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A one health scoping review of human health risks beyond heavy metal exposure in Ghana's artisanal and small-scale gold mining sector

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Abstract

Artisanal and small-scale gold mining (ASGM) remains a vital economic activity in Ghana, supporting the livelihoods of thousands. However, the sector poses multifaceted risks to human health that extend beyond the well-documented exposure to heavy metals such as mercury and lead. This scoping review adopts a One Health framework to synthesise peer-reviewed literature on the broader spectrum of health impacts associated with ASGM in Ghana, recognising the interconnectedness of human, animal, and environmental health risk outcomes. Using a systematic search strategy across major academic databases (PubMed, Google Scholar, Web of Science) and manual reference screening, we identified and analysed 70 studies published from 2006 to 2025. The findings reveal a complex interplay of occupational, environmental, and public health hazards, including respiratory illnesses, musculoskeletal disorders, noise-induced hearing loss, mental health challenges, zoonotic and infectious diseases, and ecological degradation. Notably, we observed that heavy metal exposure is frequently conceptualised as a direct health outcome rather than a modulating factor influencing broader disease patterns in mining communities. This review highlights critical gaps in the literature, particularly the underrepresentation of specific communicable and non-communicable disease outcomes and the limited integration of animal and ecosystem health risk considerations. By moving beyond a narrow toxicological lens, we underscore the urgent need for integrated health interventions and policy reforms that align with One Health principles. Such approaches are essential for addressing the complex and interdependent risks faced by ASGM workers, residents of mining communities, and mineral-rich sub-Saharan contexts.

Keywords Artisanal and small-scale gold mining, One health, heavy metal exposures, Injuries, Communicable diseases and Non-Communicable diseases, Ghana

1 Introduction

Artisanal and Small-scale Gold Mining (ASGM) is a low-tech, labour-intensive sector of mineral processing and extraction that is widely practised around the globe, particularly in resource-rich regions of Africa, Asia, Latin America, and the Caribbean [1–3].



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Research has shown that ASGM significantly contributes to the socio-economic well-being of individuals, especially in low and middle-income countries (LMICs) [2, 4]. The global economic impact is illustrated by statistics showing that over 44 million people are employed across 80 countries [5], with Ghana alone benefiting from over one million direct employments and 4.5 million dependents [6]. While the sector plays a vital role in economic development, it has also raised international concerns due to its environmental and social impacts. This duality has been a focal point in various development discussions relating to poverty alleviation, good governance, and the promotion of sustainable mining practices [2, 7]. For example, reports on sustainable development goals (SDGs) by the United Nations and the World Bank have shown that the ASGM sector's economic contribution could become an avenue to achieving poverty reduction in the global South [5, 8]. While studies underscore the latent opportunities for LMICs to strengthen efforts towards streamlining the ASGM sector to achieve global poverty reduction, the challenge of sectoral formalisation remains a serious policy concern in many countries [9, 10].

In the context of sub-Saharan Africa, the Yaoundé Vision Framework of 2002 for ASGM highlights the economic imperatives of the sector and the expert guidance needed to be pursued for poverty alleviation in the sub-region [8]. Yet to date, the sector poses complex and multifaceted risks to human health, the environment, and animal populations, due to the absence of proper sectoral regulation that creates numerous harmful environmental outcomes [2]. Sectoral challenges include contamination of water bodies with hazardous chemicals, land degradation, and mercury exposure. Among these, mercury remains the most widely used and dominant chemical in ASGM operations [9–11]. Indeed, the environmental impact of the sector has been extensively discussed in the literature, with debates centred around legalism, particularly on the issue of licensure procurement versus environmental pollution [12, 13]. In Ghana, for instance, the involvement of political elites in illegal mining (popularly known as 'galamsey') has been linked to its proliferation and failures by government to implement reforms or regulate the sector [14–16], creating a difficult governance regime where interventions have rarely been successful.

Others argue that the difference between licensed and unlicensed miners regarding environmental challenges and health risks is unclear, as the former has merely become a label for operational classification [12, 17]. Some studies show that unregulated small-scale gold mining has increased the cost of water treatment for households and has been linked to environmental pollution, prevalent occupational health risks [12, 14] and risks of unsafe water consumption [15]. In addition, there are indications that encroachment by illegal miners on forest reserves in the western and eastern regions of Ghana [16, 18] promotes increasing human-wildlife interaction with disease pathogens, although potential risks of this are understudied and represent an important gap in the evidence base. Addressing this, critics argue that inadequate efforts by government to reform and regulate the sector reflect a double-standard position, especially where there is notable evidence of involvement of certain political elites in illegal mining activities [19, 20].

Along with the looming environmental and human health challenges highlighted in the current literature [21–23], anecdotal evidence indicates that the impacts of ASGM have currently moved beyond discussions of economic livelihoods and environmental degradation [24, 25] to include serious public health concerns such as birth defects and

foetal poisoning in pregnant women¹. In addition to heavy metals and occupational hazards, some studies have highlighted the burden of malaria and other Neglected Tropical Diseases (NTDs) [26]. Over 10 NTDs, including dengue, lymphatic Filariasis, and schistosomiasis, are endemic in Ghana, some of which are notable in mining areas [26, 27]. While the association between ASGM and malaria outbreaks is well established [28–30], the environmental and social conditions that facilitate the spread of malaria vectors and other NTDs (such as inadequate sanitation) represent gaps in the evidence base. Moreover, the geographical overlap between ASGM zones and areas with poor sanitation, which create ideal breeding grounds for disease vectors, heightens the vulnerability of mining populations [3, 4, 31, 32]. Despite these concerns, gaps exist in the evidence base on specific pathways linking ASGM to disease transmission dynamics, underscoring the need for integrated surveillance and targeted public health interventions guided by the One Health framework. Emphasis by One Health on the often-overlooked interconnections between human, animal and environmental health are particularly relevant for ASGM operations risks in settings where neglected tropical diseases remain prevalent. This is particularly true in areas where mercury pollution, water contamination combined with increased human contact with animals in forested areas have potential to create/enhance pathways for emerging infectious diseases and contribute to complex health risks across all domains.

In the Tarkwa, Prestea and Obuasi mining areas of Ghana, studies of food crops have shown that levels of cadmium, arsenic, lead and mercury are above internationally recognised safe limits for human health [24, 33]. Heavy metals in the soils and waterbodies discharged by ASGM activities are taken up by food crops and fish through bioaccumulation processes, which becomes dangerous to both human health and aquatic environments [10, 11]. Yet, to date, no attempt has been made to catalogue health issues beyond heavy metal exposure. There is a growing need to explore broader health implications within a more integrated framework. This scoping review synthesises peer-reviewed literature to map the range of human health risks associated with ASGM in Ghana. While much of the current literature focuses on toxic exposures like mercury, this study broadens the scope to include other conditions like infectious diseases, respiratory and dermatological conditions, occupational injuries, and psychosocial stressors. Guided by the One Health framework, which emphasises the interconnectedness of human, animal, and environmental health, this review identifies critical gaps in the knowledge and evidence base and highlights the need for collaborative and cross-disciplinary research. By drawing on available evidence, the goal is to build a more comprehensive understanding of health and disease outcomes linked to ASGM that will inform better conceptualisation of future health studies and how these issues can be addressed.

Against this background, we ask the overarching question, “What evidence of health and disease challenges exists in ASGM communities in Ghana? Linked to the overarching question, three specific sub-questions are explored: (1) What health and disease outcomes (burdens) are linked to ASGM? (2) How are they distributed geographically? (3) To what extent does ASGM contribute to the spread and emergence of disease outcomes (burdens)? In the concluding section, we discuss how existing evidence could contribute

¹ https://www.myjoyonline.com/galamsey-fight-its-sad-to-give-birth-to-a-child-with-deformity-samreboi-resident-s-lament/#google_vignette.

to formulating targeted health and safe mining interventions through the application of a One Health framework.

2 Materials and methods

We adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) [34] to synthesise existing peer-reviewed evidence in the scientific literature on Ghana. Synthesised evidence was retrieved from three bibliographic databases (Web of Science Core Collection, PubMed, Google Scholar) and a manual reference search. The databases were chosen due to their international reputation and multidisciplinary contents, which cover a wider domain of issues in public health, ecotoxicology, biology and social science and health literature [35].

2.1 Search strategy

An initial literature search was conducted to answer the questions “what evidence of health and disease outcomes exists in the ASGM literature, and to what extent are they distributed across Ghana’s ASGM landscape? A pilot search in Cochrane Library² was conducted using a combination of Boolean search terms (Small-scale gold mining OR Artisanal gold mining AND Health OR Disease outcomes), which retrieved only five relevant outputs specifically from Zamfara state in Nigeria, South Africa and Peruvian Amazonia. The search terms were then tested in PubMed³ database, from which the next iteration of search terms was developed for the other databases. Final searches were conducted in two stages: the preliminary search and the main search. The search terms were refined between April and June 2024 and were used in the main search, which took place between July and November 2024, after success was achieved upon reviewing the initial search terms to cover a wider search output. An additional literature searches was conducted in March 2025, which yielded one citation.

Literature searches in the databases were conducted in three stages: title, abstract and full-text review, upon which the inclusion and exclusion criteria were applied (Table 1). Title-level reviews in the databases were based on articles with keywords: “Artisanal and Small-scale Mining, Small-scale Gold Mining, Small-scale Mining and Health and Disease” (see S1 File). There was no timeline restriction to publication; however, focused publications were written in English and published in peer-reviewed journals. We chose

Table 1 Eligibility criteria for included studies

Inclusion/exclusion domain	Definition
Study focus	Studies that focus only on health and disease in small scale mining. Studies that do/do not specifically mention health in titles but report specific related diseases and health systems
Publication type	Only peer-reviewed articles, published in scientific journals
Scope	Only publications focused on Ghana were included
Study design	Reviewed articles and empirical/primary research on the subject matter
Language	Only articles published in English language were included
Accessibility	Publications inaccessible for full-text review were excluded
Date/timeline	No timeline/limit placed on the literature search

²Independent databases containing high quality health publications that cuts different geographies: Cochrane Library— <https://www.cochranelibrary.com/>.

³PubMed— <https://pubmed.ncbi.nlm.nih.gov/>.

to focus on English language publications as the primary medium for disseminating scientific research findings in Ghana.

2.2 Review criteria and selection of the study

The principal reviewer (EST) initiated the database searches and screening of titles, abstracts, and full-text documents. To minimise bias, the collated publication information was further reviewed independently by three other reviewers (MSR, FAA and SJ) and discussed in regular (monthly) meetings. Although scoping reviews do not typically enforce strict/formal inter-rater reliability measures (e.g., Cohen's Kappa) [36], our independent review process allowed for cross-checking individual assessments and resolving areas of disagreement in scoring. To ensure rigour and address methodological limitations in different publication types, we excluded commentaries, editorials, letters, and other forms of grey literature to enhance the reliability of reported health findings across peer reviewed studies. This was done to maintain a consistent position on reported information available in the peer-reviewed articles on ASGM and health. A careful review of the study implies that our inclusion criteria were strictly applied, with 70 articles (Fig. 1) retained after removing duplicates and ineligible studies.

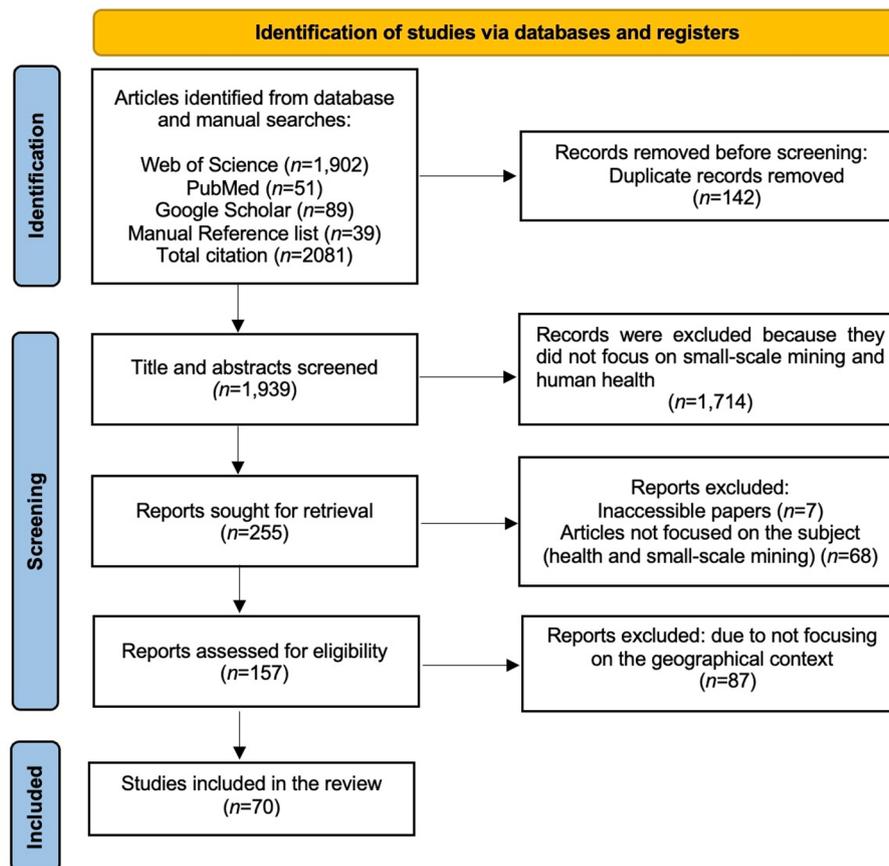


Fig. 1 A flowchart of the selection process of included articles. Adapted from the preferred reporting items for systematic review and meta-analysis (PRISMA) protocol by Page et al. [34].

2.3 Data extraction and thematic analysis

For the purposes of extracting relevant information from the publications, a code-book was first developed in MS Excel for data extraction. Data extraction codes were grouped into five main themes: (i) background information of the eligible study (study design, geographic location of study); (ii) methodology; (iii) livelihood and governance issues; (iv) ASGM-related health risk outcomes; (v) policy and practice. Extraction codes included pre-coded sections and open text boxes where inferences were scripted based on critical judgement by the reviewers. The codes for information extraction were developed and refined using the existing knowledge derived from the ASGM literature and other relevant systematic and scoping review publications. Health outcomes were surveyed based on four domains as they emerged from the reviewed articles: heavy metal poisoning and ecotoxicology; occupational health and safety; communicable diseases; and non-communicable diseases. The assessment of these domains was based on the lead author's experiences in the sector and team discussions. Following the initial coding of the 70 included studies, we identified patterns across human, animal, and environmental health domains. This observation informed a subsequent recoding of the studies using a One Health framework (Table 3). We systematically extracted evidence on human, animal, and environmental outcomes, exposure pathways, and socio-economic drivers. The extracted information was further categorised into studies that: explicitly measured clinical/pathological conditions; self-reported symptoms; inferred conditions; risk factors rather than diseases, as presented in Table S3. Biological and environmental samples from each study were systematically examined to understand how disease and health outcomes were measured.

2.4 Appraisal of methodology quality and risk of bias

Although we did not perform a formal bias risk assessment (e.g. Inter-rater Reliability) for this study, which aligns with standard practice in scoping reviews [31], the methodological strengths and limitations of the reviewed articles were assessed and noted.

2.5 Data analysis

The extracted publication information follows a qual-quant review method [37]. As noted in Sect. 1, the analysis was based on three research questions as outlined below:

(1) What health and disease outcomes (burdens) are linked to ASGM? (2) How are they distributed geographically? (3) To what extent does ASGM contribute to the spread and emergence of health and disease outcomes (burdens)? To address research questions (1) and (2), we extracted information on health and disease outcomes and the geographical distribution of the study as recorded in the code book. We analysed the extracted information in MS Excel using descriptive statistics, including frequencies and percentages, in the form of graphs and tables. We performed choropleth mapping using locational information in Quantum QGIS version 3.2 to map the spatial distribution of health and disease outcomes from the reviewed studies. To address question (3), we examined the reviewed studies for evidence of how ASGM contributes to the spread and emergence of health and disease burdens or the identification of hypothesised pathways linked to environmental, biological and other forms of risks.

3 Results

This section provides a synthesis of health and disease outcomes associated with small-scale gold mining. It begins with a general overview of the reviewed studies, followed by discussions on health, spatial distribution, and pathways of disease emergence.

3.1 Overview of the publications on ASGM and health

The study retrieved a total of 70 eligible papers after a full-text review (Table S2), comprising 65 original research articles and 5 review papers (Fig. 1). Publications were retrieved from Web of Science ($n = 1,092$), PubMed ($n = 51$), Google Scholar ($n = 89$), and a manual reference search ($n = 39$). Duplicates of 142 articles were removed, followed by a title and abstract screening, which retained 157 articles.

The 70 eligible papers were screened via a three-stage review process (title, abstract and full text reviews), as described above and guided strictly by the inclusion and exclusion criteria (Table 1). The review recorded 93% as empirical papers (original research articles) and 7% as reviews (Fig. 2D). There were more quantitative ($n = 46$) than qualitative ($n = 13$) studies, with a relatively limited number of studies that employed a mixed-methods approach ($n = 11$). Surveys, laboratory (chemical) testing and interviews were the predominant methods employed in the reviewed articles. Environmental science and toxicology emerged as the scientific discipline with the most published studies ($n = 28$) related to ASGM and health, with a significant focus on heavy metal exposure to humans. This was followed by physical injuries ($n = 19$) and public health ($n = 12$) (Fig. 2C). We identified two peak years in the publication timeline in 2015 and 2021. These years marked a period during which considerable attention was given to ASGM activities across the country, following political promises to reform the sector, as seen in

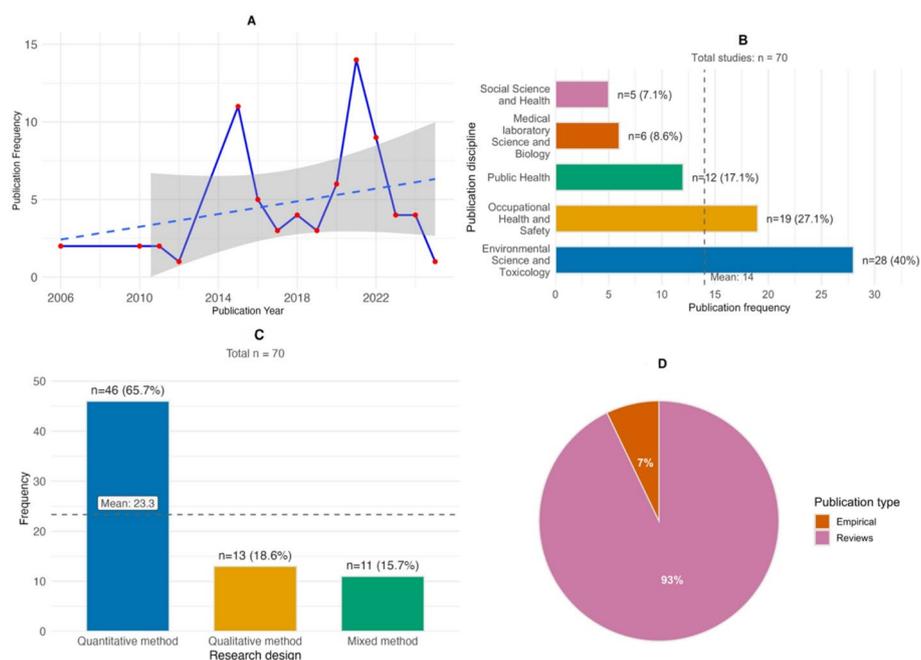


Fig. 2 Descriptive summary of included studies. **A** Publication timeline, 2006–2025. **B** Scientific discipline in which the publications are based. **C** Number of publications by study design. **D** Categorisation of publication by study type

‘Operation Vanguard’ in 2017 and ‘Operation Halt’ in 2021. Thirty-one studies reported not to have received funding from any funding bodies/government. Out of the 39 funded studies, 31 were internationally funded, particularly from the USA ($n = 17$), Denmark ($n = 5$), and Japan ($n = 4$), compared to domestically funded studies ($n = 3$). Only two studies were jointly funded (USA-Ghana and Canada-Denmark). Despite the dominance of internationally funded projects, particularly from the USA, we did not see the same reflection in the institutional affiliation of authorship, as the study affiliations tended to be largely based in Ghana ($n = 41$).

3.2 What health and disease outcomes (burdens) are linked to ASGM?

To understand the disease outcomes and burden associated with ASGM, we categorise disease outcomes under four main domains as reported in the peer-reviewed articles: (1) heavy metal poisoning and exposure; (2) physical injuries; (3) communicable diseases, and (4) non-communicable diseases. These are presented in order of frequency in Fig. 3B. Of the overall reviewed studies, only 16% reported on a specific disease linked to ASGM activities, while the remaining 84% did not mention a disease or lacked a specific disease focus. The higher proportion of studies without a specific pathogen/disease focus suggests that the disease categorisation in ASGM activities remains quite challenging. For example, across the included studies, some studies reported tuberculosis, cardiovascular diseases, and mental health conditions loosely without standardised diagnostic criteria, reflecting a lack of methodological consistency (see Table S3). Although the certainty of disease reporting across the included studies warrants caution, a subset of studies provides data-driven conclusions supported by diagnostic evidence, as detailed in Table S3.

3.2.1 Heavy metals and exotoxins in small-scale gold mining areas

The review highlights a shift in the focus of health risk and disease outcome studies in ASGM. Historically centred on physical injuries, research has increasingly emphasised heavy metal exposures ($n = 31$), particularly mercury poisoning, followed by physical injuries ($n = 21$). This trend underscores the evolving nature of occupational health

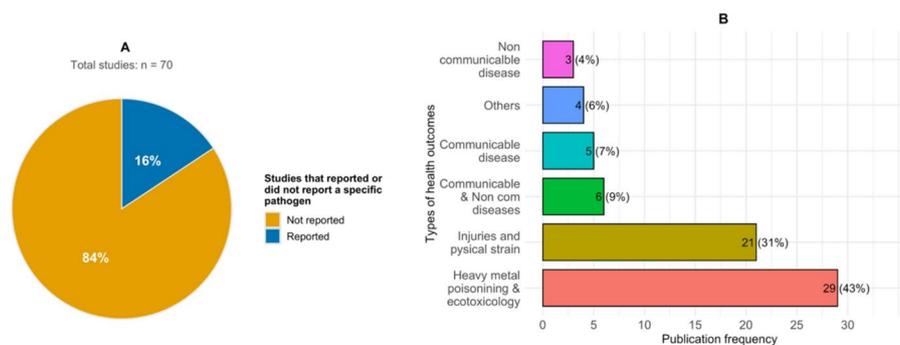


Fig. 3 **A** Percentage of studies that reported or did not report a specific pathogen. **B** Types of health outcomes reported in the included studies. Communicable diseases (CD) reported in the studies include zoonotic diseases (not specified), upper respiratory infections, and the presence of vector-borne diseases. Non-Communicable Diseases (NCDs) reported in the included study include cancer, high blood pressure, cardiovascular diseases and neurological disorders from heavy metal poisoning; Physical injuries: cuts, fractures, musculoskeletal disorders (back and waist pains). (NB: zoonoses and birth deformities were largely hypothesised in the included study). Health outcomes in the context of this review involve all observable and measurable effects on the health of miners and mining communities resulting from exposures, behaviours and conditions associated with mining activities

concerns within the sector. The reviewed studies show that disease burden and potential health outcomes in the form of cancer-related diseases are linked to carcinogens released by heavy metals and the risk of increased thyroid hormone levels. Heavy metal poisoning was also associated with neurological challenges, a potential condition among miners and residents of mining communities (Fig. 4). Another health issue raised with heavy metal exposures was congenital/birth deformities and fertility challenges in ASGM communities [38]. However, references to such outcomes were primarily hypothesised rather than supported by empirical data, indicating a significant gap in the evidence base that requires further investigation.

We observed that studies related to heavy metal poisoning exhibited a notable spike in 2021 (Fig. 2A) and remained the most dominant topic across publications, as shown in Fig. 3B. An analogous pattern was noticed in the dominance of publications related to physical injury in 2015, coinciding with the time the Minerals and Mining ACT 2006 (ACT 703) was revised into ACT 2015 (ACT 794) [39]. This shift also reflects a long-standing and traditional emphasis in ASGM publications on physical injuries (Fig. 3B) associated with poor occupational health and safety conditions.

The analysis of biological and environmental samples across the included studies investigating health, disease, and risk outcomes revealed a predominance of heavy metal assessments in both laboratory and clinical testing. Specifically, studies focusing exclusively on heavy metals accounted for 30% ($n=21$) of environmental samples and 24% ($n=17$) of biological samples. Biomarkers commonly employed for heavy metal analysis included urine, hair, and blood, while environmental sampling primarily involved soil and water matrices. In contrast, only a limited number of studies addressed non-heavy metal conditions such as malaria, cholera, and tuberculosis, utilizing blood, stool, and sputum samples for clinical and laboratory testing.

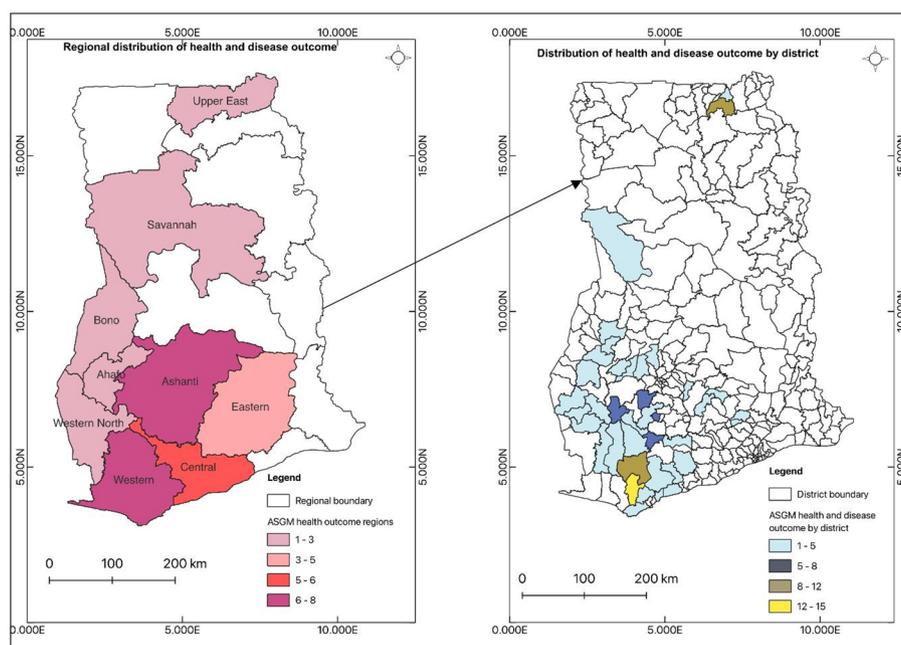


Fig. 4 Shows: (Left) Regional map of Ghana, identifying regions to which reviewed articles relate. (Right) A breakdown of the number of articles relating to each district

3.2.2 Beyond heavy metal exposure—communicable and non-communicable diseases

In contrast to the well-established health-related topics of heavy metals and physical injuries, health outcomes associated with communicable (CD) and non-communicable diseases (NCDs) were less well represented in the surveyed literature indicating a gap in the evidence base. For instance, only 16% of the reviewed studies reported on specific pathogens, whereas 84% did not (Fig. 3A)—a gap that highlights the limited focus on pathogen-specific investigation. We recorded only 6 publications that specifically focused on communicable diseases, whereas 3 focused on NCDs. Only 6 studies were specifically focused on both CDs and NCDs (Fig. 3B). Communicable diseases in the form of tuberculosis and upper respiratory tract infections, and malaria were associated with ASGM while NCDs (including high blood pressure, hyperkeratosis, diabetes, mental health and cardiovascular diseases) were also linked to ASGM. Despite being mentioned casually in several studies, we found only two articles that specifically focused on malaria. For CDs, health outcomes reported were generalised by using ‘infectious disease’ as a broader term to describe health outcomes in the sector. Interestingly, 4 out of the 6 studies that focused on communicable diseases were mostly qualitative in methodological design. No study employed a mixed-methods approach to investigate communicable disease in ASGM, suggesting a methodological gap that—if addressed in future studies—would help to reveal quantitative trends alongside qualitative insights on miners’ health. In contrast, all specific publications on NCDs ($n = 3$) were quantitatively designed. Overall, the reviewed studies revealed a notable lack of detailed information regarding specific diseases, on both CDs and NCDs, in relation to ASGM activities.

3.2.3 Complexities in categorising health outcomes in ASGM

Health risks and the disease burden in small-scale mining landscapes are quite complex to categorise due to the lack of health-related data reported/obtained in the reviewed studies. However, the reviewed studies identified different levels of health outcomes and disease burden using different indicators such as: socio-economic indicators (income, education and years of experience); demographic indicators (age, sex); type of operation (processing and non-processing unit); and environmental factors. In the present review, for example, females were identified as more susceptible to health risks and experienced diverse forms of health complications. Persons working in the processing department of mining operations, where chemicals such as mercury and cyanide are commonly used, were reported to experience a higher incidence of health-related challenges compared to those employed in non-processing units. In addition, the lower income levels of females imply that they are exposed to different social vices such as prostitution, which increases their risk of sexually transmitted diseases in mining communities [32].

Males in ASGM have been associated with an increased risk of physical injuries due to operating in underground pits and tunnels and exposure to explosives during blasting. Mental health issues and death were also reported as conditions primarily faced by men. The review also found that children who accompany their parents to mining sites tend to suffer from fever, colds and headaches due to dust inhalation. Persons with high educational levels tend to avoid working in risky areas, such as underground, or in direct contact with poisonous chemicals. Young male adults, usually between 18 and 35 years, were the dominant age group in small-scale mining activities and usually bear the brunt of negative health and disease outcomes [40]. The youthful population in ASGM was

associated with several risky behaviours, including unprotected sexual intercourse with multiple partners [41] and the use of unauthorised drugs [32], which they claim boosts energy levels and work performance in ASGM. In summary, our review identified only a limited body of literature on the interplay between biological and social determinants that influence disease outcomes in ASGM. This contrasts sharply with the extensive research dedicated to understanding the adverse health effects associated with heavy metal exposures and chemical contaminants.

3.3 How are disease/health outcomes in ASGM distributed geographically?

Artisanal and small-scale gold mining is a widely distributed economic activity that covers a significant part of Ghana's economic regions. Out of the 16 administrative regions in Ghana, ASGM-health related studies were found in 9 regions, predominantly in the Ashanti, Western, Eastern and Upper East regions (Fig. 4). We recorded a total of 32 studies from the Western region and 14 from the Ashanti region, underscoring the historically rich mineral deposits and widespread mining activities in the southern belt of Ghana. Despite the fewer regional publications from the northern sector, a district-by-district analysis revealed quite a high number of studies from the Talensi district ($n = 11$) in the Upper East Region (Fig. 5). The literature reported large numbers of ASGM-related health issues in Tarkwa Nsuaem ($n = 14$) and Prestea Huni-Valley ($n = 8$) districts (Table 2), particularly upper respiratory infections and heavy metal poisoning. Targeted Hazard Quotients for arsenic in spring onions grown at ASGM sites were recorded above the value of 1, a condition described as highly carcinogenic according to the United States Environmental Protection Agency [42]. Cadmium, lead and arsenic levels above WHO and Environmental Protection Agency (Ghana) guidelines were also identified in the reviewed studies as posing a health risk to most mining communities, particularly in the Western and Ashanti regions. Only 3 studies were specifically from the Central region, followed by the Eastern region ($n = 5$), with similarly low reported health outcomes.

Malaria and heavy metal poisoning were the major health concerns identified in Eastern and Central regions. In general, heavy metal poisoning remains ubiquitous across small-scale mining communities, signalling the widespread use of mercury in

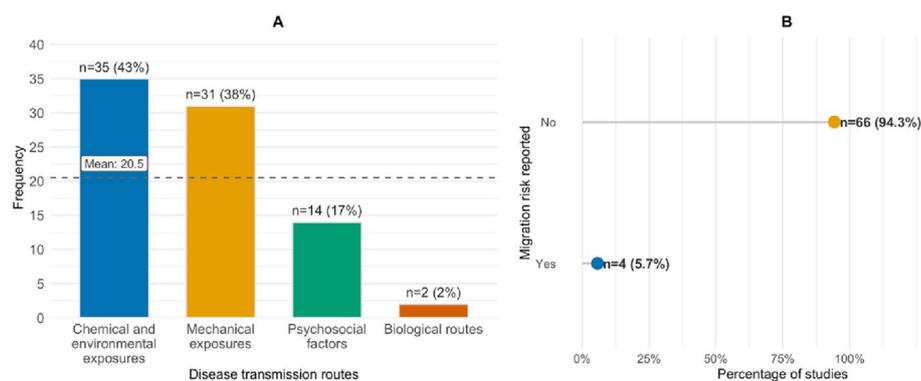


Fig. 5 **A** Potential and established ASGM disease transmission routes in ASGM activities in the included studies. **B** Mining-induced migration as a risk to disease exposure reported in the included studies. That, in **(A)**, some publications reported more than one disease transmission route (e.g., chemical and environmental exposures). Transmission routes reported in the included studies involves pathways through which infectious agents spread among miners and mining communities (e.g., cuts by mining equipment's and bacterial infection, respiratory drooping from coughing and sneezing, drinking contaminated water)

Table 2 Top 5 regional health and disease foci of the reviewed studies

Geographic location	Examples of broad health concerns commonly reported	Specific health case mentioned in the study
Western region	Heavy metal poisoning ($n = 14$), injuries ($n = 8$), communicable diseases ($n = 5$), non-communicable diseases ($n = 3$),	Upper respiratory infections, cancer, blood mercury level, sub-sector inequalities, injuries (slips, falls, and burns)
Ashanti region	Heavy metal poisoning ($n = 7$), injuries ($n = 3$), communicable diseases ($n = 3$), non-communicable diseases ($n = 1$),	Injuries and carcinogen exposure, colds, fever, headaches, and coughs linked to dust and mental health, tuberculosis, death from pit collapse, and social stigma on women
Ahafo region	Heavy metal poisoning ($n = 3$), injuries ($n = 1$), communicable diseases ($n = 1$)	Slip and falls, tuberculosis, heavy metal poisoning
Eastern region	Physical injuries ($n = 3$), communicable diseases ($n = 1$)	Malaria, heavy metal poisoning,
Upper East region	Heavy metal poisoning ($n = 3$), injuries ($n = 3$), communicable diseases ($n = 5$)	Heavy metal poisoning, high blood pressure, cancer, injury and tuberculosis.

small-scale gold mining activities. A top 5 regional ranking of ASGM health outcomes (Table 2) shows that only a few studies were focused on heavy metal poisoning ($n = 3$) and communicable diseases ($n = 5$) in the northern region (Upper East). On the contrary, studies in the southern regions (Western, Ashanti and Eastern) topped with publications on heavy metal poisoning ($n = 27$) and communicable diseases ($n = 7$), underscoring the regional unevenness in ASGM publications on health. Despite the differential socio-cultural practices and microclimatic variations between the northern and southern regions, our findings did not reveal any significant disparity in health and disease outcomes between the two ecological zones (north and south regions). The north-south analysis was conducted due to the differences in weather and cultural practices, which could inform health outcomes. Although a high number of publications were concentrated in the south, a synthesis of the literature shows that health outcomes such as tuberculosis, cancer, physical injuries and heavy metal poisoning were commonly reported in both regions (Table 2).

3.4 To what extent does AGSM contribute to the spread and emergence of disease?

Based on the reviewed studies, we categorise potential and established routes through which diseases and health risks could be transmitted and identify key knowledge and evidence gaps. The reviewed studies show that miners and other residents of mining communities' contract and spread disease via chemical-environmental exposure ($n = 35$), mechanical media ($n = 31$), psychosocial ($n = 14$) and biological exposures ($n = 2$); see Fig. 5A. Our review indicated that transmission of disease via environmental and chemical media can occur through bioaccumulation of heavy metals. Here, some studies, particularly in the Tarkwa, Prestea and Obuasi mining areas in the Western and Ashanti regions, highlight how certain crops and staple foods like root tubers (cassava) and vegetables absorb/contain poisonous metals beyond an acceptable threshold. The Targeted Hazard Quotients (THQ) of heavy metals in these areas exceed the WHO permissible limit of 0.3 mg/kg for root tubers [23], posing a serious health risk to miners and mining communities. Drinking water was identified as a potential exposure route, where residents of mining communities mostly depend on contaminated water sources. The consumption of fish laden with high levels of methyl mercury poses serious neurological health risks for certain communities. Aside from mercury, cadmium and arsenic

were found to be indiscriminately disposed of in mining communities, seeping into water and food sources.

Mechanical media for health risk and disease transmission were defined in terms of the inhalation of dust and particulate matter. Here, respiratory diseases in the form of tuberculosis and upper tract infections were visible across the investigation. In addition, only a few studies reported on silica and biomass fuel exposure as a potential respiratory condition.

Although most of the studies reported chemical exposure as a prevalent health risk, poor sanitation and behavioural risk were also occasionally cited across the reviewed studies. As indicated in Fig. 7, disease and health outcomes in ASGM settings are influenced by diverse but interconnected pathways that are sometimes/often overlooked. These include poor sanitation, chemical exposure and environmental conditions. Out of 70 reviewed studies, only 4 highlighted sanitary conditions but failed to connect this to the extent to which poor sanitation, including a lack of toilet facilities and malnutrition, could contribute to disease spread and emergence. For instance, in one study, miners and non-miners were identified as vulnerable to cholera due to poor sanitation at ASGM sites.

Women were commonly identified as food sellers in these environments, and site workers remained at risk of cholera due to their reliance on food prepared under such conditions. The presence of sex workers and the prevalence of unprotected sex were identified as common practices [32, 41]. The prevalence of sex workers was attributed to high poverty and low educational levels, contributing to increased levels of HIV infection in these communities [32, 43], as shown in the instance of risky behaviours in Fig. 7.

Apart from malaria, no studies specifically reported on vector-borne and zoonotic diseases despite highlighting prevailing conditions as hotspots where these diseases and/or their vectors could thrive. The radical transformation of topography and hydrology in mining settings was identified in most studies as important in creating breeding grounds for disease vectors such as mosquitoes. Overall, information on biological and viral disease risk was virtually absent. The few publications (virtually absent specific studies) on vector and zoonotic health risks in this study underscore the limited attention given to other important infectious diseases or plausible emerging disease pathways. This underrepresentation is particularly true for studies regarding human-environment interactions in ASGM, coupled with overlooked social determinants of health risks across reviewed publications. For example, only 4 studies (Fig. 5B) reported on miners' geographical mobility (migration) as a potential health risk that could contribute to disease transmission within and across mining areas.

Polluted water bodies, which are also water sources for household use, were identified as a health risk in mining communities. Widespread water pollution by heavy metals has meant much reliance on boreholes, while manually dug shallow wells by households could promote disease emergence. In relation to social determinants of health, some studies have also highlighted the role of behavioural factors such as poor hygiene practices, limited health-seeking behaviour, and low awareness of environmental health risks in exacerbating disease vulnerability within these communities (see Fig. 6). For instance, behavioural factors (Fig. 6) involving the mixing of marijuana with other local substances like tobacco were identified as widespread among miners in the Western region, particularly Tarkwa, highlighting rising cases of substance abuse [44].

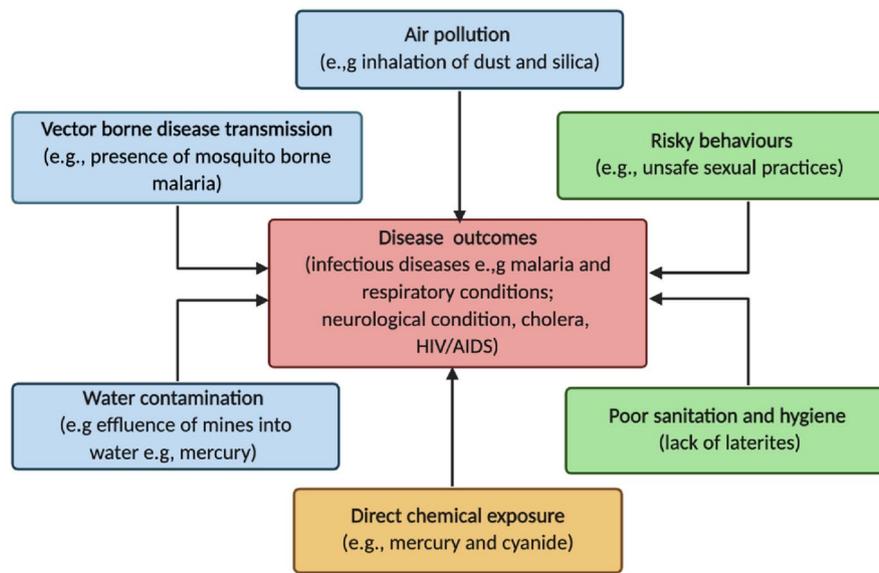


Fig. 6 Synthesised health risk factors influencing outcomes in small-scale mining. Expanded based on Fig. 5A from the included studies. Risk factors in the context of ASGM involve conditions, behaviours and environmental exposures that increase the likelihood of adverse health outcomes both to miners and mining communities. The boxes underscore how environmental conditions (blue boxes), social/behavioural factors (green boxes), and chemical exposures (orange box) contribute to disease outcomes in small-scale gold mining

The potential risk of disease emergence in ASGM areas may be partly attributed to the absence of essential infrastructure, such as national water systems provided by entities like the Ghana Water Company. Inadequate access to clean water and sanitation creates conditions conducive to the spread of waterborne and communicable diseases. In addition, the lack of access to healthcare related to tuberculosis diagnosis and treatment, coupled with malnutrition, was cited as a condition aggravating health burden. Regarding the reporting on tuberculosis as a health outcome in ASGM, we did not find any distinction between clinically diagnosed and microbiologically observed tuberculosis, as the studies did not provide further information.

3.5 Advancing one health frameworks in ASGM health outcomes

A synthesis of One Health domains, as outlined in Table 3, reveals a complex interplay between human activities and environmental dynamics in the context of ASGM. To unpack this intricate nexus, the One Health framework serves as a conceptual lens enabling a deeper understanding of the sectoral interdependencies. One Health as a unifying framework emphasises that achieving human health is closely linked to environmental and animal health [31, 45]. In the context of extractive industries, this approach therefore suggests deliberate integration of relevant disciplines and sectors in the knowledge production and governance of the ASGM sector. In view of this, we examined the various disciplines involved in producing the current ASGM literature. Even though the reviewed studies indicated a stronger emphasis and a skewed orientation towards human health, connections within the complex health outcomes of ASGM activities were drawn to understand the fuller scope of health issues in the sector.

Table 3 A synthesis of one health domains in ASGM reviewed studies

One health domain as identified in the reviewed study	Description	Number of studies	Specific hazard/risk condition within the study	Focal health/disease outcome reported in reviewed study ^(a, b, c, d, e, f, g, h, i, j, k, l)
Human health risk	Physical factors that directly influence human health	67	<ul style="list-style-type: none"> • Contact with wildlife via deforestation • Consumption of contaminated-bioaccumulated aquatic food • Exposure to zoonotic disease risk, and • Vector exposure 	<ul style="list-style-type: none"> • Injuries • Zoonotic and vector-borne diseases • Mental health • High blood pressure • Hyperkeratosis • Diabetes • Cardiovascular diseases • Stress • Tuberculosis and Silicosis
	Behavioural, psychological conditions, access to health care/facility, poor sanitation	20	<ul style="list-style-type: none"> • Unprotected sex • Poor sanitation • Migration of workers • Limited health care • Unemployment • Overcrowding 	<ul style="list-style-type: none"> • HIV • Typhoid • Cholera • Diarrhoea
Environmental health risk	Direct and indirect factors that contaminates/pollutes the environment	39	<ul style="list-style-type: none"> • Contaminated water, soil and air • Biodiversity loss, Bioaccumulation of heavy metals. Heat exposure in mining pits • Underground tunnels for bats and animal habitation • Burning of chemicals in open environment • Poor ventilation in underground tunnels 	<ul style="list-style-type: none"> • Heavy metals poisoning • Occupational dermatitis
Animal health risk	Bioaccumulation of heavy metals in animals (fishes and ruminants in small scale mining communities)	3	<ul style="list-style-type: none"> • Exposure to wildlife and displacement • Bioaccumulation in aquatic life 	<ul style="list-style-type: none"> • Infectious and zoonotic disease risk

a=Aram et al. 2024, b=Opore et al. 2012, c=Asare-Doku, 2021, d=Rajaee et al. 2015, e=Gyamfi et al. 2022, f=Quarm et al. 2022, g=Agyemang, 2010, h=Aram, 2024, i=Ohene et al. 2021, j=Saim, 2021, k=Afrifa et al. 2019, l=Adomako and Hausermann, 2023

3.5.1 Human health risk in artisanal gold mining reported in the reviewed studies

Out of the 70 included studies, 29% ($n=20$) specifically reported on direct human health risk or health outcomes. Commonly human health risk and outcomes reported were linked to chemical and environmental exposures (Fig. 5). Generally, the reviewed literature reveals a strong association between environmental exposures and adverse human health outcomes in artisanal gold mining (ASGM) contexts. A significant number of studies highlight that environmental degradation, particularly water pollution, contributes to the prevalence of diarrhoeal diseases, as many rural communities rely on contaminated water sources for domestic use. Similarly, exposure to toxic substances through activities such as bathing in chemically polluted water has been linked to dermatological conditions, including dermatitis and skin infections.

Beyond heavy metals posing a substantial health risk to mining populations, poor sanitation and hygiene practices at mining sites (Fig. 6) were reported as a risk in the reviewed studies. Although only a limited number of studies explicitly addressed

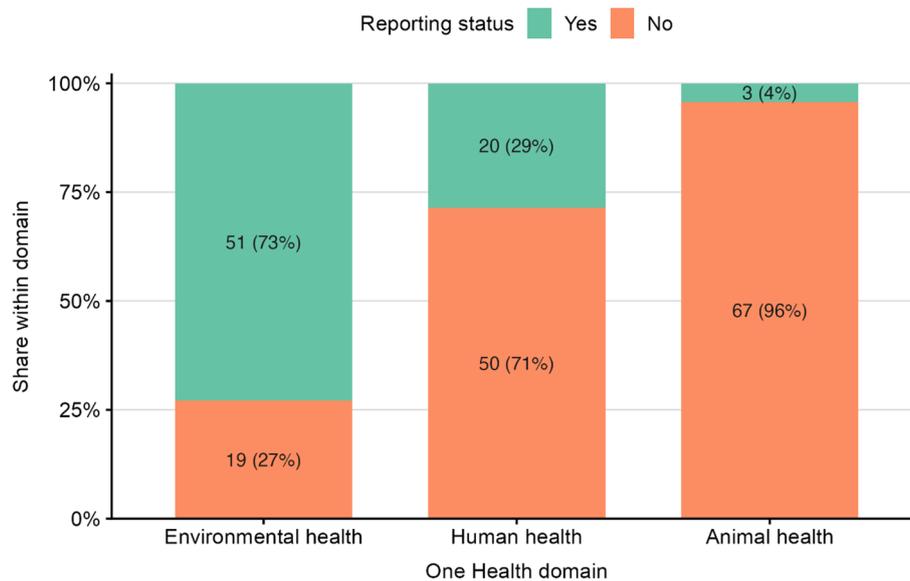


Fig. 7 Reported studies on One Health Domains in ASGM contexts. The orange colour represents the number of studies that did not report on the One Health domains, whereas the teal colour shows those that did report

sanitation-related health risks, these issues were often discussed in conjunction with inadequate infrastructure and limited access to healthcare services. For example, one study [46] demonstrated that overcrowding and unsanitary conditions in mining communities significantly increased the risk of communicable diseases such as cholera and typhoid. These risks are further compounded by socioeconomic vulnerabilities, including poverty and unemployment, which often compel women and children to engage in mining activities, thereby heightening their exposure to health hazards.

The influx of migrant workers (particularly those engaged in sex work), many of whom establish permanent residence in mining areas, was also identified as a contributing factor to the spread of infectious diseases, including sexually transmitted infections (STIs) and diarrhoea (Table 3). The reviewed studies show that individuals living in proximity to mining operations face elevated risk of disease outbreak due to environmental contamination, exposure to hazardous substances and compromised public health infrastructure. Aram [47], for instance, suggests that proximity to mining sites may act as a determinant of disease transmission, particularly for respiratory infections, due to increased exposure to environmental pollutants such as dust.

3.5.2 Environmental health risk reported in the reviewed studies

The reviewed studies highlight a range of environmental health risks associated with ASGM activities. More than half 73% ($n = 51$) of the studies (Fig. 7) focused on environmental risk ($n = 45$). Environmental health risks were associated with the release of heavy metals into the environment, coupled with contamination of air or soil (Table 3). For instance, poor ventilation in underground tunnels was associated with degraded air quality and increased incidence of respiratory and dermatitis conditions [13]. In addition to environmental health risks, soil and water contamination with heavy metals was associated with reduced agricultural productivity, which disrupts soil microbial activity and compromises water quality, posing broader ecological and public health risks. Here, most studies focused on heavy metals and demonstrated that ASGM operations

contribute significantly to water pollution, as toxic substances are often discharged directly into nearby water bodies.

In relation to disease burden, some review studies have highlighted gendered health risks, especially for women involved in the gold extraction processes. The review papers reported on an activity, known as “shanking”, which involves manually loosening compacted soil using sieves or nets, predominantly performed by women, exposing them to dust and other airborne contaminants. As a result, women and children who accompany family members to mining sites face a disproportionate burden of respiratory illnesses, including tuberculosis, which has been frequently reported among female miners due to prolonged dust exposure [48]. Additionally, we also found reference to uncovered mining pits as breeding grounds for mosquitoes, thereby increasing the risk of vector-borne diseases such as malaria. Such observations establish a clear link between environmentally hazardous mining practices and heightened exposure to infectious diseases in surrounding communities.

3.5.3 Animal health risk reported in the reviewed studies

As Fig. 7 shows, few studies were reported on animal health risk 4% ($n = 3$) representing an important gap in the evidence base. Animal health was tightly connected to humans due to the widespread presence of heavy metal accumulation in fish and some ruminants in mining communities. This process, known as bioaccumulation, occurs when plants and animals absorb heavy metals during nutrient uptake [23, 49, 50]. For instance, we found contamination in fish species (Table 3) from the Pra and Ankobra Rivers, which also serve as a source of food for many rural communities [10]. The most frequently reported health risk pathway involved mercury contamination in aquatic ecosystems, bioaccumulation in fish, and subsequent human exposure through ingestion. Although most studies did not primarily focus on the concentration of heavy metals in aquatic and terrestrial animals, there are indirect implications for human health, especially in rural communities that rely on these food sources. Supporting this concern, Bortey-Sam et al. [51] reported that while the estimated daily intake of arsenic (As), cadmium (Cd), mercury (Hg), and manganese (Mn) from animal-based foods in mining areas was generally below recommended safety thresholds, certain organs like chicken gizzards and livers showed elevated levels of these metals. Despite the Target Hazard Quotient (THQ) values being under 1—suggesting low immediate risk—the findings still raise potential health concerns for both adults and children. One reviewed publication also highlighted that mercury concentration in the Bonsa River in the Tarkwa mining areas (Western Region) of Ghana was observed above the recommended and tolerable level when compared to other countries in Africa and Asia, thereby posing a potential public health concern [52].

3.6 Towards cross-disciplinarity in ASGM—A one health framework based on reviewed studies

Our review shows that current publications relating to the ASGM sector are predominantly concentrated in the disciplines of toxicology and occupational health and safety (Fig. 2B), a significant gap that warrants broader interdisciplinary research to address environmental, social, and animal health dimensions of ASGM. These studies typically conceptualise health impacts in terms of heavy metal exposure and physical injuries,

respectively. While this framing remains partly valid given the high visibility of documented health risks such as chemical toxicity and workplace accidents, other indirect disease-modulating factors, such as uncovered mining pits and deforestation of forest frontiers that bring disease vectors close to humans, have been rarely discussed.

Emerging evidence from a small subset of studies in the social ($n = 5$) and biological ($n = 6$) sciences suggests the need for a more expansive and integrative understanding of health outcomes in ASGM contexts. For example, only three studies from the biological sciences focused on animal health, specifically examining the bioaccumulation of heavy metals in aquatic ecosystems and livestock (e.g., goats and sheep) within mining communities. These findings underscore the interconnectedness of environmental, animal, and human health—a core principle of the One Health approach and the wider public health concern [45, 53]. The One Health framework becomes imperative in the ASGM context because exposure to heavy metals poses health risks not only to these animals but also to the people who depend on them as a food source.

Although only few studies directly addressed specific disease outcomes (Table 2), notable contributions linked heavy metal exposure to non-communicable diseases (NCDs), including neurological disorders and cancer (Fig. 3B). This highlights the necessity of incorporating NCDs into the ASGM health impact framework, alongside communicable diseases (CDs). A One Health approach that integrates both CDs and NCDs offers a more holistic and transdisciplinary lens through which one can understand and address health risks in mining communities.

4 Discussion

Prioritising health and disease concerns within the broader context of human livelihood remains a critical focus in global health discourse. This subject is well articulated by the One Health Commission, which underscores the importance of integrating health and disease outcomes in environmental, animal and human health [54]. This has meant that activities directly and indirectly linked to human-environment interaction, such as small-scale gold mining, require critical attention in health studies.

4.1 Human health outcomes and ASGM

In Sect. 1, we identified three research questions for exploration in our scoping review: (1) What health and disease outcomes (burdens) are linked to ASGM? (2) How are they distributed geographically? (3) To what extent does ASGM contribute to the spread and emergence of disease outcomes (burdens)? We consider each in turn.

4.1.1 Health and disease burdens

In this review, we found that the factors modulating health and disease outcomes in ASGM represent a complex nexus of governance, behavioural, environmental, social and structural challenges [4, 13, 32]. The health and disease implications of ASGM are situated within more traditional conceptualisations of occupational health and safety concerns that include the recent emergence of heavy metal poisoning and ecotoxicology. The high visibility of the health risk of human exposure to heavy metals, as demonstrated in our reviewed studies, highlights instances that led to the adoption of the Minamata Convention on Mercury in 2013. While Ghana's commitment to this convention stems from its extensive use of mercury in the artisanal gold sector. There was

a notable absence of published research on the topic until 2006. The sharp increase in publications from 2015 coincides with the period in which Ghana became a signatory to Minamata Convention, and which subsequently entered into force in 2017. As such, the international treaty catalysed research interest and focused policy attention on heavy metal-related health and environmental issues in the ASGM context.

We identified physical injuries as the common health focus of earlier studies [44, 55–57], underscoring a traditional conception of health in the ASGM sector. Within this purview, ‘occupational health and safety’ can be viewed as a phrase that is most often used synonymously with physical injuries linked to the absence or the non-wearing of protective gear. This skewed conceptualisation of health tends to overlook several contextual realities in ASGM operations. This situation is also true for the rising number of studies on heavy metal exposures and ecotoxicology [14, 33, 42, 58], which look at the classification of the different forms of heavy metals present in mining communities as either above or below a certain hazard quotient. Based on the reviewed studies, we see heavy metal exposures appearing as health outcomes rather than a risk factor that could exacerbate disease burden and health outcomes. Heavy metal nomenclature, often regarded in the reviewed studies as synonymous with health outcomes, creates a problematic perspective in toxicology, particularly when the metals themselves are not the direct outcome but rather represent a hazardous condition at levels exceeding certain thresholds that could result in birth deformities, cardiovascular diseases, and neurological disorders (see Fig. 4). On the other hand, studies that do focus on health outcomes sometimes lack the necessary clinical specificity to fully understand the health risk posed by the sector [42]. In view of this, we recommend a cross-sectoral research approach that integrates biological, environmental, and epidemiological perspectives to better characterise the specific health conditions prevalent in ASGM communities.

A detailed inspection of the data reveals that, by focusing narrowly on heavy metal exposures [29, 59], other important aspects of health and disease outcomes in ASGM communities are overlooked. For instance, the limited emphasis on communicable diseases raises concerns about whether these aspects of health outcomes exist in mining communities or may not have received adequate academic and policy attention. While this would be a difficult question to answer from the present data, some studies in East Africa [60] and French Guiana [53, 61] present an interesting focus, highlighting the disease burden and threats from zoonoses and non-communicable diseases in the ASGM sector. In our application of the One Health framework, we noticed that even though health outcomes for One Health can be implicitly and explicitly visible in ASGM activities, complexities arise in defining specific disease outcomes. This presents a challenging situation in cataloguing specific disease pathogens and health outcomes linked to the sector.

4.1.2 Geographical distribution of ASGM health outcomes

Figure 4 reveals that there is an uneven geographical distribution of documented health impacts linked to ASGM across Ghana. The dominant area of investigation was found to be in the Ashanti and Western region, particularly in Obuasi, Tarkwa, Nsuaem and Prestea mining areas, which may simply reflect publication biases to these areas. This is perhaps unsurprising given the famous geological composition of Tarkwain and Brimain rocks, known for their rich minerals like gold [7, 62] and historical publicity associated

with large- and small-scale gold mining operations there. In terms of funding, it is noteworthy that most health projects related to small-scale gold mining (ASGM) are concentrated in the landscapes of the Western region, primarily supported by research grants from the USA. Furthermore, a significant number (24 out of 29 studies) focused on heavy metals, with funding predominantly provided by international organisations. As noted above, this trend was particularly evident in 2015, following Ghana's accession to the Minamata Convention on Mercury, suggesting that international interest in the ASGM sector may have played a role in shaping the funding landscape.

4.1.3 ASGM, disease emergence and spread

The extent to which diseases emerge and spread in ASGM areas is generally complex and interacts with several factors, as shown in the reviewed studies. While the extant literature underscores conditions linked to mechanical, chemical, social and biological factors in modulating disease and health conditions [3, 28, 47, 62], there is currently a weak link to the ways in which social and biological media/factors contribute to disease emergence. The limited focus on biological and social conditions is expressed in the article type and methodological choices in this review (Fig. 2). The reviewed studies, for example, show that 66% of the publications are quantitatively designed, whereas only a small percentage adopt qualitative (19%) and mixed methods (15%) approaches. Most studies employed heavy metal testing methods in determining concentrations of toxic metals, microwave digestion, chemical and laboratory testing [33, 42, 58]. While these methods are fit for a unique study purpose, they are likely to overlook contextual realities, especially where human and social interactions are prevalent and complex. For example, biological laboratory testing, such as sputum and blood testing for disease, was conspicuously absent. Consequently, we argue that a balanced methodology in this aspect would present a fairer view of health impacts beyond the limited conceptualisation of health as purely mechanical and chemical. In this case, a mixed-method approach would present a more comprehensive view of health impacts. Another possible factor informing the existing findings on one-sided health and disease framing could be linked to the short duration of studies ($n = 25$) conducted in these areas, as rapid data collection techniques were mostly employed, usually within 3 to 6 months. Most studies did not specify study duration, while only 11 studies were conducted within 12 and 24 months. Against this background, we argue that a combination of qualitative methods (ethnographical and observational approaches), along with other quantitative methods, could be used to reveal temporal trends along with more hidden and underexplored health implications linked to the sector. This suggests that the dominant publication emphasis on quantitative studies as shown in our above reviewed studies are likely to overlook the depth of health concerns as compared to cases where mixed methods and qualitative approaches were adopted. The incorporation of these diverse methodologies and discipline-focused ASGM approaches, would potentially provide a basis for more effective cross-sectoral and interdisciplinary interventions.

4.2 Directions for future research: disease drivers, interfaces, and determinants—towards a one health approach

The present study acknowledges the complexities of health and disease information in Ghana's ASGM sector. This challenge stems primarily from the large number of informal

miners who evade monitoring and regulation. Our examination has revealed the empirically dominant nature of health and disease research in ASGM, with a strong emphasis on measurable outcomes such as heavy metal exposures and physical injuries. There is a need to broaden the scope of research to the full spectrum of health challenges faced by miners and mining communities, including those that may be underrepresented and less readily quantifiable. Here, a One Health framework presents a nuanced understanding of sectoral issues by visualising the complexities of health outcomes. For instance, most included studies demonstrated an association between human health outcomes and ASGM; however, integrated evidence linking human health impacts to environmental contamination and animal health was rare. Only 30% ($n=21$) of studies incorporated environmental sampling, and 4% ($n=3$) included animal data. This imbalance highlights a critical evidence gap: without simultaneous measurement of environmental reservoirs and animal vectors, attributing human outcomes to specific One Health pathways remains tentative. Future research and surveillance should adopt multi-domain protocols—combining human biomarkers, environmental sampling, and animal surveillance—alongside contextual socioeconomic data to support integrated interventions.

Despite the numerous publications, there is still a lack of information regarding emerging infectious diseases/disease pathways and the risks that they may present to populations already burdened with neglected tropical diseases. This is especially true for viral disease transmission associated with unsanitary conditions, nutritional deficiencies among miners, and exposure to disease pathogens in forest frontiers due to ecological modifications. In view of this, we suggest that further studies are needed to present a comprehensive catalogue of disease burdens and health risks, particularly where, for example, health outcomes such as tuberculosis hotspots in mining areas are examined within a One Health framework.

The integration of One Health frameworks into the investigation of ASGM offers significant potential to advance understanding of strategies for containing and managing both emerging and endemic diseases within this sector. This is particularly relevant in contexts characterised by uncontrolled migration and occupational mobility in such an informal sector, which could facilitate the diffusion of infectious diseases [63, 64]. As highlighted by [65], the influx of young individuals into these mining environments often creates conditions conducive to transactional sex, thereby introducing an additional pathway for disease transmission. This research area becomes critical, as it establishes a solid foundation for examining various health risks, especially related to chemical, mechanical, and biological exposures in an intricate manner. However, there is a noticeable lack of information regarding how small-scale mining activities in Ghana affect microbial and vector adaptation, population dynamics, and ecological modifications in the pursuit of human livelihoods. Another notable observation is the limited information available on non-communicable diseases within small-scale mining and mining communities, a situation that may be overlooked, particularly considering that some studies indicate that miners face significant challenges in accessing healthcare [4, 66]. The absence of miners at formal health centres suggests that available health and disease data may not accurately reflect the broader realities of occupational health records (underreporting of health outcomes). We propose three key areas of intervention: First, future research should prioritise other critical health concerns, particularly emerging infectious diseases, in environments burdened with neglected tropical diseases. The

lack of attention to these areas could potentially result in emerging disease events being missed or overlooked, especially where most ASGM activities are practised in unregulated settings and lack proper health and safety standards. Second, with respect to methodological advancements, we recommend that future studies adopt mixed-method approaches to capture both the breadth and depth of health and disease outcomes in the sector. Finally, we call for policy action in the health domain, specifically through strengthening targeted surveillance systems, integrating ASGM into district-level health information systems and developing environmental monitoring protocols that capture timely and up-to-date data on health issues in miners and mining communities.

4.3 Study limitations

Although this review did not apply a specific temporal restriction during the literature search, we acknowledge the possibility that some relevant studies may have been inadvertently excluded due to limitations inherent in database indexing and search algorithms. Nevertheless, we are confident that the international scope and comprehensive nature of our selected databases, supplemented by manual searches, have helped to mitigate this limitation and ensure a broad and representative coverage of the existing literature. We did not include grey literature and non-English papers primarily because the English language is considered the official lingua franca for reporting scientific research in Ghana. Although we did not apply a formal quality assessment such as Cohen's Kappa rating [36], given the breadth of evidence, all reviewers independently assessed, cross-checked, and discussed the results, as highlighted in Sect. 2.4. Despite the broad evidence highlighted in this study, we also point to the overly represented research on heavy metals potentially skewing health outcomes in ASGM. We believe that the under-reporting of ASGM health conditions could partly reflect the weak health and disease surveillance systems in these areas.

5 Conclusion

Our synthesis of the literature on health outcomes related to ASGM activities in Ghana highlights the plethora of diseases and health outcomes associated with ASGM, coupled with the spatial distribution of these impacts and how ASGM contributes to the emergence and spread of disease. This study underscores a major focus on heavy metal poisoning and a narrow conceptualisation of occupational health as synonymous with injuries (cuts, heat exhaustion and collapse of mining pits). The framing of health and disease outcomes, as well as risks associated with heavy metals, ecotoxicology, and physical injuries, often presents a skewed perspective that neglects critical contextual factors. Biological factors that influence health outcomes, particularly in the realm of viral diseases, are frequently overlooked. Given that approximately 70% of emerging diseases are zoonotic in origin, we argue that the health outcomes associated with ASGM represent an area that is both underestimated and inadequately researched. This is especially pertinent in mining contexts where intricate interactions among humans, the environment, and animals occur.

Although One Health has traditionally been applied in infectious disease contexts [4, 61], we advocate for its extension to NCDs in ASGM-related health planning [54]. This broader conceptualisation is essential, as health outcomes and risk conditions linked to animals and environmental degradation, such as deforestation, uncovered mining pits,

and increased human exposure to disease vectors, are intricately connected to human health in ASGM landscapes. Moreover, mental health, neurological disorders, and heavy metal toxicity—each profoundly influenced by environmental conditions—should not be treated in disciplinary silos. By moving beyond the narrow focus on heavy metal exposure, this review underscores the urgent need for integrated health interventions and policy reforms in ASGM formalisation that address the multifaceted risks faced by ASGM workers and their communities in Ghana. In light of these findings, we argue that the complexity of reporting health outcomes in the ASGM sector necessitates a transdisciplinary approach to health research. That is, one that moves beyond narrow exposure-based models to embrace the multifaceted interactions between environmental, animal, and human health. Overall, this review enhances our theoretical understanding of One Health as a novel approach to understanding the complex sectoral health outcomes in ASGM. It also offers practical insights for developing interventions that comprehensively address the health issues faced by miners, extending beyond traditional conceptions of health in the ASGM sector.

Abbreviations

ASGM	Artisanal and Small-scale Gold Mining
CD	Communicable diseases
LMICs	Low and middle-income countries
NCD	Non-communicable disease
THQ	Quotient -Target Hazard
NTDs	Neglected tropical diseases

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12982-026-01473-5>.

Supplementary Material 1.
Supplementary Material 2.
Supplementary Material 3.
Supplementary Material 4.
Supplementary Material 5.

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Author contributions

EST: Writing- review and editing, Writing original draft, Visualisation, Validation, Project administration, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualisation. SJ: Writing-review & editing, Visualisation, Investigation, Project administration, Validation, Methodology, Supervision. FAA: Writing-review and editing, Visualisation, Investigation, Validation. MSR: Writing-review and editing, Visualisation, Investigation, Project administration, Validation, Methodology, Supervision.

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Data availability

The authors confirm that all datasets generated or analysed during this study have been appended as supplementary information.

Declarations

Ethics approval and consent to participate

Although ethics approval is not a requirement for this study, the work described falls under a broader doctoral research project, which has received ethical approval from the University of Nottingham's School of Geography. Not applicable as the study did not involve human participants.

Consent for publication

Not applicable as no individual data or images are included in the study.

Competing interests

The authors declare no competing interests.

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