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Review Article

From Wealth to Waste: The Environmental Toll of Gold Mining in Ghana

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ABSTRACT

Background: The gold mining industry has been pivotal in driving Ghana's economic expansion and development. This sector has substantially influenced the national economy, generating significant revenue and employment opportunities. Furthermore, the financial resources accrued have enabled investments in critical domains, fostering national progress. This review provides a nuanced examination of the socioeconomic implications of gold mining in Ghana, offering insights to inform policymaking and promote sustainable practices.
Method: Extensive literature reviews were conducted across a wide range of leading academic databases, including ScienceDirect, PubMed, Google Scholar, JSTOR, Web of Science, EMBASE, and Scopus, to thoroughly investigate the relevant research on this topic.
Results: The gold mining industry generates substantial revenue and employment, yet the perceived benefits inadequate compared to its economic output. The sector has failed to consistently improve local livelihoods, with communities reporting a lack of corresponding enhancements in their standard of living. Significant concerns persist regarding environmental degradation, displacement of residents, and inequitable profit distribution. This analysis underscores the urgent need for stronger enforcement of environmental regulations and greater accountability and equity within the sector. Furthermore, there is a stark disconnect between the wealth generated by gold mining and the adverse effects on mining communities, which face grave health and socio-economic challenges due to environmental degradation.

Conclusion: This review emphasizes the pressing necessity for implementing sustainable gold mining practices in Ghana to mitigate environmental degradation. Fostering effective collaboration among all stakeholders is pivotal to achieving sustainable mining operations and the equitable distribution of mineral wealth.

Keywords: Illegal mining; Galamsey; Water pollution; Deforestation; Land degradation; Gold

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INTRODUCTION

The global gold industry is an important sector in the world economy. Small-scale gold mining contributes significantly to global gold production, accounting for around 12% of the total yearly supply. It is estimated that this sector employs around five million people across 13 major gold-producing countries, which is about eight times the number employed in large-scale gold mines. Ghana, a country with an extensive history of gold mining, has experienced the industry as a major contributor to its economy, offering employment opportunities and generating foreign exchange revenue.[1] Evidence suggests that Ghana's renowned gold mining industry has flourished in recent years, now surpassing the country's longstanding cocoa sector as the predominant driver of economic activity.[2] The revitalization of the gold mining sector can be attributed to the adoption of World Bank policy recommendations, which were incorporated into a new national mineral policy and the 1986 Minerals and Mining Law aimed at reinvigorating the industry.[3,4] The policy reforms included measures to attract foreign investment, modernize mining practices, and streamline regulatory frameworks.[5] Consequently, gold production volumes and revenues have risen significantly over the past decade, with the industry now playing a pivotal role in Ghana's economy, contributing to GDP growth, government revenues, and employment generation.[5] The gold subsector's contribution to the GDP of the minerals industry expanded from 4.3% in 2021 to 7.5% in 2022.[6] Ghana's long history of gold mining has made the industry a significant contributor to the country's economy, providing employment and foreign exchange earnings.[1] Ghana's gold mining has economically benefited the country, yet the industry's environmental and health effects are increasingly problematic.[1] Gold mining has expanded rapidly in Ghana, sparking debates over whether it is a blessing or a curse. Many see the industry failing to contribute enough to public funds, jobs, skills, and local economies.[7] Surface mining destroys forests, clears land, and digs up the earth, causing significant local environmental damage.[1]

The gold sector is often viewed as an isolated enclave disconnected from the wider economy.[8] However, evidence shows that gold mining is no longer an isolated industry but is deeply integrated into Ghana's economy after major investment and growth.[7] The mining industry in Ghana has forged a variety of economic connections, particularly backward linkages, which could be further bolstered through suitable policy measures. Ghana's favorable investment climate and abundant mineral resources have enticed more than 250 local and international companies to participate in large-scale mineral exploration. Presently, 16 major mining corporations are extracting gold, diamonds, bauxite, and manganese within the country.[9] In addition, small-scale mining of precious minerals continues to be a vital source of foreign currency for Ghana. Currently, over 3,000 registered small-scale mining cooperatives and 90 mining support firms operate in the country. All diamond production now originates from small-scale mining activities,[9] highlighting the significant role of the mining sector. These backward linkages encompass the procurement of goods and services from local suppliers, the development of infrastructure that benefits proximate communities, and the generation of skilled and semi-skilled employment opportunities in mining-related activities.[10]

Ghana's mining industry is dominated by gold extraction, which has been the primary focus for many years. For instance, in 1996, gold mining made up the main activity in the mining sector and accounted for 41% of the country's total national export revenue.[4] Ghana's economy has diversified beyond the mining sector, reducing its reliance on extractive

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industries compared to other mineral-rich nations. This diversification mitigates economic risks and enhances the overall stability and resilience of Ghana's economic development.[10] Most mining activities in Ghana are rural based, thus the illegal mining activities greatly affect the lives of the rural people because they depend on the lands and other natural resources for their well-being.[11] The small-scale mining industry continues to thrive, attracting a significant portion of the labour force in the mining sector. This burgeoning small-scale mining industry has impacted the livelihoods of thousands of individuals, particularly those residing in mining communities throughout the country.[11] Ghana's gold resources present a complex and nuanced issue, as their potential to support sustainable development and equitable distribution of benefits is heavily dependent on the government's capacity to manage and regulate the mining sector effectively, as well as diversify the economy and strengthen the linkages between the mining industry and the broader economic landscape. Illegal artisanal and small-scale mining operations, popularly referred to as 'galamsey' in local parlance, pose a substantial threat to the long-term sustainability of the mining industry and the well-being of local communities.[12] These illegal informal mining activities jeopardise the environment, undermine the formal mining sector, and deprive the government of critical revenue. Furthermore, the miners engaged in these hazardous operations and the surrounding communities face serious health risks. The wider public is also impacted by the consequences of galamsey, including environmental degradation (e.g loss of biodiversity), loss of productive land due to unsustainable mining practices and lack of reclamation activities of lands are degraded, and contamination of water sources via mercury poisoning.[12]

Despite Ghana's ratification of the Minamata Convention, an international agreement aimed at eradicating or substantially decreasing the use of mercury in artisanal and small-scale gold mining, the widespread practice of applying mercury continues unabated within the country.[13] As reported by Juliane Kippenberg, the associate director for the Human Rights Watch children's division, mercury is readily available for purchase in shops across the country, particularly in mining communities [14] Kippenberg further noted that a 12-year-old child, who had seemingly withdrawn from school, was observed engaging in the transportation, crushing, and washing of ore within a mining community. Additionally, Kippenberg stated that the child possessed a flask containing silver-like liquid mercury and provided the following account: “I use the hand to spread the mercury. Then I create the amalgam. I burn it on my own wherever I get fire, at my mother’s house or anywhere.”[14] In the past decade, the Ghanaian government has intensified efforts to address challenges in the mining sector. This has involved strengthening the regulatory framework and enforcement, as well as promoting sustainable mining practices. The long-term impact of Ghana's gold resources on the populace will hinge on the nation's capacity to balance the economic benefits of the mining industry with the imperative to safeguard the environment, ensure equitable wealth distribution, and foster sustainable development. The proliferation of illegal mining activities and environmental degradation linked to gold extraction in recent years have given rise to concerns regarding the sustainability of the industry and its ramifications for local communities.[7,10]

Despite the various efforts by the government to curb illegal mining activities, which continue to destroy freshwater resources and cause serious deforestation and severe land degradation across the country, especially in the mining communities, the practice continues to escalate daily. Although the government has implemented measures to address this issue, illegal mining activities have persisted, posing a significant threat to the country's natural resources.

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This study seeks to synthesize the latest findings relating to illegal mining in the country and suggest practical strategies to help mitigate the impact of the consequences of illegal mining, particularly on water bodies, forest cover, and land degradation. It is crucial to develop and implement comprehensive solutions to tackle this pressing problem, which has far-reaching environmental and socio-economic implications for the affected communities and the nation.

METHOD

The methodology commences with a systematic exploration of prominent academic databases, including ScienceDirect, PubMed, Google Scholar, JSTOR, Web of Science, EMBASE, and Scopus.[15] This comprehensive search aims to identify pertinent peer-reviewed articles, reports, and case studies that illuminate the environmental ramifications of gold mining in Ghana. To ensure a robust yet focused literature collection, specific keywords were employed, including "gold mining," "environmental impact," "Ghana," "sustainability," and "mining waste." This strategic approach facilitates a nuanced understanding of the complex environmental challenges associated with gold mining activities in the region. To refine the selection of studies, rigorous inclusion and exclusion criteria were established. Only those studies that explicitly addressed the environmental consequences of gold mining—such as land degradation, water pollution, and biodiversity loss— and were published in English were included in the review.[16] In contrast, articles that concentrated solely on the economic dimensions of mining, neglecting environmental considerations, were systematically excluded. This meticulous curation of literature enabled a more focused analysis of the ecological toll exacted by the industry. Following the identification of relevant studies, key information was meticulously extracted, encompassing the types of environmental impacts reported, the methodologies employed, and the geographical areas examined. This data was organized thematically, facilitating a comprehensive synthesis of findings. The synthesis unveiled recurring themes and patterns regarding the environmental consequences of gold mining, underscoring critical issues such as deforestation, soil erosion, and the contamination of water sources. Through this rigorous methodology, the review contributes valuable insights into the pressing environmental challenges posed by gold mining in Ghana, paving the way for informed discussions on sustainability and ecological preservation. The flow chart in Figure 1 illustrates the literature screening process.

RESULTS

Evaluating Ghana's small-scale gold mining industry: challenges and critiques

The gold mining industry in Ghana encompasses two disparate scales of operations - artisanal and small-scale mining, as well as large-scale industrial mining. These two distinct forms of gold extraction have co-existed and operated side by side in Ghana for decades.[17] Ghana's flourishing gold mining sector has yielded substantial economic gains, yet it has also faced intense scrutiny and debate. The industry is often perceived as an “enclave” activity, detached from the broader economy and offering limited benefits to local communities.[18,19] Critics contend that despite the marked rise in production and revenues, gold mining has fallen short in generating adequate public funds, employment opportunities, skill-building initiatives, and localized economic progress.

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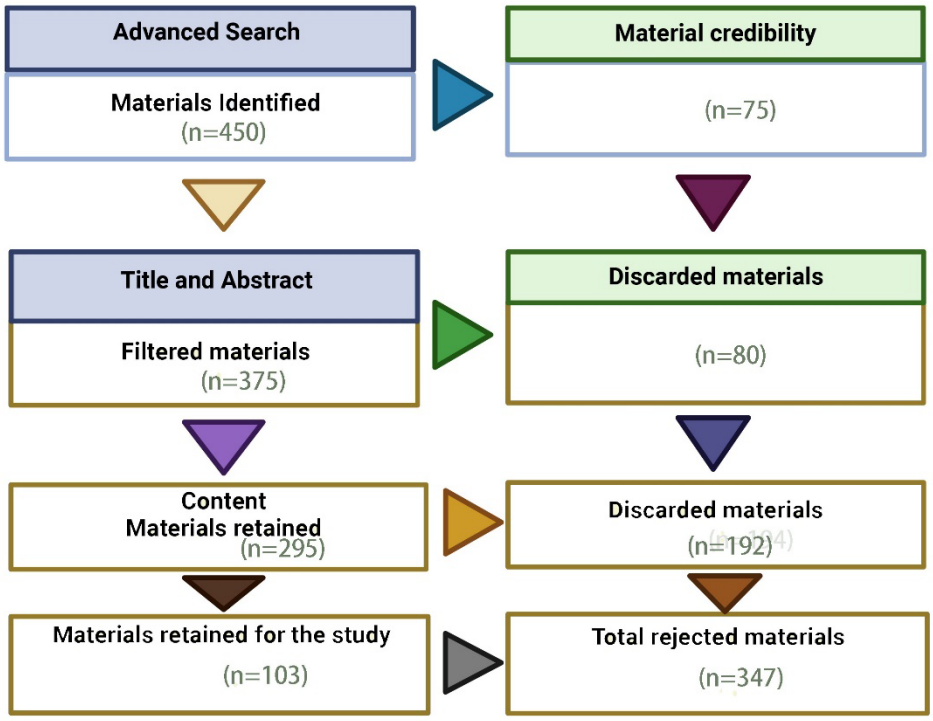

Figure 1: The flowchart of papers selected in this study.

Some existing scholarly work has challenged the "enclave" theory, providing evidence that gold mining in Ghana is now more extensively integrated into the broader economy through various economic connections, especially backward linkages.[7,20] Nonetheless, the industry's impact on mining communities remains a multifaceted and intricate matter. There may be significant untapped potential for gold mining to boost Ghana's economic and social development if the right strategies are implemented. Sustainability and environmental issues are major challenges for Ghana's gold mining industry. Although artisanal and small-scale mining is essential for maintaining local economies, mining communities heavily depend on the success of their mining operations.[17] However, this industry significantly pollutes many nearby freshwater sources. The small-scale and traditional nature of these mining activities also makes them a vital source of employment and income, particularly for the impoverished and marginalized populations in developing nations.[21] The environmental and health impacts of small-scale gold mining in Ghana have been severe. Many mining communities lack access to basic infrastructure and resources, such as healthcare and clean water.[12] Recently, some Ghanaian citizens, including health professionals, have called for a complete halt to all mining activities. This would allow the government and stakeholders to review Ghana's mining and mineral policies thoroughly, ensuring the responsible and sustainable use of the country's mineral resources, especially gold [22,23]. Addressing these environmental concerns will be crucial to ensure the long-term viability and sustainability of Ghana's gold resources.

Impact of small-scale mining activities on freshwater resources in Ghana

Freshwater resources are continually decreasing in quality and quantity due to factors such as overexploitation, pollution, and climate change. Approximately only 1% of the world's total freshwater supply is readily accessible in lakes, river channels, and underground aquifers for domestic, agricultural, and industrial use.[24] The remainder is locked up in glaciers, ice caps,

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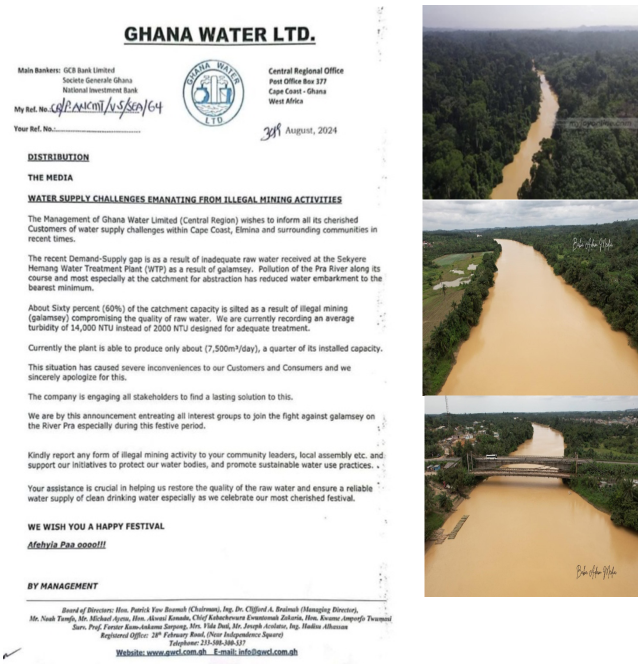
and deep groundwater reservoirs, making it difficult to access and utilize. This limited availability of freshwater resources poses significant challenges to meeting the growing global demand for clean water.[25] Ghana's aquatic ecosystems, which include rivers, lakes, and coastal areas, play a vital and multifaceted role in the country's socio-economic development. These diverse water bodies provide essential resources and services, such as supporting fisheries, supplying water for agriculture and domestic use, facilitating transportation, and sustaining biodiversity.[26] However, these aquatic ecosystems face significant challenges due to various anthropogenic activities, particularly illegal artisanal and small-scale mining and unsustainable resource extraction [27]. The Water Resources Commission reported that illegal mining activities have led to the pollution of approximately 60% of Ghana's freshwater resources, particularly in the southwestern regions, with many water bodies in a dire state [28]. The degradation of these freshwater bodies has significantly undermined the subsistence and economic activities of local populations who depend on them for drinking, irrigation, and other household purposes [29]. In 2022, the Ghana Water Company Limited was forced to discontinue the operation of its water purification facility situated in Kyebi because “the Birim River from which water is pumped for treatment to the township and its environs has been heavily polluted due to the operations of illegal miners”.[30] The Pra River, which originates in the Kwahu Plateau near the town of Mpraeso and flows approximately 240 kilometres southward before emptying into the Atlantic Ocean,[31] is a vital source of drinking water for many communities in the Central Region of Ghana, including the cities of Cape Coast and Elmina and their surrounding areas. According to recent findings from the Ghana Water Company Limited (GWCL), the Pra River has been heavily contaminated due to the activities of unlawful mining operations along its banks. This has led to a significant increase in the water's turbidity, with average readings rising from 2000 Nephelometric Turbidity Units (NTU) to an alarming 14000 NTU, representing a 600% change.[32,33] as depicted in Figures 2 and 3.



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WATER SUPPLY CHALLENGES EMANATING FROM ILLEGAL MINING ACTIVITIES

The Management of Ghana Water Limited (Central Region) wishes to inform all its cherished Customers of water supply challenges within Cape Coast, Elmina and surrounding communities in recent times.

The recent Demand-Supply gap is as a result of inadequate raw water received at the Sekyere Hemang Water Treatment Plant (WTP) as a result of galamsey. Pollution of the Pra River along its course and most especially at the catchment for abstraction has reduced water embarkment to the bearest minimum.

About Sixty percent (60%) of the catchment capacity is silted as a result of illegal mining (galamsey) compromising the quality of raw water. We are currently recording an average turbidity of 14,000 NTU instead of 2000 NTU designed for adequate treatment.

Currently the plant is able to produce only about (7,500m³/day), a quarter of its installed capacity.

This situation has caused severe inconveniences to our Customers and Consumers and we sincerely apologize for this.

The company is engaging all stakeholders to find a lasting solution to this.

We are by this announcement entreating all interest groups to join the fight against galamsey on the River Pra especially during this festive period.

Kindly report any form of illegal mining activity to your community leaders, local assembly etc. and support our initiatives to protect our water bodies, and promote sustainable water use practices.

Your assistance is crucial in helping us restore the quality of the raw water and ensure a reliable water supply of clean drinking water especially as we celebrate our most cherished festival.

WE WISH YOU A HAPPY FESTIVAL

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Figure 2. The current condition of the Pra River in Ghana, influenced by the ongoing illegal mining operations along its riverbanks
Source: Myjoyonline | Baba Adam Media Facebook Page

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Figure 3. Koforidua Water Works highlights the pollution of River Densu due to illegal mining, which affects the Weija Dam, the primary source of drinking water for Accra
Source: Gary Al-Smith|Facebook|October 2024

The pollution levels are far above the recommended threshold of 4 Nephelometric Turbidity Units set by the World Health Organization for drinking water, indicating severely compromised water quality that poses significant health risks for local communities relying on these water sources.[34] Illegal mining activities have adversely affected the water quality of the Bonsa River in the Tarkwa Nsuaem Municipal Assembly, Ghana, leading to mean turbidity levels of 155.75, 135.0, and 207.0 NTU for the downstream, midstream, and upstream sections of the river, respectively.[29] These pollution levels exceed the 4 NTU threshold recommended by the World Health Organization for potable water standards.[34] The Ghana Water Company Ltd further revealed that 60% of its reservoirs located in the Central Region are obstructed by silt, resulting in many of its treatment facilities operating at only 25% of their capacity. Furthermore, national water production has declined to 40%, a significant reduction from 70% in 2022, indicating the once highly improbable scenario of Ghana requiring importing water is now becoming a realistic possibility.[32] The President of the Society, Samuel Kow Donkoh, recently stated, “The activities of illegal Mining have devastated our water bodies. Making it expensive for pharmaceutical companies to treat water for production purposes. If this environmental degradation continues, we may soon import water to support our local manufacturing industry”.[35] A recent study investigated the presence of heavy metals, including mercury, lead, arsenic, and cadmium, in two rivers located within the Asante Akim Central Municipality of Ghana. The water samples exhibited concentrations ranging from 0.8 to 9.5 µg/L for Hg, 0.6 to 3.5 µg/L for Pb, 0.02 to 51 µg/L for As, and 0.2 to 5.2 µg/L for Cd. Similarly, the sediment samples contained concentrations of 7 to 89 mg/kg for Hg, 0.06 to 9.2 mg/kg for Pb, 10 to 998 mg/kg for As, and 0.1 to 42 mg/kg for Cd. The levels of these heavy metals in both the water samples and sediments were found to exceed the standards set by the World Health Organization.[36] Illicit gold mining activities have significantly polluted numerous rivers in the country, particularly in areas with active mining operations. The rivers affected include the Enu River, River Offin, Afram River, River Prah, Gyimi River, Subin River, Agogo River, Oda River, River Owabi, and River Fum, all located within the Ashanti region.[37] Additionally,

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rivers in the Western region, such as the Daboase River, River Ankobra, and River Pra, as well as the Birim River and Asuboni River in the Eastern region, and the Tano River in the Bono East region, have also been affected by illegal gold mining.[37] A recent study comprehensively assessed the environmental sustainability of groundwater resources in the Jacobu water system. The findings indicated that while illegal gold mining activities are present in the region, they have not yet significantly impacted the quality and availability of the groundwater supply, with an environmental sustainability index value of 0.845, indicating an excellent level.[38] A recent study investigated heavy metal pollution and its ecological risks in riverine sediments from gold mining areas such as AngloGold Ashanti, Tarkwa-Bonsa, and Kenyasi, as well as pristine locations, including Kalakpa Forest Reserve, Mole Park, Kakum Forest Reserve, Oda River reserve, Ankasa Forest reserve, Bosomkese reserve, and Atiwa range.[27] The results revealed that while some heavy metal concentrations remained below recommended guidelines in both mining and pristine sites, levels of chromium, arsenic, copper, and mercury exceeded established thresholds, particularly in the mining regions.[27] The concentration of Chromium in 134.13±3.61, 134.02±10.95, and 119.62±9.73 mg/kg for River Subri, Birim River, and River Bonsa and the pristine areas the levels were 170.80±2.21, 2224.95±3.62, and 74.22±4.42 mg/kg for Mole River, Kalakpa River and Atiwa River respectively. Similarly, the levels of nickel and cobalt were 570.49±0.76 and 167.11±1.08 mg/kg from the Kalakpa River.[27] A recent study investigated surface water quality in the Pra River Basin. The study highlighted the negative effects of illegal mining and improper use of agrochemicals. It involved interviews with 344 local farmers and a physicochemical analysis of 33 water samples from 25 rivers in the basin. The findings showed that over 80% of sampled sites exceeded the WHO-recommended levels for pH, iron and phosphorous. In contrast, the concentrations of copper, mercury, arsenic, and iron were found to exceed acceptable levels for irrigation purposes, particularly in areas near mining operations, and lead concentrations from 30% of the sites exceeded the threshold.[39] Evidence showed that between 1986 and 2020, substantial land degradation, water contamination, and a significant loss of 27,333 hectares of forest cover.[40] The analysis predicts that the continuation of current mining practices will likely lead to further ecological deterioration,[40] underscoring the urgent need for effective management strategies to mitigate prospective environmental impacts. In contrast, a study in the Wassa East district examined heavy metal contamination in drinking water from two mining districts in Ghana, Wassa East and Asutifi North. It assessed levels of iron, manganese, arsenic, and mercury in various water sources, including boreholes, wells, piped water, public standpipes, rainwater, sachet water, and surface water. The results showed that iron and manganese concentrations were consistently higher than those of arsenic and mercury.[41] Notably, arsenic and mercury levels in drinking water from households and institutions were higher in Wassa East than in Asutifi North, although water point levels were similar in both districts. Surface water in Wassa East had higher iron levels compared to Asutifi North, while Asutifi North had elevated manganese levels compared to Wassa East. Except for iron, all metals were within WHO-recommended limits. In contrast, wells and surface water in both districts were deemed very poor and unfit for consumption.[41] A recent study conducted in five small-scale gold mining communities located in the Amansie West District of Ghana's Ashanti Region revealed that the mercury concentrations in these areas surpassed the FAO/WHO permissible limit of 0.3 mg/kg. The observed concentrations were 0.68 mg/kg, 1.07 mg/kg, 1.26 mg/kg, 1.28 mg/kg, and 17.03 mg/kg, indicating levels that were 2.3 to 56.8 times higher than the FAO/WHO-recommended threshold.[42] Analysis of twenty-four water samples

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from the Obeng ne Obeng, Abuakwaa, and Odaso communities along the Oda River revealed that turbidity and total suspended solids exceeded FAO recommendations attributable to illegal mining.[43] While pH, electrical conductivity, and total dissolved solids were within acceptable limits, iron exceeded FAO guidelines, and *Escherichia coli* levels were higher in the Abuakwaa and Odaso communities.[43] These findings underscore the adverse impacts of unregulated mining activities, which pose significant risks to essential water resources needed for irrigation, public health, food safety, ecosystems, and local livelihood. The assessment of groundwater quality in the southeastern region of Ghana's West Region revealed several issues. A significant portion of the samples (16.7%) exceeded WHO guidelines for total dissolved solids and turbidity, and most water samples had a mildly acidic pH.[44] Additionally, most of the samples (91.7%) were contaminated with total coliform, and a quarter were contaminated with E. coli. While groundwater in the North exhibited good quality, Water Quality Index (WQI) of 96, the South had poor water quality (WQI=144.6). Overall, the groundwater requires treatment before it can be safely consumed, despite being suitable for domestic purposes.[44] The assessment of water quality parameters in the Pra Basin of Ghana, which encompassed eight sampling sites from upstream to downstream, revealed that the levels of turbidity, chemical oxygen demand (COD), and biological oxygen demand (BOD) exceeded the permissible limits across all sites.[45] Among the eight sites investigated, only Barekese did not exceed the permissible levels of potentially toxic metals. Arsenic (As) concentrations were found to exceed the permissible limit in all sites except Barekese. Similarly, Mn concentrations were above the permissible level in all sites except for Barekese and Brenase. Furthermore, Pb concentrations were recorded to be above the permissible level in all sites, excluding Shamaa and Barekese.[45] A study analysed 56 borehole water samples from 19 mining communities in the Amansie West District, Ghana. The results showed that while some samples met WHO standards, others had increased health risks due to color, turbidity, acidity, and high as levels.[46] The study further observed elevated health risks in some communities from mining-related contamination by heavy metals and particulate matter. Without urgent mining waste regulations, the authors warned of potential water scarcity and heightened health concerns.[46] Yeboah et al. recently examined the link between water and public health, focusing on waterborne disease risk factors and water pollution drivers for residents near Ghana's Tano River Basin. The key findings were that inadequate sanitation, poor hygiene, and illegal mining contamination were the main contributors to waterborne diseases, while floods and improper waste management also significantly impacted outbreaks. The analysis further showed that 21.2% of the basin's southern region was highly prone to flooding.[47] The unfavourable impacts of anthropogenic disturbances in major river basins, leading to significant variations in the ecosystem, have prompted this research within the Pra River Basin in Ghana.[48] The results showed a sustained increase in cropland, settlements, and mining activities at the expense of forested areas from 1986 to 2016, a trend expected to continue through 2025. The changes in land use and land cover have increased surface runoff by 124.51% and water yield by 40.13%, accompanied by a reduction in base flow by 30.08 and evapotranspiration by 13.248%.[48] A study of land use and land cover changes in the Ankobra River basin, a hub for large-scale and small-scale mining, showed a substantial decrease in closed forest areas. In 1991, closed forests covered 40.4% of the total basin, but this percentage dropped significantly to 22.8% by 2016. The main land changes in the basin were from closed forests to open forests, as well as open forests were converted to farmland, settlements, bare land, and mining areas. Mining, especially illegal mining, was the

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main cause of deforestation in the Ankobra Basin between 2008 and 2016, as mining operations greatly increased during this period.[49]

Impact of small-scale mining on environmental quality, forest cover and biodiversity

The accelerated depletion of natural resources and the alarming degradation of ecosystems have emerged as pressing global concerns, posing considerable threats to the overall well-being of the planet and its inhabitants.[50,51] The complex ecological systems on Earth, encompassing both human and non-human organisms, are increasingly strained by the unsustainable activities of contemporary civilization.[52] The primary drivers of environmental degradation are human-induced activities, including the excessive exploitation of natural resources, the release of greenhouse gases, and the pervasive contamination of air, water, and soil.[52] Mineral extraction activities, both artisanal and industrial, are extensive across numerous regions in Ghana, resulting in substantial heavy metal contamination in the surrounding environment.[41] A study on the impact of small-scale artisanal mining, focusing on alluvial and chamfi extraction, found that illegal gold mining in three towns in Ghana's western region adversely affected soil microbes.[53] Soil tests four years later showed significant problems, including increased acidity, reduced levels of essential nutrients like magnesium, potassium, phosphorus, calcium, and nitrogen, as well as changes in microbial communities,[53] underscoring the ecological ramifications of these mining practices. Heavy metals in contaminated soils have varying availability, affected by the soil's physical structure, chemical conditions, and biological processes. These include the soil's structure and ability to be penetrated, redox potential, pH, release of substances, and interactions with mycorrhizal fungi.[54] The primary pathway for human exposure to Pb, apart from drinking water, is consuming agricultural produce grown in Pb-contaminated soils.[55]

Tropical and subtropical dry woodlands support diverse ecosystems and store substantial carbon. Yet, these valuable habitats face severe deforestation risks and lack strong safeguards.[56] Global tropical primary forest loss amounted to 3.7 million hectares, equating to the destruction of nearly 10 football fields of forest per minute in 2023. Although this figure represents a 9% decline from 2022, the deforestation rate in 2023 was comparable to that of 2019 and 2021. This extensive forest loss resulted in the emission of 2.4 gigatons of carbon dioxide in 2023, approximating nearly half of the United States' annual fossil fuel emissions.[57] The situation in Ghana is not completely different from the global perspective, as illegal and unregulated mining activities continue to threaten the country's precious forest cover and endanger numerous wildlife species across the region.

According to the Ghana Forest Watch, the country has experienced a staggering 24% loss of its tree cover, equivalent to 1.46 million hectares, over the past two decades.[32] The regions where illegal artisanal gold mining is most prevalent, such as Western, Ashanti, Eastern, Central, and Brong Ahafo, have been the hardest hit by this deforestation. Disturbingly, these same areas are also grappling with the most severe water shortages.[32] The loss of forest cover has multifaceted implications including carbon dioxide (CO_2) emissions beyond the impact on the national economy.[58] The loss of tropical forests threatens biodiversity and vital ecosystem services like climate regulation, biomass production, water supply, pollination, and habitat.[59] Tropical forests cover a small portion of the Earth's land but are crucial for providing ecosystem services worldwide. Deforestation and degradation have greatly reduced tropical forest areas and disrupted these vital services, making billions of people more vulnerable.[60,61] According

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to John Allotey, the director of Ghana's Forestry Commission, illegal mining activities have impacted seven of the country's 16 regions.[62] Furthermore, unauthorised gold mining has affected 34 of Ghana's 288 forest reserves, destroying approximately 4,726 hectares of land.[62]

In 2023, Ghana's Forestry Commission arrested 8 illegal miners, including 4 foreigners. It burned 10 earth-moving machines at the Krokosua Hills Forest Reserve, a biodiversity hotspot as shown in Figure 4.

Figure 4. Eight illegal gold miners, comprising four locals and four foreign nationals, were arrested at Krokosua Hills Forest Reserve, a biodiversity hotspot designated as a Globally Significant Biodiversity Area.
Source: Forestry Commission Ghana, 2023

This reserve has been recognized as a Globally Significant Biodiversity Area due to its exceptional ecological value, emphasizing the need for strong conservation efforts.[63] Similarly, a recent study of the Atewa Range Forest in Ghana, a globally recognized biodiversity hotspot and important bird area, found a 243.7% rise in bare or developed land from 1990 to 2021. Additionally, the reserve is home to 102 tree species from 33 families, with approximately 12% of these species considered vulnerable or near threatened based on the International Union for Conservation of Nature Red List.[64] The Ghanaian cocoa industry has not escaped the severe effects of illegal gold mining. This vital economic sector of the country has faced major challenges due to illegal mining activities encroaching on cocoa farms.[65] In 2020, the Ghana Cocoa Board reported that a substantial area of 20,000 hectares of cocoa farmlands, approximately 77.2 square miles, were lost due to illegal small-scale gold mining operations.[32] The Mankrom Cocoa Cooperative Farmers Association recently reported that illegal small-

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scale gold mining has severely damaged over 100,000 acres of cocoa farms in the Mankrom community. Illegal miners searching for gold have encroached upon and exploited agricultural lands.[66] The loss of cocoa-growing land harms Ghanaian farmers and the country's vital cocoa industry and causes environmental destruction as shown in Figure 5.

Figure 5. The effects of illegal gold mining on cocoa farms in the Mankrom Community, Ghana
Source: ModernGhana.com

Mining has become the main competitor to farming across many Ghanaian communities, including Asutifi-North District. The fast growth of mining has converted large areas of farmland, transforming land use in these affected regions. Individuals who joined land-use conversion earned $31.68 more per year than others. But their incomes were unsustainable, driving them to illegal mining. This had major social, economic, and environmental impacts on local people, especially in mining areas.[5]

DISCUSSION

The Historical Trajectory of Gold Production in Ghana

The Ancient Kingdom of Ghana, the former Gold Coast Colony, and present-day Ghana have been major producers of the world's gold for over a millennium. Shortly after the establishment of the British Gold Coast Colony in 1874, the region witnessed the formation of its initial gold mining enterprises. This was followed by two consecutive gold rushes in the early 20th century, leading to the proliferation of gold prospecting and extraction activities across the country. Nonetheless, the industry subsequently entered a phase of diminished production, commencing at the time of the nation's independence in 1957 and concluding shortly after the implementation of the country's Economic Recovery Plan in 1983. Over the period from 1938 to 2002, Ghana's gold mining sector witnessed a striking revival, with production levels rising by approximately 700%.[67] Presently, the gold mining sector contributes a substantial portion of the country's mineral export earnings. In 2019 and 2020, the total mineral export values were US dollars 6,778,746,098 and US dollars 7,245,150,698, respectively. Out of this, the

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gold export value constituted US dollars 6,326,729,457 and US dollars 7,055,419,805 for 2019 and 2020, representing 93.3% and 97.4% of the total mineral export value for those respective years.[68] This reflects the significant and integral role that the gold mining industry plays in Ghana's overall economic performance and development. In 2023, Ghana continued to be the leading gold producer in Africa, with artisanal and small-scale miners compensating for the modest decrease in output from the large-scale mining sector. Consequently, Ghana's gold production rose to 114.5 tonnes in 2023, up from 105.7 tonnes in 2022, representing a 7.7% increase. The gold output from the large-scale mining segment decreased by 6.5%, falling from 3.1 million ounces in 2022 to 2.9 million ounces in 2023. In contrast, the gold production of the small-scale mining segment increased by 66.7%, rising from 0.66 million ounces to 1.1 million ounces over the same period.[69] The total volume of gold production declined from 4.577 million ounces in 2019 to 4.023 million ounces in 2020, representing a 12 per cent decrease. This reduction in gold output can be attributed to various factors, such as the impact of the COVID-19 pandemic on mining operations and global supply chain disruptions. Mineral exports accounted for 48.4 per cent of the country's total merchandise export revenue in 2020, while crude oil and cocoa contributed 20.1 per cent and 16.1 per cent, respectively, in the same year. This highlights the importance of the mining industry to the Ghanaian economy. Mineral export proceeds increased from US$ 6.678 billion in 2019 to US$ 7.228 billion in 2020, as indicated in Table 1 and Fig. 6. This growth can be attributed to higher commodity prices and continued investments in the sector. Regarding employment, the total number of persons employed by large-scale mines as of 2020 was 34,363, comprising 8,760 direct employees and 25,603 contractors. The proportion of Ghanaians in the workforce was 98.7 per cent, demonstrating the significant participation of the local population in the mining industry.[68] The extractive resource sector is anticipated to serve as a crucial driver of industrialization in the developing country, particularly through its mining operations, within the context of a post-industrial global landscape.[70]

Small-scale mining, which predates large-scale operations, remains a significant economic activity, particularly in remote and impoverished regions of the country.[71] Artisanal and small-scale gold mining operations currently comprise approximately 35% of the country's total gold output.[72] The environmental impacts of these small-scale mining activities vary based on the methods employed and the scale of operations, with economic, technical, legal, and operational factors contributing to the worsening of these environmental impacts. Key environmental and social consequences include air and water pollution, land degradation, and the displacement of traditional livelihoods.[73]

The Ghanaian government's response to galamsey, or illegal small-scale gold mining, was prompted by public pressure. This pressure stemmed from a vigorous media campaign and the involvement of various civil society organisations, including OccupyGhana, who used the hashtag #Stopgalamseynow to voice their opposition to the practice.[74] In response to public pressure spearheaded by a robust media campaign and involvement of civil society groups like OccupyGhana under the #Stopgalamseynow hashtag, the Ghanaian government initiated a crackdown on illegal mining operations. This involved deploying the military and police to enforce measures such as Operation Vanguard and the establishment of Galamsey Courts. These interventions led to the seizure of equipment, arrests and prosecution of illegal miners, closure of unlawful mining sites, land reclamation efforts, and programs to resettle the displaced galamsey operators.

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Table 1. Ghana's gold production, export and value for 2019 to 2022.

Year	Gold production, export, and value	Large-Scale Mining	Small-Scale Mining
2019	Total value of export (US $)	4,612,511,218	2,207,967,255
	Total production (oz)	2,989,444	1,587,888
2020	Total value of export (US $)	5,184,383,830	2,044,530,645
	Total production (oz)	2,847,183	1,175,318
2021	Total production (oz)	2,708,792	108,788
	Total export (oz)	2,663,438.52	100,947.48
	Total value of export (US $)	4,772,545,362	182,515,308.00
2022	Total production (oz)	2,171,593	523,551
	Total export (oz)	2,123,147.29	484,672.71
	Total value of export (US $)	3,899,019,038.02	873,049,270.98

Source: GHEiTi Mining Sector Report 2020

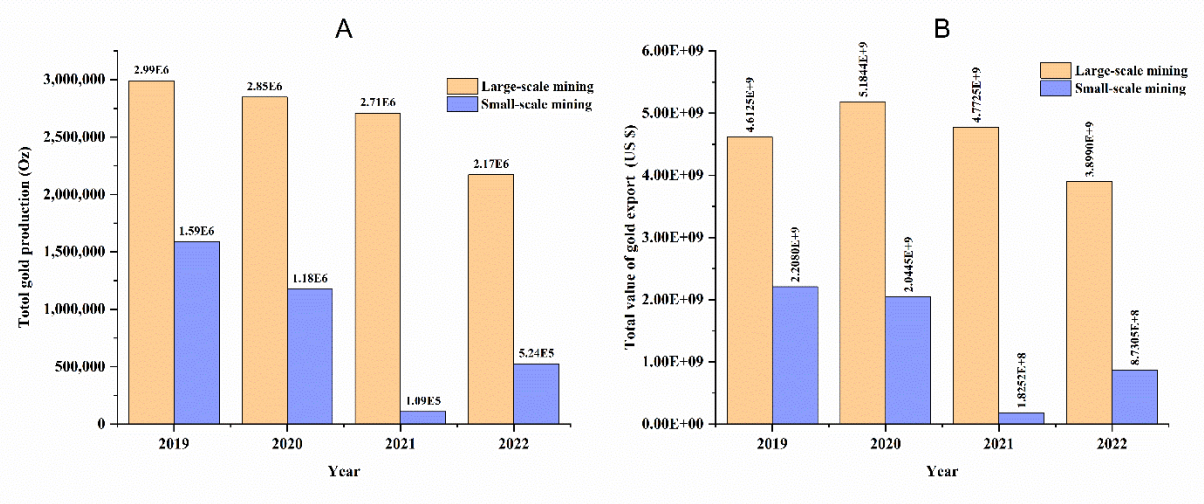

Figure 6. Ghana's gold from 2019 to 2022 (A) total gold production and (B) total value of gold export.

However, the efficacy of these actions has been limited, as the challenge of galamsey mining has persisted in Ghana.[75,76] Earlier efforts by the Ghanaian government to address the galamsey issue, including the enactment of the Small-Scale Gold Mining Law in 1989 and the military intervention 'Fight Against Illegal Mining' or 'Operation Flush Out' in 2006, were also ineffective in resolving the problem.[75] Despite the military's crackdown on illegal mining, the problem in Ghana remains deeply entrenched in the country's socioeconomic fabric. The long-term sustainability of Ghana's mining industry depends on the nation's ability to balance economic progress, environmental protection, and equitable benefit distribution. The government's actions seem to undermine efforts to combat illegal mining, as exemplified by the passage of Legislative Instrument 2462 in 2022. Despite these measures, the illegal mining challenge persists, underscoring the need for a more comprehensive and sustained approach. Addressing these challenges will be crucial in determining whether Ghana's gold resources become a blessing or a curse for the people.

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Citizens' advocacy against illegal mining activities in Ghana

Illegal artisanal and small-scale gold mining, known as "galamsey", continues to be a major issue in rural Ghana despite government efforts to regulate the sector. In 2017, Citi FM Ghana launched a media campaign to urge action on the devastating environmental impacts of illegal mining, which have harmed the country's water, forests, and biodiversity.[77] Citi FM's #StopGalamsey campaign, civil society organisations, and pressure groups have played a significant role in calling on the government to act.[78] The government instituted several measures, including the establishment of an inter-ministerial committee on illegal mining (IMCIM) in early 2017,[79,80] Operation Vanguard and the establishment of Galamsey Courts. The authorities seized equipment, burned some of it, arrested and prosecuted illegal miners, closed illegal mines, and reclaimed the land.[74,78] However, the government's actions to combat illegal gold mining, such as utilising the military and police and framing it as a "fight" against a "menace", have been criticized.[81] The government's initial anti-illegal mining efforts, involving a military and police task force, generated some short-term positive outcomes, including improvements in the turbidity levels of select polluted rivers across the country.[76] However, in February 2019, Ghanaian investigative journalist Anas Aremeyaw presented damning documentary evidence that implicated certain government officials and committee members in acts of bribery and corruption [82,83]. Subsequently, in 2021, the government dissolved the inter-ministerial committee it had previously established to address the issue of illegal mining.[84] Despite some interventions, the root socioeconomic and demographic drivers of illegal gold mining in Ghana remain unaddressed. Illegal gold mining persists due to factors like the profits from gold, lack of other income options, involvement of powerful political, foreign, and business interests, and challenges enforcing regulations in remote areas.[81,85]

Recently, the Ghanaian public and civil groups have pressured the government to ban small-scale mining in affected areas due to severe water, forest, and land damage from illegal gold mining.[86,87]. The Trade Union Congress, Ghana Federation of Labor, and other labor unions jointly asked the government to declare a state of emergency in areas where illegal mining is occurring.[30] Healthcare workers advocated for the government to ban small-scale mining in Ghana. This call spotlights the major public health threats tied to mining, like polluted water, deforestation, and air pollution.[22] The health professionals say there is “the rise in cases of respiratory illnesses, skin infections, and waterborne diseases such as cholera and diarrhea in these communities is a direct consequence of the unchecked mining activities. We are witnessing an ecological disaster with direct implications for human health, and this must be addressed with urgency”.[22] While organized labor had initially threatened nationwide strike action if the government failed to act by October 10, 2024, their subsequent meeting with government representatives resulted in the shelving of their earlier plans to strike.[88] The University Teachers Association of Ghana has officially initiated a nationwide indefinite strike in response to the government's failure to declare a state of emergency, implement a freeze on small-scale mining activities across the country, and take measures to revoke Legislative Instrument (L.I. 2462) which grants the President the executive authority to approve mining leases within the country's forest reserves.[89–91] The use of hazardous substances by illegal miners, such as mercury and cyanide, is a significant concern, as these toxins contaminate water sources and threaten human and wildlife well-being.[92] The public and civil society groups have been crucial in tackling the illegal gold mining problem in Ghana. Campaigns like Citi FM's #StopGalamsey have raised awareness and rallied support, while civil society has held the government accountable and pushed for better solutions. These efforts have kept the

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issue on the national agenda and led to the government's renewed efforts. However, a more complete and collaborative approach is needed to address the root causes of illegal gold mining. The new government under President Mahama is expected to take immediate steps to repeal the controversial L.I 2462 and implement some reform measures within the mining sector particularly the small-scale mining subsector to address the numerous bottlenecks.

Poor enforcement of mining policies and treaties

International treaties such as the Minamata Convention on Mercury seek to eliminate or drastically reduce the use of mercury in artisanal and small-scale gold mining, which is a particularly salient issue for Ghana. The Minamata Convention on Mercury is a global agreement that seeks to protect human health and the environment from the adverse effects of mercury.[93] Notably, Ghana signed and ratified this treaty on September 24, 2014, and March 23, 2017, respectively.[94] Ghana, as a signatory to a treaty, conducted an assessment to evaluate its institutional and legal frameworks for mercury management. The assessment aimed to identify mercury release sources, recognize existing gaps and determine necessary actions for effective Convention implementation. Key sources of mercury release in Ghana include artisanal and small-scale gold mining, the use and disposal of mercury-containing products, and waste incineration and open burning. The report indicated that most mercury emissions occur in the air, followed by water and soil. Furthermore, the assessment identified the most vulnerable groups to mercury exposure as communities near water bodies and mining sites, patients and healthcare workers near facilities using mercury-containing products, and people living near open dumpsites and waste incinerators.[95] A recent study examined the policy coherence across sectors impacted by artisanal and small-scale gold mining activities. The findings indicated that the legal framework governing the ASGM sector lacks sufficient detail in crucial areas like gold sourcing and has complex licensing processes. Additionally, the study revealed ineffective enforcement of existing laws and regulations, partial alignment between mining policies and those of related sectors such as agriculture, water, land, environment, and development, as well as weak inter-sectoral coordination, all of which hinder the adoption of sustainable practices throughout the ASGM value chain.[72]

Previous research suggested that Ghana's mining policy reforms were beneficial, but recent studies challenge this view. The revised framework established a more favorable licensing and fiscal system for mining companies, allowing them to keep some export earnings abroad.[96] The policy changes enabled the mining industry to attract substantial foreign direct investment. Furthermore, the policy underscored the necessity of developing local content and supply chain linkages within the mining sector. However, the degree to which this objective has been realized remains a subject of ongoing discussion.[97] Conversely, while the policy reforms have helped revive private investment in the mining industry in Ghana, the extent to which the benefits have translated to broad-based improvements in the social welfare of the citizenry, particularly people in the mining areas, remains a source of debate. The current 'small-scale' mining licensing system is overly simplistic. It fails to sufficiently account for the diverse environmental implications, safety issues, and economic consequences associated with the various artisanal and small-scale mining activities.[98]

The challenges in implementing policies to improve social welfare in Ghana's mining sector are multifaceted. Key factors include incentive problems within institutions involved in mining governance, an excessively centralized policy-making process, the power of the executive

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president, strong party loyalty, a system of political patronage, a lack of transparency, and weak institutional capacity at the political and regulatory levels.[99]. Illegal mining activities in Ghana have led to widespread mercury contamination of water, soil, and crops. Despite various approaches, the issue has persisted, underscoring the urgent need for comprehensive policy reforms and clean-up strategies to address mercury and heavy metal pollution.[13] The available evidence indicates that the government's ban on small-scale mining operations in the country during 2017-2018 resulted in improved water quality in most rivers, particularly those previously polluted by illegal mining activities.[100] This highlights the fact that if illegal mining activities are curbed, the river waters will improve again through the implementation of sustainable strategies to protect and restore the ecosystem. While policy reforms are essential in directly addressing the scourge of illegal mining in the country, another crucial aspect that must not be neglected is the issue of bribery and corruption permeating the illegal mining industry. Influential individuals have engaged in various illicit manoeuvres to exploit mineral-rich communities, with detrimental consequences for the communities, the environment, water resources, and government revenues.[101] Numerous organisations within the nation, such as the Ghana Journalists Association, Civil Society Organizations, and Organized Labour, have urgently called for the government to revoke LI2462, a recent legislative instrument implemented to govern mining activities in Ghana. These entities have also demanded the immediate cancellation of any licenses issued for prospecting and mining operations in forests, protected areas, and near water sources.[30] The recently enacted legislation, LI 2462, passed by parliament in November 2022, has significantly eased the regulatory framework governing the exploitation of forest reserves for mining activities, eliciting grave concerns regarding the appropriateness and legality of this new policy measure. One of the encroached forest reserves is the Draw River Forest Reserve. It encompasses a diverse array of ecosystems, such as wetland, and riverine habitats, established to preserve and maintain the ecological equilibrium of the country.[102,103]

CONCLUSION

Ghana's gold mining industry faces a complex balance between economic growth and environmental/social consequences. While mineral wealth has driven development, studies showed devastating environmental impacts, challenging effective policy implementation due to obstacles like inadequate community engagement and lack of political will. The nuanced reality includes poverty, limited opportunities, and the promise of profits motivating illegal mining amid complex political and social dynamics. Regulatory efforts have failed to address factors promoting unauthorized mining, threatening the environment and revenue. There is a pressing need to reevaluate gold mining's role in Ghana's development strategy, prioritizing long-term national well-being through diverse stakeholder engagement. Implementing international treaties like the Minamata Convention is crucial given the high mercury use in small-scale mining, which persists due to a lack of alternatives and inadequate support. The prevalence of illegal mining underscores the need to examine socioeconomic and political drivers, alongside prioritizing alternative mercury-free technologies to ensure environmental sustainability and productivity in small-scale mining. A comprehensive review of Ghana's mineral policy, incorporating stakeholder inputs, is urgently required. A holistic, collaborative approach can turn Ghana's golden treasure into a boon rather than a bane for the nation and its people.

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Declarations

Authors' contribution

B.I.M was solely responsible for the conceptualisation, literature search, materials evaluation, original drafting, review, and editing of this manuscript.

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Conflict of interest

There is no conflict of interest in this research.

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