil, pond water, and food crops surpass the limitations set by the World Health Organization (WHO). This is a considerable health risk [12]. Food crops such as bitter leaves, okra, and corn have substantial bioaccumulation of PTE, endangering the health of children and adults [12,49]. Heavy metals from previous mining sites can impact soil and groundwater, as well as human and animal health [17,21,22,24,27].

3.6 Radiation Hazards

The absorption rate of radiation doses in tin mining locations surpasses safe limits, raising the risk of cancer among mine workers. Mine workers are more susceptible to sickness than other locals. This is supported by the Effective Lifetime Cancer Risk (ELCR) and Annual Gonadal Dose Equivalent (AGDE) [11,20,28,40]

Tin mining also has a negative impact on the environment since it increases radioactivity. Although the WHO norm for drinking water still exceeds radioactivity levels, the risk to the community remains [8,26,29].

After tailings processing, the decay nuclide 238U had an average radioactivity rate of 29 Bq/l in still water, with a maximum value of 79 Bq/l, over 14 times greater than uranium's radioactivity in surface water [10]. Thorium and Uranium concentrations in water samples were from 29.60 to 36.20 Bq/l and 26.89 to 35.40 Bq/l, respectively, above the secular equilibrium limit of 10 Bq/l for the ^{226}Ra and ^{228}Ra offspring [8].

According to studies, in extreme conditions, personnel receive an average total effective dose of 0.5 mSv per day and a maximum of 5 mSv per day, which exceeds the International Commission on Radiological Protection's (ICRP) recommended yearly limit of 20 mSv. Long-term exposure does not represent an immediate threat, but it has a stochastic effect. According to radioecological concerns, aquatic biota are substantially exposed to radiation emitted by this industry [10,50-52].

3.7 Water Pollution

Tin mining has increased phosphate levels and water turbidity, posing a threat to fish populations and local food security. The main reason of this fish species' decrease is heavy metal contamination, specifically iron, lead, and zinc. This contamination affects the bioaccumulation of heavy metals in marine creatures including fish, squid, and shrimp, and it can be harmful to human health [38,53].

Mining activities have a deleterious influence on coral reefs, seagrass, marine life, and mangroves, as well as changing the character of aquatic bottom sediments, increasing the percentage of fine silt in the area [54-57].

Tin mining also harms coastal habitats, degrades water quality, and contaminates river flows [35]. River pollution contaminates the water, making it unclean and muddy and creating a breeding ground for malaria mosquitoes. The beach, which used to have white sand and clear water, is likewise ruined [35]. Offshore mining waste harms fishing regions by covering coral reefs, algae homes, and other marine life [58]. Tin mining pollutes coastal waters, reducing fishing productivity and harming marine ecosystems. As a result, traditional fisherman are also harmed [4,10,50,52].

3.8 Health Impact

Water pollution by heavy metals has harmed the ecology and caused poisoning and cancer [51, 55-57]. Tin miners are also extremely prone to health problems as a result of radiation and heavy metal exposures. This exposure has been linked to lung illness and other health issues [6,8,18].

According to research, radiation levels in tin mining sites frequently surpass the Supervisory Agency's standards. The ^{40}K concentration remained within the permissible level, but numerous sampling sites revealed quantities of ^{226}Ra and ^{232}Th that surpassed the global average. Radium's external hazard index (Hex), internal hazard index (Hin), and annual effective dosage levels are all below permitted limits. Nonetheless, the quantity of particles absorbed in the air and the lifetime risk of cancer are effectively over tolerable standards, indicating that the place is radiologically dangerous for inhabitants [7].

Tin mine workers have extremely high health hazards, with cancer rates above the threshold [6]. This study underlines the importance of implementing sustainable mining techniques to limit radiation effects and protect the health of the general population and mine employees [5].

In comparison to global standards, this industry has a higher lifetime risk of cancer owing to radiation exposure. The risk of cancer for indoor exposure was 2.8×10^{-3}, and for outdoor exposure 0.9×10^{-3}, for a total risk of 3.7×10^{-3} [5]. Furthermore, investigations in former tin mines in Peninsular Malaysia and Bangka Belitung demonstrate that vegetables have high amounts of ^{40}K, as well as heavy metal contamination from Pb, Cu, and Hg. Heavy metal contamination has also been detected in a variety of elements, including Pb and Cu, indicating substantial health risks [11,27].

3.9 Impact Reduction Interventions

In Malaysia, numerous actions have been done to alleviate the harmful impact. These include transforming disused mines into new communities, homes, and parks, as well as using High-Density Polyethylene (HDPE) containers to handle tailings and industrial waste [8,10]. China's sustainable tin business aims to recycle tin from electronic trash while also effectively managing tin reserves, production, and consumption. Furthermore, policies like the Environmental Protection Tax Act of 2016 have boosted the country's efforts to protect the environment [8].

To lessen the impact of mining on public health, it is also proposed that air quality monitoring stations be built in Mexico's cities to measure atmospheric pollution [2]. It is believed that these efforts would inspire more sustainable mining techniques in the future, reducing tin mining's detrimental impact on the environment and public health.

4. Discussion

Despite its enormous economic contribution, tin mining has numerous negative environmental and social consequences that must be addressed. This paper describes the economic benefits of the tin mining sector, such as job creation and economic growth as a result of mineral resource exploitation. Nonetheless, it is vital to consider how far economic gains can outweigh the social and environmental harm they produce. Pressures on the environment rise as global demand rises, and without adequate management, the negative consequences might greatly outweigh the economic benefits.

Tin mining has far-reaching and negative environmental consequences, such as deforestation, habitat destruction, water pollution, and landscape alteration. Mining frequently causes soil degradation and the loss of natural vegetation, which leads to erosion and reduced soil fertility. Furthermore, tailings waste containing heavy metals creates new worries about water pollution since it can harm aquatic habitats and jeopardize the quality of water utilized by nearby residents. Those who drink dirty water or fish jeopardize both their health and the environment.

Tin mining has serious social repercussions as well. Conflicts between governments, industry, local populations, and illegal miners are common as a result of resource rivalry. Furthermore, those who live near mining sites are more likely to develop respiratory ailments and cancer after being exposed to radionuclide-containing dust, gasses, and mining waste particles. This issue demonstrates how critical it is to manage the societal repercussions of tin mining more responsibly, especially through improved regulation and oversight.

Tin mining also reduces plankton numbers in the ocean and causes harm to coral reefs in shallow areas. On land, unreclaimed former mining pits create an unsustainable landscape that can impact the local people. This damage demonstrates how critical sustainable and efficient reclamation is for restoring damaged ecosystems and preventing further damage.

Another concerning issue is heavy metal contamination from tin mining tailings. Heavy metal poisoning from soil and water, such as Pb, Cd, Zn, Cu, and Cr, can enter the food chain and cause a variety of human disorders. Furthermore, this contamination can limit microbial activity in the soil and lower water quality, endangering human and animal health. To offset these detrimental consequences, improved waste management and ecologically friendly mining technologies are required.

Although the harmful effects of tin mining have been minimized via environmental restoration and management initiatives, there remain several issues. The primary barriers to attaining this goal are coordination among numerous stakeholders and limited resources. To ensure that mining methods are more responsible, a solid regulatory framework and long-term policies are required. Furthermore, governments, business, and communities must collaborate to find effective and long-term solutions for managing the effects of tin mining. Only by taking a methodical and long-term strategy can we assure that the economic benefits of tin mining are not at the expense of environmental health and social well-being.

5. Conclusion

This study employs the Systematic Literature Review (SLR) method and the PRISMA strategy to locate and analyze research on the impact of tin mining. According to the results of the bibliometric analysis, the key topics addressed in this study include radiation exposure, heavy metal contamination, and the effects on ecosystems and human health. According to VosViewer network visualizations, the study's key topics are "natural radioactivity," "radiation hazards," "heavy metals," and "environmental monitoring". As a result, these findings highlight the significance of improved and more sustainable management in the tin mining business in order to reduce negative environmental and human health impacts while also encouraging more responsible future practices.

Although tin mining has a severe impact on society and the environment, it also provides a major economic benefit. Deforestation, soil erosion, water pollution, biodiversity loss, and heavy metal contamination are some of the environmental issues that endanger human and animal health. Social disputes among stakeholders are common as a result of resource competitiveness. Despite different attempts for environmental rehabilitation and management, many challenges remain unresolved, including stakeholder collaboration and limited resources. As a result, a strong regulatory framework and long-term policies are required to ensure more environmentally friendly mining practices.

Acknowledgement
The authors acknowledge funding from the Nuclear Technology Innovation Program House (HITN), in accordance with the decree of the Chairman of Research Organization for Nuclear Energy Number 24/III.2/HK/2023, code RO4-DET-C-007.

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