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DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

SCHOOL OF ENGINEERING

ASSESSING THE SOCIOECONOMIC, ENVIRONMENTAL AND WATER QUALITY IMPACTS OF ILLEGAL GOLD MINING IN MANKRANSO, ASHANTI REGION, GHANA: IMPLICATIONS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT.

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By

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A Thesis submitted to the Department of Civil and Environmental Engineering, School of Engineering, University of Energy and Natural Resources, Sunyani in partial fulfilment of the requirements for the degree of Master of Science in Environmental Engineering and Management

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DECLARATION

I, ELIZABETH KWAA AFI, hereby declare that this work is my own towards the Master of Science degree in Environmental Engineering and Management and that to the best of our knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Illegal gold mining (galamsey) has become one of the most pressing environmental and social challenges in Ghana, contributing to water pollution, land degradation, and community vulnerability. Despite its role in rural livelihoods, its unregulated nature raises major concerns for sustainability. This study examined the socioeconomic and environmental impacts of illegal smallscale gold mining (galamsey) in Mankranso, Ghana. Data were collected through household surveys ($n = 372$), geospatial analysis of land use and land cover (LULC) change, and river water quality monitoring. Water samples were collected from upstream, midstream, and downstream sections of mining sites and analysed for heavy metals and physicochemical parameters using standard procedures. Results showed that unemployment (44.1%) and high profitability (30.9%) were the main drivers of participation in galamsey. Communities reported social challenges such as teenage pregnancy, child labour, drug abuse, and prostitution linked to mining. Water quality deteriorated significantly downstream, with turbidity, electrical conductivity, and total dissolved solids exceeding WHO standards, while heavy metals (Pb, Hg, Cd, As, Fe) surpassed permissible limits, particularly in the wet season. Cyanide was detectable but within WHO standards. LULC analysis revealed major declines in forest and agricultural land, with increases in bare land and mining areas, confirming widespread land degradation and riverbank erosion. Classification accuracies exceeded 85% (Kappa > 0.80). Overall, the findings highlight the dual role of galamsey as a livelihood source and a driver of severe environmental degradation and social disruption. The study recommends integrated interventions combining alternative livelihood support, stricter regulation, improved water supply, community education, and sustained geospatial monitoring to safeguard public health and natural resources.

DEDICATION

This work is dedicated to Almighty God for His guidance and strength throughout this journey. I also dedicate it to my family, whose prayers, encouragement, and support have been my greatest inspiration.

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Finally, I would like to thank God for seeing me through all the difficulties. I have experienced his guidance day by day. Isaiah 60:22 in his Own time, he makes things happen. May he continue to guide and protect me

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ASGM	Artisanal and Small-Scale Gold Mining
LULC	Land Use and Land Cover
WHO	World Health Organization
UNEP	United Nations Environment Programme
FAO	Food and Agriculture Organization
IPCC	Intergovernmental Panel on Climate Change
GIS	Geographic Information System
GPS	Global Positioning System
ppm	Parts per million
µS/cm	Microsiemens per centimeter (unit of electrical conductivity)
TDS	Total Dissolved Solids
Pb	Lead
Hg	Mercury
Cd	Cadmium
As	Arsenic
Fe	Iron

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Gold mining has long served as a pillar of economic development globally (Sovacool et al., 2020). However, the environmental cost of extracting this precious metal has become increasingly hard to ignore. Across the world, gold mining is associated with land degradation, deforestation, mercury contamination, and disruption of water systems (Afum et al., 2020). Because of high demand for gold which is driven by its monetary value and its importance in electronics, jewellery, and reserve banking, there has been a corresponding rise in small-scale and artisanal mining operations that often go undetected (Kessey & Arko, 2013). A large part of the environmental crisis stems from artisanal and small-scale gold mining (ASGM), which contributes roughly 20% of the world's annual gold supply yet is responsible for 37% of global mercury emissions into the environment (UNEP, 2013). Mercury, used to bind gold particles in ore, contaminates soil and water, bioaccumulates in aquatic organisms, and poses long-term neurological risks to humans (Arah & Arah, 2014). In many parts of South America and Southeast Asia, entire river systems are now contaminated, posing multi-generational threats to local populations (Mcquilken & Hilson, 2016).

Furthermore, the intensification of mining due to the global energy transition and growing demand for critical minerals has pushed gold mining activities into fragile ecosystems, including tropical forests, protected areas, and river basins (Baffour-kyei et al., 2021). In Latin America, countries such as Peru and Brazil have struggled with unregulated gold rushes in rainforest regions, where miner's clear large tracts of land and dump mercury laced waste into rivers that cross national borders. According to the World Bank (2017), the environmental cost of such extractive activities is rarely compensated for by short-term economic gains, especially in areas where weak governance undermines environmental protections.

Africa holds a disproportionate share of the world's untapped mineral resources, including gold, diamonds, cobalt, and bauxite (Bansah et al., 2016). While these resources offer tremendous economic opportunities, the mining sector in many African countries is marred by unsustainable practices. Artisanal and small-scale mining, in particular, has surged across the continent due to limited access to formal employment, weak land tenure systems, and high international gold prices (Arthur et al., 2016). In the Democratic Republic of Congo, artisanal mining has led to deforestation, river siltation, and toxic chemical use (Mulligan et al., 2011). In Nigeria, gold mining has resulted in lead poisoning in Zamfara State, affecting hundreds of children due to contaminated soil and dust (Gorman & Dzombak, 2018). In many of these cases, weak state capacity, corruption, and the informal nature of ASGM create significant barriers to implementing sustainable practices (Mensah et al., 2015).

While the African Union's "Africa Mining Vision" aims to promote sustainable mining that benefits citizens and protects the environment, enforcement remains uneven across member states. Many rural mining communities still face water insecurity, soil contamination, and health complications due to poor regulation (Essah & Andrews, 2016). Moreover, artisanal miners often operate in environments with no access to personal protective equipment or knowledge of safe practices, further exacerbating environmental and public health risks (Haque et al., 2014).

Ghana, once named the "Gold Coast" by European traders, remains one of the largest gold producers in Africa (Clarke, et al., 2015). The mining sector contributes about 5% of Ghana's GDP and over 40% of its total exports (Ghana Chamber of Mines, 2020). Yet, a large segment of this production is unaccounted for, originating from illegal small-scale mining.

The term ‘galamsey’ refers to informal, often illegal gold mining activities conducted by individuals or groups using rudimentary tools. While galamsey has become a lifeline for many rural unemployed youths, its environmental consequences are staggering. According to BaffourKyei et al. (2021), the upsurge of galamsey operations across Ghana has led to the destruction of forest reserves, widespread deforestation, degradation of farmlands, and the contamination of major river systems.

The environmental costs are especially visible in the country's major river basins such as the Offin, Pra, and Ankobra. Illegal miners use water-intensive techniques, including dredging and gold panning, which disrupt aquatic life and release large amounts of silt and pollutants into the water (Rajaee et al., 2015). Mercury use in these operations poses an additional danger, contaminating rivers and leading to the bioaccumulation of toxic metals in fish consumed by local communities (Wilson et al., 2015).

Galamsey also disrupts the social fabric of rural communities. As land is repurposed for mining, conflicts often arise between miners and farmers over land rights (Clarke, 2015). Moreover, the sudden influx of wealth and population into galamsey-prone areas often leads to increased crime, child labor, and the erosion of traditional community values (Renne, et al., 2015)

Located in the Ahafo Ano South West District of the Ashanti Region, Mankranso is emblematic of the complex interplay between resource extraction and environmental degradation. The district is endowed with rich gold deposits and sits within a forested ecological zone. Over the past decade, the area has seen a significant rise in galamsey activity, much of it conducted within the forest reserves and near water bodies.

Water bodies such as the Mankran, Nwini, and tributaries of the Offin River, which pass through or near Mankranso, have recorded visible signs of pollution. Residents have reported discoloration of water, fish kills, and increased incidences of waterborne diseases. Yet despite efforts by state agencies and task forces, illegal mining persists, often operating at night or with the collusion of local authorities (Laurence, 2011).

Environmental degradation in Mankranso is compounded by limited monitoring and enforcement. The Forestry Commission and Environmental Protection Agency (EPA) have often cited logistical and resource constraints in their ability to patrol and reclaim mined lands (Nyame & Blocher, 2010). Furthermore, most illegal mining sites do not undergo environmental impact assessments (EIA), nor do they adhere to land reclamation protocols outlined under Ghana's Environmental Assessment Regulations, 1999 (LI 1652). Perhaps the most alarming impact of illegal mining in Mankranso is on water quality. In areas where mining tailings are disposed of into rivers or directly on land, water sources show high turbidity and elevated concentrations of heavy metals such as mercury (Hg), arsenic (As), and cadmium (Cd). These elements not only impair the potability of water but pose long-term health risks, especially for children and pregnant women. Chronic exposure to low levels of mercury, for example, can lead to neurological damage, developmental delays, and kidney dysfunction (Osei et al., 2021).

Moreover, heavy metal pollution is not easily reversed. These contaminants bind with sediments in riverbeds and persist long after mining has ceased. They also accumulate in fish, posing dietary risks to local communities who rely on fishing as both a livelihood and a nutritional source (Prior et al., 2012). This environmental burden disproportionately affects the rural poor, who are often the least equipped to mitigate or adapt to the impacts of water pollution (Teschner, 2012).

Efforts to regulate and formalize artisanal mining in Ghana have had limited success. The Multilateral Mining Integration Project and the Small-Scale Mining Policy Frameworks introduced

over the years have struggled with enforcement, funding, and political will. Interventions such as Operation Vanguard, a military task force set up to combat galamsey, have had temporary successes but lacked the community engagement necessary for long-term
sustainability (Osei et al., 2021).

Sustainable environmental management in areas like Mankranso must therefore go beyond enforcement. It requires integrated strategies that combine environmental monitoring, community education, alternative livelihood programs, and participatory land-use planning. Moreover, datadriven environmental assessments and regular water quality monitoring are needed to guide policy interventions and public health responses.

Academic and policy attention must also turn toward assessing localized impacts. While numerous studies have evaluated mining-related pollution at the national or regional level, fewer have conducted deep-dive assessments into specific districts like Mankranso. This research aims to bridge that gap by providing empirical data on the extent of environmental and water quality degradation caused by illegal gold mining in the district.

1.2 Statement of the Problems

Illegal artisanal and small-scale gold mining (locally known as galamsey) has become a major environmental and socioeconomic concern in Ghana. Although mining has long contributed to the nation's economic development, the increasing prevalence of unregulated artisanal mining has resulted in extensive land degradation, deforestation, water pollution, and the destruction of aquatic ecosystems. Beyond the environmental effects, galamsey activities have disrupted local livelihoods, altered social structures, and created health and safety risks for communities in mining areas.

Previous studies on artisanal mining in Ghana have mainly focused on its economic importance and the challenges of formalization. However, limited research has systematically evaluated the combined environmental, social, and economic impacts of illegal mining on local communities. More importantly, there is a lack of integrated assessments that link these impacts to policy and governance failures at the district level. This gap in understanding weakens efforts by the Environmental Protection Agency (EPA) and the Ministry of Lands and Natural Resources to develop effective regulatory interventions.

Therefore, this study seeks to assess the environmental and socioeconomic impacts of illegal artisanal and small-scale gold mining activities in selected mining communities in Ghana, with the aim of generating evidence-based insights to support more sustainable community and policy responses.

Justification

This study is significant for several reasons. First, it provides a holistic assessment that integrates the environmental, social, and economic dimensions of galamsey activities, an approach often missing from earlier research. The findings will help policymakers, local assemblies, and environmental agencies understand the complex trade-offs between livelihood sustenance and environmental conservation.

Second, the study offers insights that can inform policy reforms and enforcement strategies by the EPA, the Minerals Commission, and local governments. It also contributes to academic knowledge by filling the identified gap regarding the interplay between illegal mining and community wellbeing.

Finally, by situating the problem within the Ghanaian context, the research supports national and international efforts toward achieving the Sustainable Development Goals (SDGs), particularly Goal 8 (Decent Work and Economic Growth), Goal 13 (Climate Action), and Goal 15 (Life on Land).

1.3 Research Questions

1. What are the socioeconomic impacts of illegal gold mining on livelihoods and community wellbeing in Mankranso?
2. What are the levels of heavy metals and physicochemical parameters in river water samples from mining areas in Mankranso, and how do they compare with permissible standards?
3. What are the patterns of land use and land cover (LULC) changes in Mankranso between 2015 and 2025, and to what extent has illegal gold mining contributed to land and forest degradation?

1.4 Objectives of the Study

1.4.1 Main Objectives

To assess the socioeconomic, environmental, and water quality impacts of illegal gold mining (galamsey) in Mankranso and evaluate their implications for sustainable environmental management.

1.4.2 Specific Objectives

1. To examine the socioeconomic impacts of illegal gold mining on livelihoods and community wellbeing in Mankranso
2. To determine the levels of heavy metals and the physicochemical characteristics of the river due to the mining in Mankranso.

3. To analyse land use and land cover (LULC) changes from 2015 to 2025 in Mankranso, focusing on the extent of land and forest degradation caused by illegal gold mining.

1.5 Scope and Limitations of the Study.

The project considered the chemical and physicochemical components of mined sites by carrying out tests on acquired samples. 372 respondents from different sections and sectors of the community, such as farmers, police personnel, fishermen, illegal miners (young and adults), and health workers, were interviewed to seek in-depth knowledge of the practice and its implications on their livelihood. Global Positioning System data was taken and analyzed in ArcGIS to determine the extent of degradation from past years and to the current year. The study focuses on illegal gold mining activities in Mankranso and their environmental consequences. Its scope is limited to land and water resource impacts, institutional responses, and sustainability implications. Some challenges encountered during the execution of the project were:

i. The data collection process was hindered as a result of the absence of some intended respondents for the interview. ii. Respondents, such as illegal miners, were defensive and held relevant information for the project due to security reasons.

1.7 Organisation of the Study

Chapter one introduces the general background to the study, the research problem, the research questions and objectives, the importance of the study and the limitations and challenges encountered during the project execution. Chapter two comprehensively talked about the detrimental effects illegal mining has on human and agricultural, and highlighting water quality assessments. The chemical composition and toxicology of the chemicals used in the mining process were also covered. Chapter three introduced the study area and clearly spelt out the qualitative and quantitative methods adopted to collect data, the water sampling, GPS data acquisition, the data processing and analysis and ethical consideration. Chapter four elucidates findings from the data analysis and discusses the physicochemical parameters of the water samples. Chapter five summarises the study, draws conclusions from the respondents and laboratory analysis and gives recommendations on the way forward to mitigate and curb further destruction by the activity.

CHAPTER TWO

LITERATURE REVIEW

2.1. Global and Regional Environmental Impacts of Illegal Gold Mining

Illegal gold mining has emerged as a pressing global environmental challenge (Addo Tuffuor et al., 2024). While gold remains a critical commodity for economic development, currency reserves, and technological advancement, the methods used to extract it, especially in unregulated settings are environmentally destructive, socially disruptive, and difficult to control (Agyemang et al., 2021). The global demand for gold, influenced by industrial applications and investment markets, has incentivized rapid expansion of ASGM, particularly in developing regions where regulatory oversight is weak and enforcement mechanisms are poorly resourced (Ismail Kervankiran, 2016). ASGM accounts for approximately 20% of the world's gold output, yet it is responsible for a disproportionate share of environmental damage, contributing an estimated 37% of global mercury emissions, according to the United Nations Environment Programme (UNEP, 2013). Mercury is often used in ASGM to bind fine gold particles, despite its toxicity (Yiridomoh, 2021). This process, known as amalgamation, is widespread due to its simplicity and low cost. However, it introduces mercury directly into the environment, where it can contaminate soils, leach into water systems, and volatilize into the atmosphere. Once released, mercury converts into methylmercury, a neurotoxic compound that bioaccumulates in aquatic food chains and affects human populations through fish consumption and water exposure (Mensah & Tuokuu, 2023).

The environmental effects of illegal gold mining are neither isolated nor short-lived. Across South America, particularly in the Amazon basin of Peru, Brazil, and Colombia, unregulated mining operations have led to the deforestation of millions of hectares of tropical rainforest (Ngom et al., 2023). These activities not only destroy plant and animal habitats but also release sediments and toxic chemicals into rivers, leading to turbidity, loss of aquatic biodiversity, and community displacement (Armah et al., 2013). Satellite imagery from the Monitoring of the Andean Amazon Project (MAAP) has shown how ASGM operations have permanently altered forest ecosystems and river courses, leading to massive ecological fragmentation in areas that serve as global carbon sinks and biodiversity hotspots (Ngom et al., 2023).Similarly, in Southeast Asia, countries like Indonesia and the Philippines face extensive environmental degradation in coastal and forest regions due to ASGM (Casso-Hartmann et al., 2022). Mangrove forests, critical for coastal protection, biodiversity, and fisheries are frequently destroyed to access shallow gold deposits (Gilbert & Albert, 2016). In Indonesia, mercury contamination in artisanal mining zones has reached such levels that entire communities have shown signs of mercury poisoning, with children particularly at risk due to developmental sensitivity (UNEP, 2013; Bawa et al., 2022). Africa presents a particularly complex scenario. Rich in mineral resources, the continent hosts millions of artisanal miners who engage in unregulated gold extraction as a survival strategy amid limited employment opportunities, land tenure insecurity, and fluctuating global commodity prices (Agyemang et al., 2021). While these activities offer livelihood options, they often operate outside formal governance structures and without regard for environmental impact assessments or sustainable land-use planning (A. Kuffour et al., 2020). In the Democratic Republic of Congo (DRC), for example, ASGM is linked to widespread deforestation, river siltation, and contamination from both mercury and cyanide (Barenblitt et al., 2021). Likewise, in Nigeria's Zamfara State, artisanal gold mining was directly implicated in lead poisoning outbreaks that killed hundreds of children and affected thousands more through contaminated soil and dust.

Ghana, as one of Africa's top gold producers, exemplifies both the potential and the peril of illegal mining. Historically dubbed the "Gold Coast," the country's mining sector contributes over 5% to national GDP and more than 40% of export earnings (Ghana Chamber of Mines, 2020). However, research by Asare et al. (2024) shows a significant portion of Ghana's gold output comes from informal sources, primarily illegal mining operations known locally as "galamsey". These activities have proliferated rapidly over the past two decades due to population pressures, unemployment, and the lure of quick profits. Unfortunately, their environmental toll has been severe. River basins such as the Pra, Ankobra, and Offin have experienced extreme sedimentation, aquatic habitat destruction, and mercury contamination (Nti et al., 2024).

Illegal gold mining in Ghana is deeply embedded in social, political, and economic systems (Kuffour et al., 2020). Many galamsey operators are organised into informal networks, sometimes with the backing of powerful politicians or traditional authorities who benefit economically from the practice. While the Minerals and Mining Act (2006) and the Environmental Assessment Regulations (1999) set out clear protocols for licensing and environmental compliance, these are rarely enforced in galamsey. As a result, many communities experience the environmental costs of mining: deforestation, contaminated water, and degraded agricultural land without reaping the economic benefits (Owusu-Prempeh et al., 2022). In addition to ecological damage, illegal gold mining contributes to the weakening of institutions and the rule of law (Kuffour et al., 2020). The presence of unregulated mining often leads to disputes over land use, increased crime, child labor, and breakdowns in community cohesion. Traditional livelihoods such as farming and fishing become unsustainable due to soil and water degradation, forcing more individuals into mining and deepening cycles of poverty and environmental exploitation (Asare et al., 2024). Once noted as an agricultural zone with forested ecosystems and clean river systems, the area has seen an influx of galamsey operators exploiting gold-rich soils with little regard for environmental sustainability. Rivers like the Mankran and Nwini, which feed into the Offin basin, are visibly polluted and farmlands have been converted into mining pits. The ecological transformation of Mankranso mirrors national and global trends: the shift from subsistence livelihoods to environmentally destructive activities due to poor regulation, economic desperation, and governance failure (Hilson, 2002).

In summary, the global and regional literature converges on a clear conclusion that while artisanal and small-scale gold mining can provide economic benefits in resource-rich but infrastructurepoor settings, it also produces severe environmental impacts (Wireko-Gyebi et al., 2020). These include mercury pollution, forest and biodiversity loss, sedimentation of waterways, and contamination of soils and aquifers. The challenge is acute in countries like Ghana, where the scale of illegal mining and the fragility of environmental institutions make mitigation difficult. The case of Mankranso encapsulates this crisis and serves as a microcosm of the ecological destruction that unfolds when mineral extraction proceeds without environmental planning, regulation, or community safeguards (Asamoah et al., 2018).

2.1.2 Conceptual Framework

Illegal mining (galamsey) in Ghana presents an interconnected challenge spanning environmental degradation, socioeconomic disruption, and weak institutional governance. To holistically assess these dimensions, the study adopts an integrated framework that connects illegal mining activities, environmental and socioeconomic impacts, and policy responses.

1. Core Constructs and Linkages

i. Illegal Mining Drivers: Poverty, unemployment, weak enforcement, and political patronage are central drivers (Anoyege & Alatinga, 2024).

ii. Environmental Impacts: Include deforestation, soil erosion, and water contamination (Mestanza-Ramón et al., 2022).

iii. Socioeconomic Consequences: While illegal mining provides income for marginalized groups, it undermines agricultural productivity, health, and local governance (Appiah et al., 2024; Gyekye et al., 2023).

iv. Spatial Dimension: Spatial analysis through GIS and Remote Sensing enables mapping of deforestation, pollution hotspots, and land cover changes, linking physical patterns to social and economic variables (Adusei et al., 2024).

v. Policy and Institutional Context: Weak monitoring and fragmented policy implementation exacerbate these impacts (Asare et al., 2024).

Recent literature (Casso-Hartmann et al., 2022; E. K. Nti et al., 2024; Owusu-Prempeh et al., 2022) suggests hybrid methodologies, combining geospatial data with participatory GIS and ground validation to produce robust, multi-scalar assessments. For instance, AI-assisted remote sensing now enables automated detection of mining sites (Ofori et al., 2024), while participatory mapping enhances local accountability (Chakuya et al., 2023).

2.2. Water Quality Degradation and Heavy Metal Contamination from Illegal Gold Mining

Water is a critical natural resource whose integrity underpins public health, food security, and ecological sustainability (Armah et al., 2013). However, illegal gold mining, especially when carried out using rudimentary tools and unacceptable methods, poses one of the most significant threats to water quality in gold-rich regions across the globe. The unregulated use of mercury, exposure of sediments, and direct discharge of untreated waste into rivers and streams degrade water bodies both chemically and physically, with far-reaching consequences for human and environmental well-being. In Ghana, these impacts are becoming increasingly severe and visible, demanding urgent scholarly and policy attention (Bagah et al., 2016).

One of the main causes of water pollution in illegal gold mining is the widespread use of mercury amalgamation (Bawa et al., 2022). Mercury is used to bind with gold particles during the extraction process, forming an amalgam that is later heated to evaporate the mercury and isolate the gold (Adusei et al., 2024). This process is convenient and inexpensive for small-scale miners but is ecologically disastrous. Mercury is released into rivers, either directly during sluicing or indirectly through soil runoff, especially during rainfall. Once in the aquatic system, mercury is transformed into methylmercury, a potent neurotoxin that accumulates in fish and other aquatic organisms and poses a serious health risk to humans who consume contaminated water or aquatic life (Daemane, 2012).

Scientific studies conducted in various parts of Ghana, including Dunkwa-on-Offin and Tarkwa, have revealed that rivers near illegal mining activities exhibit mercury concentrations far above the permissible limits set by the World Health Organization (WHO) and Ghana Standards Authority (GSA). According to Appiah et al. (2024), hair samples collected from residents in such communities consistently showed elevated levels of mercury, often surpassing reference levels linked to neurological and kidney dysfunction. These findings align with global patterns observed in South America and Southeast Asia, where communities living near ASGM sites exhibit similar contamination profiles and health symptoms.

In Mankranso, preliminary observations and community reports strongly suggest that water bodies such as the Mankran have become unsafe for consumption. Residents have reported the discoloration of river water, the death of aquatic species, and an increased frequency of skin irritation, gastrointestinal infections, and unexplained illness all of which are consistent with exposure to polluted water (Milstein & Castro-Sotomayor, 2020). These signs serve as qualitative evidence of the deteriorating state of local water sources, though empirical testing of chemical concentrations is needed to quantify the severity. In addition to mercury, other heavy metals commonly associated with illegal mining include arsenic (As), cadmium (Cd), lead (Pb), chromium (Cr), and zinc (Zn). These metals are often embedded in gold-bearing ores and are released into the environment during excavation and ore processing. In areas where tailings and waste rock are dumped without containment measures, rainwater can leach these contaminants into groundwater and surface water sources. In some parts of Ghana, arsenic concentrations in rivers have exceeded the WHO guideline value of 0.01 mg/L, raising concerns about cancer risks, skin lesions, and long-term cardiovascular effects (Asare et al., 2024; Milstein & CastroSotomayor, 2020; Owusu-Prempeh et al., 2022).

Cadmium, although less commonly discussed, is concerning due to its persistence and cumulative toxicity. Long-term exposure to cadmium in drinking water has been linked to bone demineralization, renal failure, and hypertension. In mining-affected communities, cadmium levels are often under-reported, despite emerging evidence of their contribution to chronic disease profiles (Appiah et al., 2024).

Lead, on the other hand, is dangerous for its impact on cognitive development in children (Anoyege & Alatinga, 2024). Its presence in water sources especially in communities with limited access to alternative potable supplies, poses a hidden public health crisis, with implications that span generations (Armah et al., 2010).

Water pollution from illegal mining also includes physical degradation, notably increased turbidity and sediment loading. During dredging, panning, and sluicing, miners disturb large amounts of soil and riverbed material. This material is washed downstream, increasing the total suspended solids (TSS) and turbidity of water bodies. High turbidity affects light penetration, disrupting photosynthesis in aquatic plants and degrading aquatic habitats (Andrews, 2015). Fish and invertebrates suffer oxygen deprivation, and breeding grounds are destroyed. These conditions lead to declines in fish populations, affecting both biodiversity and the livelihoods of fisherfolk in communities like Mankranso (Asamoah et al., 2018; Gyekye et al., 2023).

The bioaccumulation of heavy metals in aquatic species is another major concern. Fish, crustaceans, and molluscs exposed to contaminated water accumulate metals in their tissues. Consumption of these species by humans introduces these toxins into the food chain. Attua et al., (2014) note that in Ghanaian communities, tilapia and catfish, which are the most consumed local fish, often test positive for mercury and arsenic when sourced near illegal mining sites. Chronic ingestion of contaminated fish can lead to mercury poisoning, which manifests as fatigue, headaches, motor dysfunction, and behavioral disturbances (Asamoah et al., 2018). Such symptoms may not always be immediately linked to environmental exposure, leading to misdiagnosis and underreporting in rural health facilities.

One dangerous characteristic of heavy metals is that they do not degrade over time (Adusei et al., 2024). Metals such as mercury, arsenic, and cadmium become embedded in riverbed sediments and persist long after mining activities have ceased. During the rainy season or in periods of strong water flow, these sediments are often resuspended, spreading pollutants to previously unaffected areas (Adomako, 2019). This cyclical disturbance makes pollution control extremely difficult and highlights the importance of upstream monitoring and source control (Al-Hassan & Amoako, 2014)

The socio-economic implications of water degradation are profound. In many affected communities, including those in the Mankranso area, rivers serve as primary sources of drinking water, irrigation, domestic use, and fishing. As water quality declines, households are forced to spend scarce resources on bottled or sachet water. Irrigated crops may absorb contaminants, introducing additional exposure pathways. The cost of health care also rises as families' deal with illnesses that may be indirectly caused by polluted water. For women and children, who often bear the burden of water collection, the degradation of nearby water sources leads to increased time and effort spent fetching clean water from distant locations, reducing time for education and incomegenerating activities (Gyekye et al., 2023)

Moreover, the lack of reliable data on water contamination in galamsey-affected communities compounds the problem. Regulatory agencies like the EPA and Water Resources Commission often lack the funding, equipment, or personnel to carry out routine testing. This data gap hinders evidence-based policymaking and weakens the accountability of polluters. In some districts, civil society organizations have stepped in to fill this gap, but their efforts remain sporadic and underfunded (Appiah et al., 2024; Bagah et al., 2016)

To combat these challenges, researchers and environmentalists have advocated for water quality monitoring frameworks that incorporate both laboratory testing and community-based observation. Early warning systems, and mobile water testing kits could be used to empower residents with real-time information about the safety of their water sources. Additionally, the use of geospatial technologies such as remote sensing and GIS, can support the identification of highrisk areas and track the spatial spread of pollution over time (Álvarez-Berríos et al., 2021)

The degradation of water quality due to illegal gold mining is not only a local environmental issue but a public health and development crisis. The evidence from Ghana and other gold-producing regions clearly shows that unregulated mining introduces a suite of pollutants into aquatic systems, most notably mercury and other heavy metals that compromise water safety, human health, and ecosystem function (Limited & Engineering, n.d.). In Mankranso, the urgent need for comprehensive water monitoring, pollution control, and community engagement cannot be overstated. Protecting water resources must be a central pillar of any sustainable environmental management strategy in the region.

2.3. Health Risks Associated with Contaminated Water in Mining Communities

Access to clean water is essential for the survival and development of human populations, especially in rural communities where water serves not only as a drinking source but also supports sanitation, agriculture, and livestock (Adomako, 2019). However, the expansion of illegal gold mining, has compromised the integrity of water sources in many parts of Ghana. Communities such as Mankranso, face growing health challenges directly linked to contaminated water bodies, resulting in a range of acute and chronic health outcomes. These health effects are a direct consequence of both chemical and microbial pollutants introduced into the water systems through illegal mining operations (Al-Hassan & Amoako, 2014; Attua et al., 2014). A major health risk associated with illegal mining is the release of toxic heavy metals such as mercury (Hg), arsenic (As), lead (Pb), cadmium (Cd), and chromium (Cr) into rivers and groundwater systems. These metals are either intentionally introduced (such as mercury used in gold amalgamation) or are mobilized from ores and soils during mining activities (Bansah et al., 2018). Mercury, in particular, poses an acute and long-term hazard. When released into rivers, mercury can undergo methylation, a process that transforms it into methylmercury, a highly toxic and bioavailable form that accumulates in aquatic life and ultimately enters the human food chain through fish consumption (Suglo et al., 2021).

Methylmercury exposure has been extensively studied and is linked to neurological and developmental disorders (Adusei et al., 2024). In communities where fish is a dietary staple, continuous low-dose exposure has been associated with tremors, memory loss, impaired vision, hearing loss, and motor dysfunction (A. Kuffour et al., 2020). For pregnant women, the effects are even higher. Mercury can cross the placental barrier, disrupting fetal brain development and resulting in cognitive impairments, reduced IQ, and motor coordination issues in children (Appiah et al., 2024). In some mining impacted districts of Ghana, hair and urine samples collected from residents have tested positive for mercury levels far exceeding safe limits, and these indicates urgent intervention (Bagah et al., 2016).

Arsenic is another dangerous contaminant commonly found in gold-rich geologies (Duncan, 2020). It is often mobilized into groundwater and surface water during ore processing. Long-term arsenic ingestion can cause skin lesions, keratosis, bladder and skin cancers, cardiovascular disease, and diabetes (Casso-Hartmann et al., 2022). In high concentrations, arsenic can also lead to vomiting, abdominal pain, and diarrhea, compounding the public health burden in communities already grappling with infectious diseases (Barenblitt et al., 2021). Affected individuals often present symptoms that mimic other illnesses, resulting in misdiagnosis and underreporting in primary healthcare facilities.

Lead exposure is equally concerning. Even small amounts of lead can cause significant neurodevelopmental effects in children, including learning disabilities, attention deficits, and behavioral problems (Hilson, 2002). Lead also accumulates in bones and can remain in the body for decades, posing risks of anemia, hypertension, renal dysfunction, and reproductive issues in adults (Armah et al., 2013). Cases from illegal mining towns in Ghana show higher-than-normal blood lead levels in children, attributed to both direct ingestion of contaminated water and indirect exposure via dust and soil (Appiah et al., 2024).

Cadmium toxicity primarily affects the kidneys, liver, and bones (Milstein & Castro-Sotomayor, 2020). Chronic exposure leads to renal tubular dysfunction, osteomalacia (softening of bones), and skeletal deformities (Andrews, 2015). Presence of heavy metals in water samples near mining zones has been confirmed in several environmental studies in Ghana (**Table 2.**1), reinforcing the need for comprehensive water quality surveillance.

Table 2. 1: Summary of considered heavy metals, sources and their key findings

Study	**Sources**	**Heavy Metals Considered**	**Key Findings**	**Implications**

1: Zhang et al. (2019) (Owusu et al., 2019). (Okyere, Ayitey, & Ajabuin, 2021).	Mining activities	Lead, Cadmium	Elevated levels of Pb, Cd, and Zn in soil and water near mining sites. Significant impact on soil quality and water contamination.	Potential health risks for local communities due to exposure to contaminated soil and water. Increased environmental degradation.
2: (Keane et al., 2023) (Arifin et al., 2020) (Aram et al., 2021)	Mining emissions	Mercury	High concentrations of mercury emissions from gold mining causing widespread contamination of water bodies and fish.	Health risks from mercury exposure through contaminated fish consumption. Need for strict regulation and control of mining emissions.
3: Li et al. (2020)	Mine tailings	Arsenic, Chromium	Presence of high levels of arsenic and chromium in mine tailings. Contamination of groundwater observed, posing risks to nearby communities' water sources.	Long-term health risks, including cancer and other serious health issues due to prolonged exposure to arsenic and chromium.
4:UNEP (United Nations Environment Programme) (2019)	Mining activities	Lead, Mercury, Cadmium	Global assessment highlighting the pervasive impacts of mining activities on heavy metal contamination, leading to soil degradation, water pollution, and health risks in affected communities.	Urgent need for stricter regulations, effective waste management, and sustainable mining practices to mitigate environmental and health hazards.

In addition to chemical contaminants, illegal mining introduces physical and biological hazards to water systems (Boadi et al., 2016). Sediment-laden runoff from mining pits increases turbidity and disrupts aquatic ecosystems, reducing water oxygenation and increasing microbial growth (Attua et al., 2014). Stagnant pools left by abandoned mining sites serve as breeding grounds for mosquitoes, leading to increased incidence of vector-borne diseases such as malaria and dengue fever. In Mankranso and surrounding areas, malaria remains one of the top reported illnesses, with field data indicating a possible link between increased mining activities and higher malaria prevalence (Asare et al., 2024). Further**,** waterborne diseases are prevalent in areas where illegal mining degrades water quality (Adusei et al., 2024).

The absence of proper sanitation and the use of polluted rivers for bathing, washing, and cooking lead to the spread of diseases such as cholera, typhoid, giardiasis, and dysentery (Gyekye et al., 2023). The high turbidity and presence of organic matter in such waters facilitate the survival and proliferation of pathogenic bacteria, viruses, and protozoa (Adomako, 2019). In communities dependent on untreated surface water, these infections are common, particularly among children and the elderly (Bagah et al., 2016).

The health risks from contaminated water also have psychosocial and economic dimensions (Ismail Kervankiran, 2016)**.** Households affected by mining-induced pollution often bear the cost of medical treatment out of pocket. For low-income families, frequent illness means increased financial pressure, reduced income-generating capacity, and school absenteeism for children (Gilbert & Albert, 2016). Over time, these factors contribute to deepening poverty and reduced human capital development. In interviews conducted in affected regions, residents expressed growing anxiety about the long-term safety of their water and food, reflecting the mental health burden associated with environmental degradation (Mensah & Tuokuu, 2023).

In nearby communities around Mankranso, access to healthcare is already limited by distance and transportation costs. This means many illnesses related to water contamination go untreated or are managed through self-medication. Moreover, local health professionals often lack the training or equipment to detect environmental diseases or link them to specific contaminants. This diagnostic gap results in underreporting and weakens the case for targeted public health interventions. In most cases, the full scale of exposure is not captured due to the absence of biomonitoring systems that track contaminant levels in human tissues, such as blood, urine, or breast milk (Addo Tuffuor et al., 2024).

Environmental exposure also affects reproductive health. Several studies have documented increased miscarriage rates, low birth weights, and stillbirths in areas heavily impacted by mining. These outcomes are consistent with exposure to lead, mercury, and arsenic, all of which interfere with fetal development and hormonal regulation. In the long term, chronic exposure to heavy metals may also impair fertility, leading to reduced birth rates and reproductive complications in both men and women (Armah et al., 2013).

Alarmingly, these health effects are cumulative and often irreversible (Appiah et al., 2024). Unlike biological agents that can be treated with antibiotics or managed through vaccination, heavy metals accumulate in tissues over time. This means that even when exposure is reduced or eliminated, the damage may continue to unfold, especially in vulnerable groups. For this reason, prevention through clean water access, pollution control, and community education is more effective than post-exposure treatment (Andrews, 2015).

To mitigate these health risks, several strategies must be adopted. First, routine water quality monitoring is essential. Local authorities, in partnership with universities and health research institutions, should conduct regular testing for both microbial and chemical contaminants. This would allow early detection of dangerous levels and enable timely public warnings and interventions (Adusei et al., 2024).

Second, there is a need to strengthen the public health system to recognize and respond to environmentally linked diseases. This involves training health workers, improving diagnostic infrastructure, and incorporating environmental health into public health planning. Community health nurses, often the first point of contact in rural areas, should be equipped with knowledge about the symptoms of heavy metal poisoning and waterborne illnesses (Gyekye et al., 2023). Third, access to clean water alternatives must be expanded. Investments in boreholes, protected wells, and rainwater harvesting systems can reduce dependency on polluted rivers. Equally important is community education on water safety, hygiene, and the dangers of consuming untreated water from mining-affected sources.

Finally, environmental governance must be enforced, and polluters must be held accountable, and illegal mining operations dismantled. Without addressing the root causes of water contamination, health interventions will only serve as temporary relief rather than lasting solutions (Bansah et al., 2018).

The health impacts of illegal gold mining on water quality are extensive, multifaceted, and deeply entrenched in the lives of affected populations (Suglo et al., 2021). From neurological disorders and organ damage to infectious diseases and reproductive failures, the consequences are not merely individual but systemic (Boadi et al., 2016). In Mankranso, as in many other rural Ghanaian districts, safeguarding public health will require a concerted effort involving environmental regulation, public health reform, water infrastructure investment, and empowered community participation (Eduful et al., 2020).

2.4. Land Degradation, Forest Loss, and Ecosystem Disruption Due to Illegal Mining

Illegal gold mining is not only a major cause of water pollution and human health risks, it also wreaks devastating impacts on land, vegetation cover, and entire ecosystems (Chakuya et al., 2023). In Ghana, illegal gold mining has become synonymous with the widespread degradation of arable land, deforestation, and the collapse of ecosystem (Al-Hassan & Amoako, 2014). These land-based consequences are profound and long-lasting, often leaving landscapes ecologically and economically barren long after mining operations have ceased (Adomako, 2019).

A study by Ayelazuno & Mawuko-Yevugah (2019) states that mechanisms of land degradation in illegal mining zones are both direct and indirect. Directly, land is cleared of vegetation to access gold-bearing soils. Excavation pits are dug manually or with excavators without any consideration for slope stability, erosion control, or post-mining reclamation. Indirectly, the opening of mine sites leads to the development of informal access roads, trampling of vegetation, displacement of wildlife, and an influx of migrant laborers who place additional pressure on the local environment. In districts such as Mankranso, this has resulted in the conversion of farmlands and forest reserves into barren, cratered landscapes, often devoid of productivity and unsuitable for any alternative land use (Tom-Dery et al., 2012).

One of the most visible consequences of illegal mining is deforestation, which in Ghana is occurring at alarming rates. The Ashanti Region, historically known for its lush semi-deciduous forests and biodiversity, has witnessed a dramatic loss of tree cover due to mining encroachments (Emmanuel et al., 2018). Remote sensing analyses have shown that forest loss in Ghana's mining belts increased by more than 60% between 2000 and 2020, with illegal mining accounting for a significant portion of this change (Serwajja & Mukwaya, 2021). These deforestation rates surpass national averages and point to a crisis in ecological integrity and forest governance.

Forests perform several critical ecological functions, from regulating local microclimates and preserving biodiversity to preventing soil erosion and recharging aquifers. In Mankranso, forests protect watersheds like the Offin River Basin and act as buffer zones that support both ecological and social resilience. When these forests are cleared for galamsey activities, the resulting loss of canopy cover leads to erosion, increases surface runoff, reduces infiltration rates, and raises the risk of flash floods during the rainy season (Asiedu-Amoako et al., 2016).

Moreover, the indiscriminate removal of vegetation also affects soil quality and fertility. The topsoil, rich in organic matter and microorganisms essential for plant growth, is often scraped off during surface mining. Mining tailings composed of crushed ore, silt, and residual chemicals are dumped without containment, often spreading across wide areas through wind and water erosion. The chemical composition of tailings may include toxic metals like arsenic, mercury, cadmium, and chromium, which alter soil pH, reduce microbial activity, and inhibit vegetative regeneration (Ofori et al., 2024). In some areas, soil samples have shown heavy metal concentrations exceeding WHO limits for agricultural land, rendering them unsuitable for food production or forest regeneration for decades (Okyere, Ayitey, Ajabuin, et al., 2021).

Such chemical degradation of land not only disrupts plant growth but also affects food security (Bansah et al., 2018). Many residents in Mankranso rely on subsistence agriculture, growing crops like plantain, cassava, maize, and cocoa. When arable land is converted into mining pits or when remaining lands are contaminated by acid mine drainage or metal-rich dust, agricultural productivity declines sharply (Boadi et al., 2016). This leads to livelihood losses, food shortages, and rising tensions between farmers and miners, especially in areas with poorly defined land tenure (Attua et al., 2014; Bansah et al., 2018)

Beyond farmland, illegal mining often occurs in and around protected areas and forest reserves, which serve as habitats for endemic flora and fauna. The Ashanti Region hosts species of ecological and conservation interest, many of which are under threat due to habitat fragmentation and loss. Mining activities destroy breeding sites, disturb feeding patterns, and increase the risk of species extinction (Boadi et al., 2016). For example, the removal of vegetation and sedimentation of streams have been reported to reduce amphibian and insect diversity, disrupt bird nesting areas, and drive away mammalian species that are sensitive to human intrusion and noise (Chakuya et al., 2023).

The collapse of ecosystem services due to land degradation is evident in riparian zones, thus, the vegetated interfaces between land and rivers (Leone, 2025). These zones play an essential role in filtering pollutants, stabilizing banks, and supporting aquatic biodiversity. However, in many illegal mining zones, riparian vegetation has been completely removed, riverbanks have collapsed due to dredging, and entire streams have been diverted to serve mining needs (Adolph, 2016). In the Mankranso, for instance, rivers such as the Nwini and Mankran have experienced severe siltation and bank erosion due to the encroachment of miners. This leads to hydrological alterations that disrupt downstream ecosystems, damage farmlands through flooding, and increase the cost of water treatment for human consumption (Annan, 2024).

One of the most persistent and under-addressed consequences of illegal mining is the presence of abandoned mining pits and tailings dumps, which litter the landscape. These pits pose both environmental and safety hazards. They collect stagnant water, creating breeding grounds for mosquitoes and increasing the incidence of malaria and waterborne diseases (Olivia, 2015). During the rainy season, these pits may overflow, spreading contaminants over wider areas. Children and animals often fall into these pits, resulting in injuries or fatalities. The lack of land reclamation is a defining feature of illegal mining and stands in stark contrast to the requirements imposed on large-scale, legally operating mines (T. Nti et al., 2020).

Efforts to reclaim degraded land have been minimal and largely unsuccessful due to a lack of funding, weak institutional coordination, and the absence of community engagement (AsieduAmoako et al., 2016). The Environmental Protection Agency (EPA) and the Ministry of Lands and Natural Resources have developed policies for land rehabilitation, including the use of tailings backfill, topsoil replacement, and reforestation (Mensah & Tuokuu, 2023). However, these interventions have primarily targeted legal mining concessions and have not effectively extended to illegal sites. In the few pilot projects where reforestation has occurred, survival rates of planted seedlings have been low due to poor soil conditions, grazing by animals, and lack of follow-up maintenance (Amankwah, 2013).

Illegal mining often takes place on communal or family-owned lands, leading to disputes over access, compensation, and control (Annan, 2024). In Mankranso, chiefs and traditional authorities sometimes lease lands informally to miners without consulting landowners or following legal procedures. This creates tensions between generations, genders, and social classes, undermining traditional governance systems and exacerbating rural inequality (Mantey et al., 2020).

To address these challenges, there is a need for spatial mapping and monitoring of land degradation using satellite imagery and drones (Kinyondo & Huggins, 2021). Geospatial tools can help identify high-risk areas, monitor illegal encroachments in real time, and evaluate the effectiveness of reclamation activities. Such data can be integrated into district planning and environmental management frameworks to prioritize rehabilitation efforts (Duff & Downs, 2019).

A robust legal and institutional framework for land protection and restoration is important because this strengthens the enforcement capacity of the Forestry Commission, Lands Commission, and EPA at the district level. Joint taskforces that include chiefs, community watchdogs, and decentralized government representatives can enhance surveillance and local ownership of land protection measures (Espin & Perz, 2021). Community participation and benefit-sharing must be central to reclamation and land-use planning. When communities are involved in tree planting, land surveying, and ecological restoration as part of job creation or public works programs, they are more likely to protect reclaimed areas and discourage further degradation (Gyamfi et al., 2019). Projects such as the Ghana Forest Landscape Restoration Initiative and the Green Ghana Day campaign are important for community engagement and awareness creation.

Also, long-term ecological monitoring is essential to ensure that restored lands recover their function (Adolph, 2016). Soil testing, biodiversity assessments, and carbon stock measurements should be part of post-reclamation protocols (Ofori et al., 2024). This not only helps track progress but also provides scientific data that can attract funding from environmental donors, climate finance mechanisms (e.g., REDD+), and corporate social responsibility (CSR) programs by mining firms (Leone, 2025).

Land degradation due to illegal gold mining is a multi-dimensional crisis affecting soil fertility, food production, forest cover, biodiversity, and social cohesion (Fish, 2020). Reversing these trends will require sustained investment in land reclamation, ecological restoration, and community-based land governance (Serwajja & Mukwaya, 2021). Without such efforts, the scars left by illegal mining will remain etched into the landscape and the socio-economic setting for generations to come.

2.5. Institutional and Policy Gaps in Environmental Regulation and Enforcement

While Ghana possesses a fairly comprehensive set of environmental laws and regulatory frameworks to govern its mining sector, illegal gold mining remains widespread and largely unregulated (Adusei et al., 2024). The persistence of this phenomenon, shows deep-rooted institutional and policy gaps that continue to undermine environmental protection efforts (Milstein & Castro-Sotomayor, 2020). These gaps are not limited to technical or logistical shortfalls but are embedded in issues of governance, coordination, and enforcement capacity (Appiah et al., 2024).

2.5.1 Legislative Framework: Strong on Paper, Weak in Practice

Ghana's mining and environmental governance is anchored in several legal instruments. Key among them are:

a) The Environmental Protection Agency Act, 1994 (Act 490)
b) The Environmental Assessment Regulations, 1999 (LI 1652)
c) The Minerals and Mining Act, 2006 (Act 703)

d) The Water Resources Commission Act, 1996 (Act 522)

e) The Forestry Commission Act, 1999 (Act 571)

These laws outline provisions for environmental impact assessments (EIAs), reclamation bonding, water use permits, and penalties for environmental infractions. However, the problem lies not in the absence of legislation but in the failure of effective enforcement (Andrews, 2015). In many mining-affected communities, these laws are poorly enforced, or completely disregarded, especially when it comes to illegal operations (Gyekye et al., 2023). These operations are not registered, do not file environmental management plans, and often shift location rapidly to evade monitoring (Attua et al., 2014). Because galamsey miners operate outside the legal framework, they do not undergo mandatory EIAs, are not subjected to audits, and cannot be easily held accountable through formal legal channels (Adomako, 2019).

2.5.2 Institutional Overlap and Fragmentation

The Environmental Protection Agency (EPA), Minerals Commission, Forestry Commission, Water Resources Commission, and district assemblies all have some role in regulating mining and environmental activities (Amankwah, 2013). However, these institutions often operate in silos, with minimal coordination or shared data systems (Annan, 2024). For example, the Minerals Commission may grant reconnaissance or prospecting licenses in an area that overlaps with forest reserves or protected lands, without consulting the Forestry Commission (Olivia, 2015). Likewise, the EPA may lack the authority to shut down illegal mining sites unless accompanied by a directive from the Ministry of Lands and Natural Resources or law enforcement (T. Nti et al., 2020).

Moreover, district assemblies, although empowered to implement environmental by-laws often lack the technical expertise and funding to monitor mining activities or carry out land-use planning that incorporates environmental protection (adar BakhshBaloch, 2017). In Mankranso, for instance, local officers from the EPA or Forestry Commission face logistical challenges such as poor road access, and insufficient personnel to carry out inspections (Mantey et al., 2020).

2.5.3 Enforcement Challenges: Lack of Capacity and Political Will

Environmental regulators often operate with outdated equipment, insufficient laboratory support, and limited field mobility (Kinyondo & Huggins, 2021). Many district EPA offices have only a handful of staff, tasked with covering vast territories that include forests, rivers, and settlements vulnerable to illegal mining (Duff & Downs, 2019). This situation severely limits the frequency and quality of environmental monitoring, and makes it difficult to build credible cases against polluters (Espin & Perz, 2021). Illegal mining is a lucrative enterprise, generating quick profits for miners, middlemen, and sometimes influential political figures (Gyamfi et al., 2019). Reports have documented cases where local officials and politicians obstruct law enforcement efforts to protect their electoral support or personal interests (Yeboah, 2025). As a result, taskforces set up to curb galamsey, such as "Operation Vanguard" and "Operation Halt", often face resistance from within the system. Arrested miners are sometimes released without prosecution, and confiscated equipment may disappear or be returned without explanation (Hilson & Maconachie, 2020). This lack of accountability erodes public trust and shows that environmental laws can be ignored with impunity (Yeboah, 2025). In Mankranso and other mining-affected communities, residents are aware of the corruption and collusion that allow illegal operations to continue despite official bans. This leads to a sense of powerlessness and discourages community reporting or cooperation with environmental authorities (Banchirigah, 2008).

2.5.4 Formalization Failures

To address the challenges of unregulated mining, Ghana has attempted to formalize artisanal and small-scale mining (ASM). The Small-Scale Mining Act (1989) and later the Minerals and Mining Act (2006) outline a framework for licensing small-scale miners, provided they meet certain environmental and safety conditions (Mantey et al., 2020). In theory, formalization is supposed to bring galamsey operators under the purview of regulation, improve their access to better technologies, and ensure environmental compliance (Milanez & Puppim de Oliveira, 2013).

However, in practice, the formalization process has been ineffective and poorly managed as many miners complain about high costs of licensing, unclear land boundaries, and favoritism in permit issuance (Zvarivadza & Nhleko, 2018). As a result, the vast majority of small-scale miners continue to operate illegally. In Mankranso, efforts to register miners have yielded limited success, often due to a lack of trust in government processes and fears of increased taxation or operational restrictions (Bansah, 2019).

Further, the failure to provide adequate training, equipment, and incentives for environmentally responsible mining undermines the very goals of formalization. The formal sector becomes unattractive, while the informal sector continues to flourish unchecked (Eduful et al., 2020).

2.5.5 Data Deficiencies and Transparency Gaps

Many government agencies either do not collect detailed environmental data or fail to make it available for public scrutiny (Mantey et al., 2020). For instance, water quality testing in galamseyaffected rivers is often conducted irregularly, and the results are not published in a timely or accessible format (Adolph, 2016).

This data gap hampers evidence-based policymaking and makes it difficult for researchers, NGOs, and community groups to track trends, assess risks, or advocate for reforms (Duff & Downs, 2019). In Mankranso, there is no centralized database where residents can access real-time information about water pollution levels, land degradation patterns, or enforcement actions taken against illegal miners.

In contrast, other countries have developed environmental information systems that combine satellite imagery, field data, and community observations to monitor environmental degradation in real time (Bester & Groenewald, 2021). Ghana lags behind in adopting these technological innovations, despite having local universities and IT companies capable of supporting such initiatives (Duncan, 2020).

2.5.6 Limited Community Engagement

Another critical policy gap is the exclusion of communities from environmental decision-making. While Ghana's environmental laws mandate public consultation in EIAs and development planning, these provisions are often ignored or applied superficially (Duff & Downs, 2019). In mining-affected areas, most residents are not aware of their rights to participate in environmental governance, and few have been engaged in monitoring, restoration, or awareness programs (Kinyondo & Huggins, 2021).

When communities are left out of environmental governance, enforcement becomes a top-down affair, lacking legitimacy and sustainability. By contrast, community-based environmental management (CBEM) approaches where local residents participate in monitoring, restoration, and advocacy have shown greater success in curbing environmental degradation (Fish, 2020). The inclusion of traditional authorities, youth groups, farmers, and women's associations in environmental planning could significantly improve compliance and ownership of conservation efforts (Anoyege & Alatinga, 2024).

Ghana's institutional and policy environment presents a paradox: well-articulated laws exist to regulate mining and protect the environment, yet illegal mining persists, largely unchallenged (Mestanza-Ramón et al., 2022). The case of Mankranso reflects broader national and regional failures, marked by weak enforcement, poor coordination, political interference, and limited community engagement. Tackling these institutional gaps is not only essential for environmental sustainability but also for public health and social stability (Yeboah, 2025).

2.6 Use of Remote Sensing and GIS in Monitoring Environmental Impacts of Illegal Mining

Remote Sensing (RS) and Geographic Information Systems (GIS) have emerged as critical tools for understanding, mapping, and managing the complex spatial and temporal dynamics of environmental impacts related to illegal mining (Maconachie & Conteh, 2021). These technologies offer a non-intrusive, cost-effective, and data-rich alternative for authorities, researchers, and planners seeking to address the environmental crisis posed by galamsey operations (Bansah, 2019).

2.6.1 Remote Sensing and GIS Applications

Remote sensing refers to the collection of information about the Earth's surface from satellites, aircraft, or drones without making direct physical contact. It involves the use of sensors to detect and classify objects or features on Earth based on reflected or emitted radiation. Common sources of remotely sensed data include Landsat, Sentinel-2, MODIS, SPOT, and commercial satellites such as PlanetScope and WorldView (Anoyege & Alatinga, 2024).

GIS, on the other hand, is a framework for capturing, managing, analyzing, and visualizing spatial and geographic data. It allows users to overlay different data layers such as land cover, elevation, hydrology, and population on a digital map to detect patterns, relationships, and changes over time (Mestanza-Ramón et al., 2022). Together, remote sensing and GIS offer powerful capabilities for environmental monitoring, policy formulation, and spatial planning (Maconachie & Conteh, 2021).

2.6.2 Application in Mining-Related Environmental Monitoring

One of the most significant applications of RS and GIS in Ghana's mining is in land cover and land use change (LULC) detection. Through the comparison of multi-temporal satellite imagery, analysts can assess the extent of deforestation, land degradation, and expansion of mining effects over time (Madonsela et al., 2025). In Mankranso, where illegal mining is often carried out covertly in forest reserves, riparian zones, and agricultural lands, such tools are essential for documenting landscape transformation and identifying emerging hotspots (Duncan, 2020). For example, using NDVI (Normalized Difference Vegetation Index) derived from Landsat and Sentinel-2 imagery, researchers have been able to track vegetation loss in areas where mining has intensified (Eduful et al., 2020). A decline in NDVI values over time is a reliable indicator of deforestation and soil exposure which are common signs of mining activities. Similarly, supervised classification techniques, such as maximum likelihood or support vector machines, can be used to categorize land into classes like forest, water, built-up, bare soil, and mining sites, with high degrees of accuracy (Bester & Groenewald, 2021).

GIS modelling complements this by enabling the spatial overlay of mining locations with environmental risk layers such as slope stability, soil type, rainfall intensity, and population density (Zvarivadza & Nhleko, 2018). This can help identify areas most at risk of landslides, erosion, water contamination, or community displacement due to illegal mining activities

2.6.3 Monitoring Water Quality and Hydrological Impacts

Remote sensing is also increasingly being used to monitor water quality indicators, especially in regions where water bodies are vulnerable to mining-induced pollution (Eduful et al., 2020). Spectral indices such as the Turbidity Index (TI), Suspended Particulate Matter (SPM), and Normalized Difference Water Index (NDWI) allow analysts to detect sediment plumes, algal blooms, and chemical changes in rivers and lakes (Bester & Groenewald, 2021).

Satellite imagery has revealed that rivers flowing through illegal mining zones show higher reflectance in shortwave infrared bands, an indication of sedimentation and suspended solids (Gilbert & Albert, 2016). This makes it possible to assess not only where water quality is deteriorating but also how it evolves seasonally or in response to enforcement operations. GIS tools can further support watershed modeling, and this helps hydrologists to simulate how mining activities affect river flow patterns, groundwater recharge, and flood risk (Duncan, 2020). Digital elevation models (DEMs) and hydrological datasets can be used to trace pollutant pathways from mine sites to downstream communities (Anoyege & Alatinga, 2024). In Mankranso, such models could predict the movement of mercury concentrated runoff during the rainy season and inform early warning systems.

2.6.4 Detecting Illegal Mining Sites in Real-Time

Another key advantage of remote sensing is its ability to detect and monitor active illegal mining sites, including those hidden within dense forests or remote areas. High-resolution imagery from commercial satellites (e.g., PlanetScope, Maxar) or drone-based mapping can identify mining pits, access roads, campsites, and tailings ponds with spatial resolutions as fine as 0.5 meters (AlHassan & Amoako, 2014). These data are valuable for district-level enforcement teams who need georeferenced intelligence to carry out operations.

In recent years, the Ghana government has attempted to make use of Unmanned Aerial Vehicles (UAVs) to monitor galamsey activities, particularly in inaccessible forest zones (Andrews, 2015). In collaboration with institutions like the Forestry Commission, drone teams have flown missions over known hotspots, capturing high-resolution imagery that is processed and analyzed using GIS software to generate enforcement maps and land disturbance reports (Appiah et al., 2024). Moreover, emerging technologies such as machine learning and artificial intelligence (AI) are being applied to automate the detection of illegal mining sites from satellite images (Adusei et al., 2024). Algorithms trained on labeled mining features can scan large swathes of territory and flag areas showing the spatial signatures of galamsey, including color changes, bare soil patches, and unnatural topographic depressions (Daemane, 2012).

2.6.5 Community Mapping and Participatory GIS

Participatory GIS (PGIS) and community mapping initiatives allow residents to document and share their knowledge of mining impacts, including loss of farmland, pollution of local water sources, and encroachment into sacred groves or cultural heritage sites (Bagah et al., 2016).

At Kunsu, a suburb of Mankranso, the community has deep ancestral ties to the land, involving locals in environmental monitoring builds trust and improves the accuracy of data collection. Trained community members can use handheld GPS devices or mobile phones with mapping apps to record the coordinates of degraded areas, water sources, and health risk zones. These data points can then be integrated into GIS platforms and used to update land use plans, guide reclamation projects, and support advocacy campaigns. Participatory mapping also empowers communities to hold authorities accountable (Asamoah et al., 2018). Maps generated by local residents can be presented to district assemblies, the EPA, or the Minerals Commission during stakeholder engagements, reinforcing the legitimacy of their environmental concerns and ensuring that development decisions are informed by ground realities.

2.6.6 Challenges to Implementation

Despite the promise of remote sensing and GIS, several challenges hinder their full integration into Ghana's environmental governance. First is the issue of technical capacity (Wireko-Gyebi et al., 2020). Many district-level agencies lack the skilled personnel needed to interpret satellite imagery or use GIS software effectively. Although training programs have been introduced by NGOs and international partners, these remain limited in scale and continuity.

Second, infrastructure and resource limitations remain significant as high-resolution imagery from commercial satellites can be expensive, and UAV operations require permits, hardware, and data processing equipment that are not readily available in all districts (Hilson, 2002). Internet connectivity and data storage infrastructure are also inadequate in many field offices.

Third, there is a lack of institutional coordination and data sharing protocols among the various stakeholders, thus, regulators, researchers, civil society, and local government. In some cases, data collected by one agency is not shared with others due to bureaucratic silos, mistrust, or concerns about data ownership. Lastly, the legal framework around data use and surveillance is underdeveloped as questions remain about who owns drone imagery, how it can be used in legal proceedings, and what privacy rights communities have in relation to overhead monitoring. These concerns must be addressed through clear policies that balance environmental surveillance with human rights.

2.6.7 Policy Recommendations and Future Directions

To achieve the full potential of remote sensing and GIS in managing illegal mining impacts, several policy actions are recommended:

a) Capacity building: Invest in training programs for EPA staff, district planning officers, and community groups on satellite image interpretation, GIS mapping, and environmental modelling.

b) Infrastructure development: Provide district-level offices with the necessary equipment, example computers, software, data storage systems, and GPS units to support geospatial analysis.

c) Partnerships and collaborations: Encourage collaboration between government agencies, academic institutions, private GIS firms, and donor organizations to share data, develop monitoring frameworks, and build open-access platforms.

d) Legislative reforms: Update existing environmental laws to incorporate remote sensing and GIS as formal tools in environmental assessment, monitoring, and enforcement procedures.

e) Community inclusion: Institutionalize participatory mapping as a required component of local development planning, and ensure that local voices are reflected in GIS data layers used for policy and project design.

2.7. Strategies for Sustainable Environmental Management in Mining-Affected Communities.

The environmental devastation caused by illegal gold mining in Ghana underscores the urgent need for sustainable environmental management strategies that are pragmatic, inclusive, and adaptable. While enforcement-driven responses have been frequent, often involving military interventions and temporary shutdowns of illegal mining sites, such measures have not produced lasting results(The et al., 2024). The persistence of galamsey activities reveals the deep socioeconomic, institutional, and ecological complexities of the problem. According to Asare et al. (2024), sustainable environmental management must therefore go beyond punitive measures to address root causes, build community resilience, and restore ecological integrity.

2.7.1 Formalization of Small-Scale Mining

One of the most widely advocated strategies is the formalization of artisanal and small-scale mining (ASM). Formalization refers to the process of integrating informal or illegal miners into the legal economy through licensing, training, regulation, and technical support (E. K. Nti et al., 2024). The idea is that when miners are recognized and monitored by the state, they are more likely to adopt environmentally responsible practices.

In Ghana, attempts at formalization have faced numerous challenges, including:

a) Complex and lengthy licensing procedures
b) High application fees
c) Land access difficulties due to poor land tenure records
d) Mistrust between miners and regulatory authorities

To improve outcomes, formalization must be simplified, decentralized, and supported by technical extension services. This means reducing the bureaucratic hurdles in licensing, offering mobile registration units in rural areas like Kunsu and Mankranso, and linking miners to cooperatives or associations that can provide environmental training, credit access, and equipment. Additionally, certified miners should be provided with incentives such as tax breaks or priority access to green technologies based on their compliance with environmental guidelines (Casso-Hartmann et al., 2022).

2.7.2 Promotion of Alternative Livelihoods

Illegal mining often thrives in areas of economic deprivation where employment opportunities are scarce (Barenblitt et al., 2021). As such, any sustainable environmental management strategy must include alternative livelihood programs to divert people especially youth, from environmentally destructive practices.

Feasible alternatives for mining-prone areas include:

a) Agroforestry and cash crop farming: Cocoa, palm oil, and cashew farming can provide stable income if supported with access to inputs, markets, and land tenure security.
b) Aquaculture and fish farming: Especially relevant in areas where river pollution has decimated wild fish stocks.
c) Eco-tourism and forest conservation jobs: Using natural and cultural assets for economic gain.
d) Handicrafts, carpentry, and vocational training: Particularly for women and young adults not involved in mining.

2.7.3 Environmental Education and Awareness

Sustainable environmental management depends on public awareness and environmental literacy (Agyemang et al., 2021). Many miners and community members are unaware of the long-term impacts of mercury use, water pollution, or forest loss. Others may understand the risks but lack information about safer practices or alternatives.

Environmental education campaigns should:

a) Target schools, religious institutions, and market centres.
b) Use local languages and visual media (radio, posters, dramas).
c) Address the link between environmental degradation and health risks (e.g., mercury poisoning, waterborne disease).
d) Promote positive behaviour change, such as tree planting or waste disposal habits.

Education is especially critical for children and youth, who will become future stewards of the environment. Integrating environmental topics into school curricula and organizing youth-led clean-up or tree planting activities can build long-term environmental consciousness (Ngom et al., 2023).

2.7.4 Technology Transfer and Cleaner Mining Practices

A major contributor to environmental degradation is the use of rudimentary and unsafe mining technologies (Addo Tuffuor et al., 2024). Mercury amalgamation causes long-lasting pollution of water, land, and biota.

However, these technologies are often expensive and require technical knowledge. Public-private partnerships and cooperatives can play a key role in subsidizing technology access. Additionally, miners who demonstrate compliance with environmental guidelines can be prioritized for technology access under government schemes or donor-funded projects.

Technology transfer should also include training in land reclamation techniques, such as: a)

Backfilling mining pits

b) Using compost and topsoil for vegetation regrowth

c) Constructing sediment traps to protect nearby water bodies

These technical solutions, if widely disseminated and supported, can significantly reduce the ecological effects of ASM operations (Armah et al., 2013).

2.7.5 Institutional Strengthening and Multi-Level Governance

Effective environmental management requires a strong institutional framework, with clear mandates, adequate resources, and inter-agency coordination (Ismail Kervankiran, 2016). This includes:

a) Improving staffing, logistics, and monitoring tools for local EPA, Minerals Commission, and Forestry Commission offices
b) Establishing inter-agency taskforces at the district level
c) Enhancing coordination between government agencies, traditional authorities, and civil society groups
d) Implementing digital systems for permit tracking, environmental audits, and enforcement data

The district assembly, for example, may lack vehicles to visit remote mining sites or computers to manage GIS data. Investments in capacity-building, ICT infrastructure, and staff training are essential to ensure that laws and regulations are not just symbolic but enforceable (Bawa et al., 2022).

2.7.6 Reclamation and Ecological Restoration

Land degraded by illegal mining must be restored to ecological functionality. This involves not only filling in abandoned pits or stopping pollution but also restoring biodiversity, soil fertility, and landscape stability. Effective reclamation involves:

a) Mapping degraded areas using drones or satellite imagery
b) Prioritizing high-risk zones (e.g., near water bodies, farmlands)
c) Replacing contaminated topsoil
d) Replanting native tree species
e) Engaging local communities and youth groups in restoration efforts

Ghana's national initiatives such as "Green Ghana" and the Forest Landscape Restoration Initiative can be extended to Mankranso as part of a restoration agenda. Moreover, ecological restoration can be linked to carbon credit programs or climate adaptation funds, providing additional resources to sustain efforts.

2.7.7 Policy Integration and Sustainability Planning

Sustainable environmental management cannot be compartmentalized. It must be mainstreamed into district development plans, climate change strategies, public health policies, and poverty reduction programs (Yiridomoh, 2021). Key cross-cutting priorities include:

a) Incorporating environmental indicators into district planning dashboards
b) Aligning local interventions with Sustainable Development Goals (SDGs), especially SDGs 6, 12, 13, and 15
c) Setting up Monitoring and Evaluation (M&E) systems to assess progress and adapt strategies
d) Engaging academia and research institutions for continuous environmental assessments

In Mankranso, such integration would allow policymakers to assess trade-offs, anticipate future challenges, and allocate resources more effectively.

Sustainable environmental management in illegal mining-affected communities like Mankranso requires more than enforcement, it demands a transformation of how communities, institutions, and ecosystems interact. The pathways to sustainability lie in formalization, livelihood diversification, community stewardship, environmental education, institutional reforms, cleaner technologies, and ecological restoration (Odumo et al., 2018). While the challenges are complex, they are not insurmountable. With political will, strategic investment, and participatory governance, Mankranso can transition from an environmental crisis zone to a community-led sustainability and resilience.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter outlines the methodology adopted for assessing the environmental and water quality impacts of illegal gold mining in Mankranso, Ashanti Region, Ghana. It details how data were gathered, processed, and interpreted in line with the study's three specific objectives: (1) to determine the socioeconomic impacts of illegal mining in Mankranso; (2) to determine the levels of heavy metals and toxic substances in water samples; (3) to assess the extent and nature of land and forest degradation. The methods selected reflect the interdisciplinary nature of the research, combining geospatial, laboratory, survey, and qualitative techniques.

3.2 Description of the Study Area

Mankranso is the capital of the Ahafo Ano South West District, located in Ashanti Region. Geographically positioned between latitudes 6°40′N and 6°55′N and longitudes 1°45′W and 2°00′W, the district spans approximately 1,126 km² (Ahafo Ano South-West District Assembly, 2025). The area map of Mankranso is shown in **Figure 3.1** below. It is bordered by the Ahafo Ano south –East district to the north, Atwima Mponua District to the south, and Atwima Nwabiagya District to the east, with the Ahafo Ano North municipal forming its western boundary. Several rivers, including the Mankran, Nwini, and tributaries of the Offin, traverse the town, making some members of the community dependent on these water sources for agriculture and other domestic purposes (Ghana Districts, 2023).

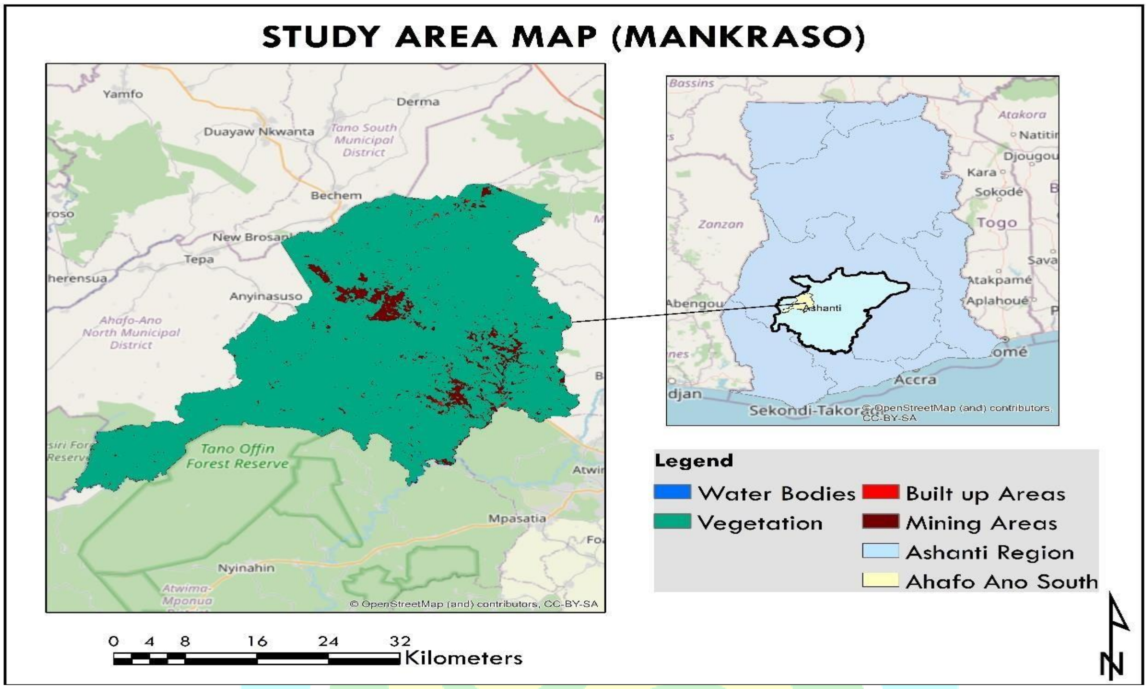

Figure 3. 1: Map of Mankranso

Climatically, Mankranso is a semi-deciduous forest zone and exhibits a tropical rainforest climate with two distinct rainy seasons, thus, April to July and September to October. The dry season typically extends from November through March, but is influenced by the harmattan winds. The town experiences annual rainfall between 1,200 mm and 1,600 mm and maintains temperature ranges from 22°C to 32°C throughout the year. These climatic conditions support dense vegetation and fertile soils.

The topography of Mankranso is defined by an undulating terrain with elevations ranging from 250 to 450 meters above sea level. The terrain comprises low hills, gentle slopes, and valleys interspersed with riverine systems. These features influence both human settlement and ecological processes, including surface runoff, erosion patterns, and water flow regulation. The natural drainage system made the area suitable for farming, but it also increases vulnerability to sedimentation and siltation, especially where illegal mining disturbs the landscape.

Geologically, Mankranso is rich in gold and they have drawn thousands of artisanal miners seeking to exploit surface-level deposits using rudimentary tools and mercury. This has made the area highly attractive to illegal miners, who often operate without any regard for safety or environmental sustainability.

According to the 2021 Population and Housing Census, the Ahafo Ano South West District has a population of approximately 65,770 people, with Mankranso accounting for more than half of the population. The population is predominantly Akan, with Asante as the main ethnic subgroup. The majority of residents are engaged in subsistence agriculture, growing cocoa, cassava, maize, plantain, and vegetables. However, in the past decade, economic hardship, rising unemployment rate, and declining farm productivity have led many young people to engage in galamsey (illegal small-scale mining). This socio-economic shift has led to increased land conflicts, declining interest in agriculture, and the deterioration of traditional values and livelihoods.

Illegal mining has triggered widespread deforestation, sedimentation of rivers, and the conversion of productive farmland into barren and cratered landscapes. Satellite imagery from 2015 to 2025 shows a consistent trend of land cover change, with dense vegetation giving way to mining camps, tailings, and degraded soil. Several forest reserves in the district have been heavily encroached upon. Mining in these areas often occurs without any environmental impact assessment, and the lack of land reclamation means the scars of extraction persist for decades. Water samples collected from various sites in Mankranso indicate elevated levels of mercury, arsenic, and other contaminants, far exceeding safe limits established by the World Health Organization. These pollutants not only compromise aquatic ecosystems but also endanger human health, especially in communities that rely on untreated surface water for drinking, cooking, and bathing.

3.3 Research Design

The research adopted a mixed-methods case study design to assess the environmental and water quality impacts of illegal gold mining in Mankranso. This design was selected to ensure that both empirical (scientific) data and community-based perspectives were captured and analyzed. The quantitative component focused on measuring levels of contamination in water samples collected from mining-affected sites. The study quantified heavy metal concentrations (e.g., mercury, arsenic, cadmium, and lead) and other physicochemical parameters such as pH, turbidity, and total dissolved solids using Atomic Absorption Spectrophotometry (AAS), Milwaukee MW805 MAX 4-in-1 pH/EC/TDS/Temp Combo Meter, and Hanna HI88703 Precision Turbidity Benchtop Meter respectively. Additionally, satellite imagery and geospatial tools were used to measure land use changes and forest loss over a defined time period (2015–2025). These data provided objective indicators of environmental degradation and allowed for temporal and spatial analysis. The qualitative component captured local knowledge, stakeholder experiences, and policy gaps through interviews, and structured community surveys. This helped explore information such as health implications, community and institutional challenges.

3.4 Population and Sampling Technique

Mankranso has an estimated population of approximately 5,374 people based on projections from the Ghana Statistical Service (2010). A total of 372 respondents successfully completed the research questionnaire and this included individuals from various occupational and social categories such as farmers, miners, health workers, traders, youth, women, and community leaders. The number of respondents (n = 372) was considered appropriate for the study, analytical needs, and available resources. It also meets the sample size requirement for statistical analysis with a 95% confidence level and a 5% margin of error. This also allowed assessing of differing perspectives across gender, age, livelihood, and proximity to mining activities.

A stratified purposive sampling method was adopted given the diversity of the population and the research's needs. The population was first divided into strata based on occupation (e.g., Community members, artisanal and small-scale miners, health professionals, local government and environmental agency officers), and then a purposive selection was applied to include individuals with in-depth knowledge or experience of the mining activities and their impacts. This minimized the risk of over-representing any particular subgroup and helped for easy comparative analysis.

The study targeted residents of Mankranso and its surrounding areas who had lived in the community for at least one years. Eligible participants were adults aged 18 years and above, particularly those directly affected by mining activities or possessing knowledge of its environmental or health impacts. Only individuals who provided informed and voluntary consent were included. Excluded from the study were visitors and temporary residents, individuals below 18 years of age, persons unwilling to provide informed consent, and those with no direct or indirect knowledge of mining-related activities.

The sample size for this study was determined using the Yamane (1967) formula **(Equation 1)**, which is appropriate for surveys involving a finite population where the population size (N) is known, and a specified level of precision is desired. The formula is expressed as:

$$n=\frac{N}{1+N(e)^2}$$ ………………………………**Equation 1**

$$n=\frac{5374}{1+5374(0.05)^2}=372$$

where:

n = sample size,

N = total population = 5374 e = desired level of precision (sampling error), often set at 0.05 for a 95% confidence level. This formula assumes a simple random sampling framework and provides a statistically defensible estimate of the minimum sample required for representativeness. It is widely used in social and environmental studies in Ghana where population data are finite and discrete

3.5 Data Collection Methods

The study employed a range of data collection methods to meet its three research objectives. A combination of quantitative and qualitative data was gathered using both structured and flexible methods. These included questionnaire surveys, scientific sampling of water, key informant interviews (Figure 2,3,4 and 5), direct field observation, remote sensing and GIS, and document review.

3.5.1 Questionnaire Survey

A structured questionnaire served as one of the primary tools for collecting community data. Considering the diversity in education, access to technology, and availability among community members, the questionnaire was administered in two formats: digital (Google Forms) and printed hardcopy.

a. The Google Forms version was disseminated via WhatsApp to stakeholders, community youth, educated residents, and colleagues with smartphone and internet access. This format helped to reach a large population with faster response time, and automatic collation of responses.

b. The hardcopy version was designed for individuals who lacked smartphones or internet access, including the elderly, non-literate residents, and those in more remote areas. We visited these respondents in person, explained the questions in Twi when necessary, and recorded the answers manually.

Out of the 372 total valid responses**,** 127 were collected via hardcopy and the remaining 245 were received through the Google Form shared on WhatsApp. This dual-mode approach ensured inclusivity and allowed participants from different segments of the population, regardless of literacy level or technological access.

Figure 3. 2: Visit to the police station and Assemblyman

Figure 3. 3: Researcher with the HR of the District Assembly

The questionnaire captured information on:

i. Perceptions of water quality and availability before and after the onset of illegal
mining ii. Reported health symptoms linked to contaminated water iii. Observations on

farming impacts and environmental changes iv. Awareness of mining regulations and enforcement

v. Suggestions for improved environmental management

The structure included both closed-ended questions, for quantitative analysis, and open-ended questions, to allow respondents to express opinions and experiences. All responses were later organized for statistical analysis and thematic categorization.

Figure 3. 4: Interview with the HR of Mankranso Hospital and some victims of teenage pregnancy

Figure 3. 5: Interview with the teachers and Headmaster of Mankranso Snr High

3.5.2 Water Sampling

To scientifically determine the levels of contamination in water sources, the study collected and analysed water samples from key locations in and around the mining zones **(Figure 3.6)**. Samples were taken from rivers such as the Mankran, Offin, and Nwini, both upstream and downstream of active galamsey operations to compare pollution impacts.

A total of thirty-six (36) samples were collected over six-month period, from February 2025 to July 2025, comprising 18 samples during dry season (February to April 2025) and 18 samples during the wet season (May to July 2025). Samples were meticulously taken at predetermined sampling locations. Each 500 ml sampling bottle was thoroughly cleaned with distilled water after initial wash with tap water to prevent contamination. For each river three samples were collected from three different points (upstream, mid-stream, and down-stream) and combined to form composite sample. The water samples were analysed for key physico-chemical parameters, including pH, electrical conductivity (EC), turbidity, temperature, and total dissolved solids (TDS). These parameters were analysed in-situ.

The samples were collected bi-weekly because of the following reasons;

i. To capture variation due to diverse activities occurring at different river ii.
To reduce overall cost of sample analysis.

In the lab, more advanced analyses were conducted using Atomic Absorption Spectrophotometry (AAS) to determine heavy metal concentrations. The study focused on mercury (Hg), arsenic (As), lead (Pb), cadmium (Cd), and zinc (Zn) all commonly linked to mining activity and known for their harmful health effects. These tests were compared against WHO guidelines and Ghanaian standards for drinking water and agricultural suitability. Sample triplicates were collected to assess field variability, field duplicates to evaluate sample reproducibility, and equipment and transport blanks to ensure contamination-free sampling. Laboratory analyses were subject to strict validation protocols to ensure precision, accuracy, and reproducibility. Analytical quality control followed APHA (2022) and EPA (2017) guidelines and adhered to ISO/IEC 17025:2017 laboratory quality standards. Field duplicates and lab replicates were analysed to assess precision, using Relative Percent Difference (RPD ≤ 20% for metals). Accuracy was checked through laboratory control samples (LCS), and certified reference materials (CRMs). Classification accuracy was evaluated using 70/30 training-validation split and ≥200 ground-truth GPS points (±3–5 m). Accuracy metrics included Overall Accuracy (≥85%) and Kappa Coefficient (≥0.80). Change detection validation employed cross-tabulation matrices, co-registration (RMSE ≤ 0.3 pixels), and morphological filtering to reduce noise. Spatial uncertainty was assessed using buffer error analysis and confidence zones (±10 m) near boundaries.

Figure 3. 6: Picking of water samples (and later preserved with HNO_3) to be transported for analysis

3.5.2.1 Analysis of pH, Electrical conductivity, Temperature, and Total dissolved solids The instrument used to measure these parameters was calibrated following standard procedures from the manufacturer prior to the usage. A multi-meter (Milwaukee MW805 MAX 4-in-1 pH/EC/TDS/Temp Combo Meter) was used to measure the pH of the samples. The pH value for each sample was taken after submerging the probe (the bulb was immersed to appropriate depth as recommended by the manufacturer) in the water sample and was held for stabilized reading. After each measurement, the probe was rinsed with distilled water to prevent cross contamination among the samples. The other probes for the other parameters were calibrated following standard procedures from the manufacturer and the parameters were measured.

3.5.2.2 Test for Turbidity

The meter (Hanna HI88703 Precision Turbidity Benchtop Meter) was calibrated with the buffers provided by following the manufacturer's instruction in calibrating the meter. The buffer was poured into the cuvette provided till it reaches the mark indicated on the cuvette. The cuvette was then inserted into the meter and the calibration button was pressed. The meter reading was allowed to stabilize, and the final reading was recorded. The same procedure was repeated for the other buffers provided. The turbidity of the sample was record in NTU.

3.5.2.3 Test for heavy metals

The analysis of heavy metals in the water samples was carried out using Atomic Absorption Spectrophotometry (AAS). All water samples were first collected in acid-washed polyethylene bottles to avoid contamination. Immediately after collection, each sample was preserved by acidifying it with concentrated nitric acid to maintain a pH below 2, a step which prevents metal ions from adsorbing onto the container walls. The samples were then stored at 4°C and were transported to the laboratory for the further analysis.

3.5.3 Key Informant Interviews and Direct Field Observation

To complement survey data, semi-structured interviews were conducted with several key informants, including; Officials from the Environmental Protection Agency (EPA), District Assembly representative, Health officers from Mankranso Government Hospital, Forestry Commission and Lands Commission staff, Traditional leaders and community elders. The interviews explored sections such as: Environmental enforcement challenges, Health trends and common illnesses, Institutional constraints and political interference, Community engagement in environmental governance. These interviews were recorded (with consent), transcribed, and analyzed thematically. In addition to formal data gathering, researchers conducted direct field observations to document environmental conditions first-hand.

Site visits revealed; Open mining pits abandoned after use, severely discolored and sediment-filled rivers, deforested areas with exposed soils, and mercury processing zones near water sources. Field notes, photographs, and GPS coordinates were collected to map and validate field conditions. Observational evidence strengthened the interpretation of scientific data and verified claims made during interviews and survey responses.

3.5.4 GIS and Remote Sensing for Land Use and Land Cover (LULC) Change Detection

To assess the environmental degradation associated with illegal gold mining in Mankranso, Geographic Information Systems (GIS) and remote sensing techniques were employed to analyze land use and land cover (LULC) changes between 2015 and 2025. This directly addresses the third specific objective of the study: to evaluate the extent of land and forest degradation caused by illegal gold mining and to assess landscape changes over time.

3.5.4.1 Image Acquisition and Pre-processing

Multi-temporal satellite imagery was obtained from the Landsat 8 Operational Land Imager (OLI) for the years 2015 and 2025. The 2025 imagery was derived from the most recent composite available (late 2024 to early 2025) to minimise seasonal variation. Landsat 8 was chosen for its consistent 30-meter spatial resolution, radiometric reliability, and free accessibility via the USGS Earth Explorer platform. To ensure image quality, cloud-free scenes (≤10% cloud cover) from the dry season (December–March) were selected to provide clearer surface features for classification. Pre-processing steps included:

- Geometric correction to align all images to a common coordinate system (WGS 84, UTM Zone 30N).

- Radiometric correction to standardise brightness values across acquisition dates.
- Atmospheric correction using Dark Object Subtraction (DOS) to minimise haze and atmospheric distortions.
- Sub-setting of imagery to the Mankranso catchment using shapefiles generated from GPS field points.

These pre-processing procedures ensured that datasets were standardised and suitable for accurate classification.

3.5.4.2. Land Use and Land Cover Classification

A supervised classification approach was applied using the Maximum Likelihood Algorithm (MLA), which is widely recognized for delivering high accuracy in mining-impacted landscapes (Owolabi, 2021). Five LULC categories were defined: Dense Forest, Open Forest, Bare Land, Built-up Area, and Mining-Affected Land. Ground-truth data were collected during field visits to establish training sites for each class, complemented by high-resolution imagery from Google Earth. The classification process was performed in QGIS (v3.22) using the Semi-Automatic Classification Plugin (SCP). Accuracy assessment was conducted through a confusion matrix, supported by 50 randomly selected validation points from GPS field data and Google Earth images. The 2015 classification achieved an overall accuracy of 88.4%, while the 2025 classification achieved 86.9%, with Kappa coefficients above 0.80 in both cases, indicating excellent reliability.

3.5.4.3. Change Detection and Rate of Change Calculation

Post-classification comparison was employed to detect LULC transitions between 2015 and 2025. The resulting change detection matrix identified class conversions (e.g., forest to mining, cropland to bare land), providing insights into the spatial extent of mining-related expansion. The annual rate of change for each land cover category was calculated using the Puyravaud (2003) equation **(Equation 2)**:

$$r = \frac{1}{t_2 - t_1} \times \ln\left(\frac{A_2}{A_1}\right) \text{ …………………….. Equation 2}$$

Where:

i. r = Annual rate of change ii. A_1=

Area of the land use class in 2015 iii.

A_2 = Area of the same class in 2025 iv.

$t_2 - t_1$ = Time interval (10 years)

3.5.4.4 NDVI Analysis for Vegetation Health

To complement the classification and better assess vegetation degradation, the Normalized Difference Vegetation Index (NDVI) was computed using the **Equation 3** below:

$$\text{NDVI} = \frac{(NIR - RED)}{(NIR + RED)} \text{ ……………………Equation 3}$$

Where:

i. NIR = Near-Infrared band (Band 5 in Landsat 8) ii.

RED = Red band (Band 4 in Landsat 8)

NDVI values range from -1 to +1, with:

i. Values above **0.5** representing dense, healthy vegetation ii. Values

between **0.2- 0.5** indicating sparse or degraded vegetation iii. Values

below **0.2** representing bare surfaces or built-up/mined areas

NDVI maps for 2015 and 2025 revealed a clear decline in vegetation cover over the 10-year period. Areas with NDVI values above 0.6 in 2015 dropped below 0.3 in 2025, especially around riverbanks, forest edges, and active mining zones.

3.6 Data Processing and Analysis Methods

Data analysis transformed raw information from questionnaires, river water samples, and remote sensing outputs into insights addressing the study's objectives. Two main approaches were employed. First, socioeconomic survey data were coded and analyzed using SPSS (v26) and Excel 2019. Descriptive statistics (frequencies, percentages, means) were used to summarize respondents' characteristics and perceptions, while cross-tabulations and chi-square tests explored relationships between variables. Second, environmental and spatial analysis was conducted. Laboratory results of river water samples were compared with WHO and GSA guideline values, and seasonal variations were assessed through descriptive comparisons and statistical tests. For LULC analysis, Landsat imagery was classified in QGIS (v3.22), supported by NDVI and postclassification change detection. Accuracy was verified using confusion matrices and Kappa statistics.

3.7 Ethical Considerations

This study adhered strictly to ethical research standards to protect the rights, privacy, and wellbeing of all participants. Participants were fully informed about the study's purpose, their voluntary involvement, and their right to withdraw at any time. Informed consent was obtained in either written or verbal form, with local language support provided where needed. To ensure confidentiality, no identifying information was recorded, and all data were anonymised and securely stored. Care was taken to avoid causing harm either physically, psychologically, or professionally by conducting surveys and interviews during non-disruptive periods and framing questions in a respectful and non-threatening manner. Participants were assured that the research findings would be used solely for academic and policy development purposes and that individual responses would remain untraceable. Overall, the study was guided by principles of integrity, respect, and responsibility, ensuring that ethical standards were upheld throughout the research process.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Respondents

A total of 372 respondents were surveyed, comprising 227 males (61.02%) and 145 females (38.98%) (Table 4.1). This male-dominant workforce reflects broader patterns in Ghana's artisanal and small-scale gold mining (ASGM) sector, where the physically demanding nature of pit excavation, exposure to hazardous environments, and entrenched cultural perceptions of mining as a masculine activity limit women's participation (Basu, Clarke, et al., 2015; Hilson & Maconachie, 2019). Nonetheless, the proportion of females (38.98%) in this study is higher than reported in some mining districts, suggesting that women in the study communities are increasingly diversifying into auxiliary and direct mining-related roles such as trading, ore washing, and processing.

Educational attainment among respondents was generally low. Only 12.9% had attained tertiary education, while nearly one-third (29.0%) reported no formal schooling. The largest group (32.3%) had completed junior high school, followed by 25.8% at secondary school. These figures highlight the limited access to higher education in rural mining communities, where socio-economic pressures often drive children into informal mining rather than extended schooling (Wilson et al., 2015). The predominance of respondents with junior-level or no formal education further underscores the structural challenges in promoting alternative livelihoods that require higher skills or technical training. A majority of respondents (55.6%) had lived in their community for less than five years, while 23.4% reported stays of 5–10 years. Only 7.0% had lived there for more than two decades. This mobility suggests high rates of inward migration, likely driven by the lure of gold mining opportunities. Such migratory patterns have been documented in other Ghanaian mining areas, where transient populations often put pressure on local infrastructure, increase competition for land, and heighten social tensions (Rajaee et al., 2015).

Participation in illegal mining (galamsey) was widespread, with 69.4% of respondents actively engaged. Males accounted for a larger share (43.0%) than females (26.3%), though female participation was still significant. This finding aligns with the perception of galamsey as a household livelihood strategy in which both men and women participate, albeit in different capacities (Clarke, 2015). The persistence of high engagement rates despite state-led crackdowns reflects the limited livelihood alternatives and the economic attractiveness of small-scale gold mining. Among those involved in galamsey, the largest share (40.3%) had been active for 0–5 years, with 18.3% involved for 5–10 years and 8.1% for over a decade. Notably, 33.3% indicated uncertainty about their duration of involvement. This pattern suggests both recent entry into the sector and a lack of formalized work histories, common in the informal mining economy where workers often shift between multiple income sources depending on opportunity.

Outside mining, respondents reported a diverse set of livelihood activities. Farming was the dominant occupation (46.2%), followed by trading (20.7%) and illegal mining (15.9%). A smaller share was engaged in public sector or auxiliary roles, including district assembly work (11.3%), policing (3.2%), and immigration services (2.7%). The dominance of farming underscores the continued reliance on agriculture, but the significant proportion of respondents also engaged in mining reflects how ASGM has become a parallel livelihood system. The presence of public sector workers in galamsey further reveals the pervasiveness of mining across socio-economic classes, raising important questions about governance, regulation, and community dependence on the gold economy.

Table 4. 1: Socio-Demographic Characteristics of respondents, stratified by gender

Variable	**Male (Freq, %)**	**Female (Freq, %)**	**Total (Freq, %)**
Education			
Junior high school	74 (19.9%)	45 (12.1%)	120 (32.3%)
Secondary school	60 (16.1%)	36 (9.7%)	96 (25.80%)
Tertiary education	29 (7.8%)	19 (5.1%)	48 (12.9%)
No formal education	67 (18.0%)	41 (11.0%)	108 (29.0%)
Years lived in community			
<5 years	128 (34.4%)	79 (21.2%)	207 (55.6%)
5–10 years	54 (14.5%)	33 (8.9%)	87 (23.4%)
11–20 years	32 (8.6%)	20 (5.4%)	52 (14.0%)
Over 20 years	16 (4.3%)	10 (2.7%)	26 (7.0%)
Actively engaged in galamsey?			
Yes	160 (43.0%)	98 (26.3%)	258 (69.4%)

No	72 (19.4%)	43 (11.6%)	114 (30.6%)
Operation duration			
<5 years	92 (24.7%)	58 (15.6%)	150 (40.3%)
5–10 years	41 (11.0%)	27 (7.3%)	68 (18.3%)
Over 10 years	16 (4.3%)	14(3.8%)	30 (8.1%)
Not sure	76 (20.4%)	48 (12.9%)	124 (33.3%)

Variable	**Male (Freq, %)**	**Female (Freq, %)**	**Total (Freq, %)**
Major economic activities			
Farmers	107 (28.8%)	65 (17.5%)	172 (46.2%)
Traders	48 (12.9%)	29 (7.8%)	77 (20.7%)
Illegal miners	36 (9.7%)	23 (6.2%)	59 (15.9%)
Police	7 (1.9%)	5 (1.3%)	12 (3.2%)
Immigration	6 (1.6%)	4 (1.1%)	10 (2.7%)
District assembly workers	26 (7.0%)	16 (4.3%)	42 (11.3%)

4.2 Social Impacts of Illegal Mining

4.2.1 School Dropout

Table 4.2 presents respondents' views on the relationship between illegal gold mining and school dropout rates. The findings indicate a strong perception that illegal mining contributes significantly to increased school dropout, though opinions varied by duration of stay in the community. Among those who had lived in the community for <5 years, an overwhelming majority either agreed

(27.7%) or strongly agreed (26.1%) that galamsey activities fuel dropout. Similar patterns were observed among respondents with 5–10 years of residence, with 13.7% agreeing and 9.4% strongly agreeing. Interestingly, those with longer durations of stay displayed more mixed views. For residents with 11–20 years, agreement dropped to 5.4%, with 3.8% strongly agreeing, while 2.1% expressed either disagreement or no clear opinion. The starkest contrast emerged among respondents with over 20 years in the community, where none expressed agreement, and instead 7.1% which is the total number of respondents over 20 years either disagreed or strongly disagreed. Long-term residents may attribute dropout to structural issues such as poverty or limited access to quality schools rather than to mining alone, while newer migrants may more directly associate dropout with the economic lure of mining. This aligns with earlier studies in Ghana, which found that children in mining areas are often drawn into supporting family mining operations, either through direct labor or auxiliary tasks, leading to reduced school attendance (Basu, Renne, et al., 2015). The polarization of views underscores the importance of considering local histories and community tenure in analyzing mining's social impacts.

4.2.2 Crime Rate

Perceptions of the relationship between galamsey and crime were similarly pronounced. Among respondents who had resided in their community for <5 years, 29.6% agreed and 19.9% strongly agreed that illegal mining has fueled rising crime rates, with only 5.4% expressing disagreement. Comparable patterns were evident among 5–10-year residents, where over 12.1% either agreed or strongly agreed (11.3%). Those with 11–20 years in the community reported slightly more nuanced views, with 7.5% agreeing, 5.4% strongly agreeing, and a small minority (6.2%) either disagreeing or uncertain. Respondents with over 20 years of residence again stood out, as a notable 1.6% disagreed, while 8.1% agreed and 2.4% strongly agreed. The overwhelming agreement across most categories suggests a widely shared perception that galamsey contributes to rising insecurity, theft, and social disorder. This is consistent with national policy concerns that the influx of transient populations and the struggle for resource control in mining areas often exacerbate crime and lawlessness(Kemp & Owen, 2019). At the same time, the slightly higher rates of disagreement among long-term residents may indicate that they see crime as rooted in deeper socio-economic frustrations or governance failures rather than as an inevitable byproduct of mining alone. Taken together, these findings highlight the complex ways in which illegal mining intersects with community well-being. School dropout and crime are not viewed simply as isolated effects of galamsey but as outcomes mediated by migration, community tenure, and shifting social dynamics. Understanding these nuances is critical for designing interventions: while newcomers may require targeted awareness and child protection measures, long-standing communities may benefit more from strengthened education systems and broader social safety nets.

Table 4. 2: Relationship Between School Dropout, Crime Rate and Respondents' Characteristics and Illegal Mining

Increase in school dropout

Duration	**Strongly Disagree**	**Disagree**	**No Idea**	**Agree**	**Strongly Agree**	**Total**
<5 years	0 (0.0%)	4(1.1%)	0(0.0%)	103(27.7%)	97 (26.1%)	204(54.8%)
5–10 years	0 (0.0%)	3 (0.8%)	0 (0.0%)	51 (13.7%)	35 (9.4%)	89 (23.9%)
11–20year	11 (3.0%)	6 (1.6%)	2 (0.5%)	20 (5.4%)	14 (3.8%)	53 (14.2%)
□20 years	9 (2.4%)	17 (4.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	26 (7.1%)
Increase in crime rate						
<5 years	0(0.00%)	20(5.4%)	0(0.0%)	110(29.6%)	74 (19.9%)	184(49.1%)

5–10 years	0(0.00%)	2 (0.5%)	0(0.0%)	45 (12.1%)	42 (11.3%)	89 (23.9%)
11–20 year	0(0.00%)	2 (0.5%)	3(5.7%)	28 (7.5%)	20 (5.4%)	53 (14.2%)
□20 years	0(0.00%)	6 (1.6%)	1(0.3%)	30 (8.1%)	9 (2.4%)	46 (12.8%)

4.2.3 Teenage Pregnancy

Table 4.3 highlights respondents’ perceptions of the relationship between illegal gold mining and the rate of teenage pregnancy. Overall, the majority of respondents associated galamsey activities with higher rates of teenage pregnancy, although the intensity of agreement varied across different lengths of community residence. Among residents who had lived in the community for <5 years, 32.3% either agreed or strongly agreed (20.7%) that teenage pregnancy has increased with the rise of illegal mining. Similarly, among those with 5–10 years of residence, 15.0% agreed and 7.8% strongly agreed, producing a comparable overall consensus. Interestingly, respondents with 11–20 years of residence exhibited slightly more divided perceptions: while more than 98% acknowledged the problem, the split between agreement (7.3%) and strong agreement (6.7%) suggests a stronger conviction that galamsey directly drives early pregnancies. By contrast, longterm residents with over 20 years in the community presented a somewhat divergent perspective. While 5.7% agreed that teenage pregnancy rates had increased, none strongly agreed. A notable minority (1.1%) also disagreed, indicating that some older residents may attribute teenage pregnancy to broader social or cultural factors rather than to mining activities alone. These findings reflect wider patterns observed in mining communities across Ghana, where the influx of migrant workers, increased disposable income among miners, and weakened parental oversight contribute to early sexual relationships and unplanned pregnancies(Laurence, 2011). Teenage girls are often particularly vulnerable due to economic pressures and the absence of adequate reproductive health services in mining areas. The relative reluctance of long-term residents to strongly associate teenage pregnancy with galamsey may be explained by generational differences in interpreting social change: older community members may see early pregnancies as part of longstanding rural traditions, while newer residents more readily link the trend to the disruptive social environment created by illegal mining.

Table 4. 3: Relationship Between rate of Teenage Pregnancy, and Respondents' Characteristics

Increase in teenage pregnancy

Duration	**Disagree**	**No Idea**	**Agree**	**Strongly Agree**	**Total**
<5 years	2 (0.5%)	5 (1.3%)	120 (32.3%)	77 (20.7%)	204 (54.8%)
5–10 years	4 (1.1%)	0 (0.0%)	56 (15.0%)	29 (7.8%)	89 (23.9%)
11–20 years	1 (0.3%)	0 (0.0%)	27 (7.3%)	25 (6.7%)	53 (14.2%)
Over 20 years	4 (1.1%)	1 (0.3%)	21 (5.7%)	0 (0.0%)	26 (7.1%)

4.2.4 Drug Abuse

Respondents also overwhelmingly perceived a rise in drug abuse, particularly marijuana and tramadol consumption, as linked to galamsey activities (Table 4.4). Among those with <5 years of residence, 46.5% either agreed or strongly agreed (5.9%) that drug abuse had increased. Similarly, those with 5–10 years of stay expressed near-consensus, with 19.6% agreeing and 3.2% strongly agreeing. Residents with 11–20 years of experience were more divided but still showed strong recognition of the problem, with 9.9% agreeing and 2.4% strongly agreeing, while a small fraction

(1.3%) either disagreed or expressed no clear view. Among the longest-term residents (over 20 years), the majority still perceived a strong link, with 5.7% agreeing and 0.8% strongly agreeing, although a small minority (0.5%) disagreed.

These perceptions reinforce a growing concern that ASGM environments contribute to heightened substance abuse, particularly among young men. Prior studies suggest that the physically demanding and high-risk nature of galamsey work, coupled with irregular incomes and limited recreational opportunities, creates conditions where drug use is normalized as a coping strategy (Tuokuu, 2019; Xu et al., 2012). Tramadol abuse, in particular, has been linked to attempts to endure long hours of labor-intensive mining. The consistency of agreement across all residence categories suggests that the association between mining and drug abuse is broadly recognized, even if long-term residents are somewhat less likely to report extreme concern. Taken together, the findings on teenage pregnancy and drug abuse reveal how galamsey intensifies social vulnerabilities in mining communities. Both issues disproportionately affect youth, creating longterm risks for human capital development and community stability. Teenage pregnancy interrupts educational attainment, while widespread drug abuse undermines productivity and health. Addressing these challenges will therefore require not only law enforcement but also integrated community interventions, including youth empowerment programs, sexual and reproductive health education, and substance abuse prevention initiatives.

Table 4. 4: Relationship Between Drug Abuse and Respondents' Characteristics

Duration	ug abuse (weed Strongly Disagree	Disagree	No Idea	Agree	Strongly Agree	Total

<5 years	0 (0.0%)	5 (1.3%)	4(1.1%)	173(46.5%)	22 (5.9%)	204(54.8%)
5–10 years	0 (0.0%)	3 (0.8%)	1(0.3%)	73 (19.6%)	12 (3.2%)	89 (23.9%)
11–20 years	2 (0.5%)	2 (0.5%)	3(0.8%)	37 (9.9%)	9 (2.4%)	53 (14.2%)
Over-20 years	0 (0.0%)	2 (0.5%)	0(0.0%)	21 (5.7%)	3 (0.8%)	26 (7.1%)

4.2.5 Prostitution

Table 4.5 presents respondents' views on whether illegal mining has contributed to increased prostitution in their communities. The findings show an overwhelming consensus that galamsey activities are closely linked with rising levels of commercial sex work. Across all residence categories, more than two-thirds of respondents agreed or strongly agreed with this view. Among residents who had lived in the community for <5 years, 54.8% perceived an increase in prostitution, with 40.9% agreeing and 13.2% strongly agreeing. Similar patterns were reported among those with 5–10 years of residence, where 17.5% agreed and 6.2% strongly agreed. For respondents with 11–20 years of residence, 10.5% agreed and 3.8% strongly agreed, while for those with over 20 years in the community, 7.1% acknowledged the problem, with 4.9% agreeing and 1.9% strongly agreeing. These findings resonate with broader studies documenting the social impacts of mining settlements, where sudden inflows of income, male-dominated labor migration, and weak social regulation create conditions that foster transactional sex(Soares et al., 2024). Prostitution in such contexts often serves as a coping mechanism for women struggling with poverty, while simultaneously exposing them to health risks such as sexually transmitted infections, including HIV/AIDS(Anderson-Coughlin et al., 2021; Macdonald et al., 2015). The high levels of agreement across all groups indicate that the phenomenon is widely recognized regardless of length of residence, suggesting that prostitution is seen as a visible and entrenched outcome of illegal mining operations.

Table 4. 5: Relationship Between Prostitution and Respondents' Characteristics

Increase in prostitution				
Duration	**Disagree**	**Agree**	**Strongly Agree**	**Total**
<5 years	3 (0.8%)	152 (40.9%)	49 (13.2%)	204 (54.8%)
5–10 years	1 (0.3%)	65 (17.5%)	23 (6.2%)	89 (23.9%)
11–20 years	0 (0.0%)	39 (10.5%)	14 (3.8%)	53 (14.2%)
Over 20 years	1 (0.3%)	18 (4.9%)	7 (1.9%)	26 (7.1%)

3.3.4 Child Labour

Respondents also strongly associated galamsey with the rise in child labor (Table 4.6). Among those with <5 years of residence, 54.8% reported that child labour had increased, with 44.9% agreeing and 5.6% strongly agreeing. The perception was similar among those with 5–10 years of stay, where 19.1% agreed and 3.8% strongly agreed. Residents with 11–20 years of residence showed slightly more variation, with 10.8% agreeing and 1.6% strongly agreeing, while a small proportion (1.8%) either disagreed or were uncertain. Among the longest-term residents (over 20 years), 5.7% agreed and 0.8% strongly agreed, with only 0.6% either disagreeing or unsure.

The near-unanimous perception of increased child labour aligns with established literature on artisanal and small-scale mining in Ghana and Sub-Saharan Africa, where children are often drawn into mining either directly through hazardous work or indirectly through support roles such as washing ores, carrying loads, or selling food to miners(Anderson-Coughlin et al., 2021; Leuenberger et al., 2021; Macdonald et al., 2015; E. K. Nti et al., 2024)The high agreement levels across all residence categories underscore the pervasiveness of the problem, which undermines children's education and health. Long-term residents' responses further highlight how child labour is not a transient occurrence but a sustained challenge associated with illegal mining. The findings on prostitution and child labor underscore the broader social costs of galamsey, which extend beyond environmental degradation and economic disruption to include serious threats to human development and community well-being. Both issues disproportionately affect vulnerable groups, women and children, who often bear the hidden costs of mining booms. The persistence of these problems across different residence groups suggests systemic drivers, including poverty, weak regulation, and the informal nature of galamsey operations. Addressing them will require not only enforcement of child protection and labor laws but also alternative livelihood opportunities, community awareness programs, and stronger health and social support systems in miningaffected areas.

Table 4. 6: Relationship Between Child Labour and Respondents' Characteristics

Increase in child labour					
Duration	**Disagree**	**No Idea**	**Agree**	**Strongly Agree**	**Total**
<5 years	9 (2.4%)	7 (1.9%)	167(44.9%)	21 (5.6%)	204 (54.8%)
5–10 years	2 (0.5%)	2 (0.5%)	71 (19.1%)	14 (3.8%)	89 (23.9%)

11–20 years	2 (0.5%)	5 (1.3%)	40 (10.8%)	6 (1.6%)	53 (14.2%)
Over 20 years	1 (0.3%)	1 (0.3%)	21 (5.7%)	3 (0.8%)	26 (7.1%)

4.3.5 Respondents’ Reasons for Participation in ASGM

Table 4.7 summarizes respondents’ reasons for engaging in artisanal and small-scale gold mining (ASGM), disaggregated by gender. The results indicate that unemployment and the lucrative nature of the activity are the most significant drivers across both male and female respondents. Unemployment was the single most cited reason, accounting for 44.1% of all responses, with slightly higher proportions among men (27.7%) compared to women (16.4%). The lucrative nature of the activity followed closely, reported by 30.9% of respondents overall, with again more men (18.5%) than women (12.4%) identifying this as their main motivation. This reflects the reality that ASGM offers relatively quick financial returns in contexts where alternative employment is scarce, particularly for young men with limited formal education or vocational training.

Other reasons, though less common, reveal additional socio-economic drivers. About 5.6% of respondents reported participation due to lack of capital to start other businesses, while 10.5% cited feelings of exploitation by outsiders who were destroying their land. Finally, 8.9% reported involvement because it was considered a family business, a factor more evenly distributed between men (4.6%) and women (4.3%). Overall, the gender breakdown suggests that while both men and women are drawn into ASGM by similar factors, men are more motivated by immediate economic opportunities (unemployment and financial gain), while women show relatively higher proportions in family-related and grievance-driven participation. These patterns align with wider studies in Ghana and Sub-Saharan Africa, which document that ASGM often serves as a “last resort” livelihood strategy in the absence of viable alternatives (Okyere, Ayitey, & Ajabuin, 2021).

Table 4. 7: Respondents’ Reasons for Participation in ASGM (by Gender)

Variable	Male (F, %)	Female (F, %)	Total (F, %)
Unemployment	103 (27.7%)	61 (16.4%)	164 (44.1%)
Lucrative nature of the activity	69 (18.5%)	46 (12.4%)	115 (30.9%)
No or less capital to start other business	14 (3.8%)	7 (1.9%)	21 (5.6%)
Feel cheated by outsiders destroying land	24 (6.5%)	15 (4.0%)	39 (10.5%)
Family business	17 (4.6%)	16 (4.3%)	33 (8.9%)
Total	**227 (61.0%)**	**145 (39.0%)**	**372 (100%)**

4.3.6 Respondents' Definition of Water Pollution

Respondents were also asked how they define water pollution, with responses categorized by gender (Table 4.7, second panel). The majority (79.0%) defined pollution in terms of changes in water colour, with both men (47.8%) and women (31.2%) overwhelmingly emphasizing this visual indicator. This strong reliance on colour likely reflects the visible impacts of ASGM activities, such as siltation and turbidity, which are common in mining-affected rivers and streams.

Table 4. 8: Respondents' Definition of Water Pollution (by Gender)

Variable	Male (F, %)	Female (F, %)	Total (F, %)
Odour	24 (6.5%)	14 (3.8%)	38 (10.3%)
Taste	25 (6.7%)	15 (4.0%)	40 (10.7%)
Colour	178 (47.8%)	116 (31.2%)	294 (79.0%)
Total	**227 (61.0%)**	**145 (39%)**	**372 (100%)**

Other indicators such as taste (10.7%) and odour (10.3%) were less frequently mentioned, though still notable. Slightly more men than women reported both taste (6.7% vs. 4.0%) and odour (6.5% vs. 3.8%) as markers of pollution. This suggests that men, who are often more directly exposed to mining sites and water use for operational purposes, may be more attuned to changes beyond visual appearance. The findings indicate a narrow, largely visual perception of water pollution among respondents, which has important implications for environmental education and policy. Scientific assessments of water quality typically emphasize invisible contaminants such as mercury, cyanide, arsenic, and other heavy metals, pollutants that cannot be detected by color alone.

4.4 Seasonal Variation in Heavy Metals and Physicochemical Parameters

Across both wet and dry seasons, the most frequently detected contaminants were lead (Pb), copper (Cu), mercury (Hg), chromium (Cr), cadmium (Cd), arsenic (As), iron (Fe), and total cyanide (CN^-) (Tables 4.9 and 4.10). Seasonal patterns showed consistently higher contaminant loads downstream compared to upstream, with notable increases in turbidity, conductivity, TDS, and metals, especially during the wet season. This indicates the strong influence of illegal artisanal and small-scale gold mining (ASGM) activities on water quality (Essah & Andrews, 2016; Mulligan et al., 2011).

Physicochemical parameters reflected clear spatial and seasonal gradients. Turbidity, conductivity, and TDS increased progressively from upstream to downstream, with the wet season recording the highest values (turbidity: 100 NTU; conductivity: 910 µS/cm; TDS: 715 mg/L downstream). These levels far exceed WHO guideline thresholds for drinking water (turbidity <5 NTU; TDS <1000 mg/L) (WHO, 2022), suggesting severe sediment and solute loading during peak mining and rainfall periods. Elevated turbidity reduces light penetration, impacting aquatic ecosystems, while high conductivity and TDS reflect mobilization of ions from disturbed soils and tailings (Soares et al., 2024). pH values ranged from slightly acidic upstream (6.65 in wet season) to near neutral downstream (7.45 in dry season), consistent with neutralizing effects of carbonate geology and alkaline tailings inputs (Zhang et al., 2022).

Cyanide concentrations exhibited marked seasonal and spatial variation. While upstream levels were relatively low (0.002 mg/L wet; 0.001 mg/L dry), downstream values rose sharply to 0.023 mg/L in the wet season and 0.017 mg/L in the dry season. Both exceed the WHO guideline value of 0.07 mg/L for drinking water safety (WHO, 2022). The downstream increase reflects direct inputs from gold processing, where cyanide is commonly used to leach gold from ore. Seasonal differences suggest enhanced mobilization and transport of cyanide during heavy rainfall, which flushes contaminated soils and mine waste into surface waters (Xu et al., 2012).

Among heavy metals, lead (Pb) and iron (Fe) showed the most pronounced exceedances. Pb levels reached 0.195 mg/L downstream in the wet season and 0.135 mg/L in the dry season, far exceeding the WHO limit of 0.01 mg/L. Such high Pb levels are consistent with earlier findings in Ghana's gold belts (Gorman & Dzombak, 2018; Haque et al., 2014) and pose serious risks of neurotoxicity, especially for children. Fe levels, though not directly toxic, also exceeded the guideline value of 0.3 mg/L, reaching 2.7 mg/L in the wet season and 3.0 mg/L in the dry season downstream. Elevated Fe may arise from both natural geochemical weathering and anthropogenic disturbance from mining operations. Mercury (Hg), widely used in ASGM for amalgamation, was also detected at concerning levels. Mean downstream concentrations reached 0.009 mg/L (wet) and 0.007 mg/L (dry), exceeding the WHO guideline of 0.006 mg/L. This indicates ongoing Hg pollution, likely enhanced during the wet season by sediment resuspension and runoff from amalgamation sites (Soares et al., 2024). Chromium (Cr), cadmium (Cd), and arsenic (As) also exceeded permissible limits with higher levels consistently observed downstream. The presence of Cd and As, both highly toxic, highlights the risk of chronic exposure, which is linked to kidney dysfunction, carcinogenesis, and developmental impairment (Coetzee et al., 2020).

Table 4. 9: Mean Concentrations of physiochemical and heavy metals during the Wet Season

Parameter	**Kunsu**		**Nwini**		**Mankran**		**WHO Standards**
	Mean	**±SD**	**Mean**	**±SD**	**Mean**	**±SD**	
Temperature (°C)	25.15	0.495	26.05	0.212	26.85	0.212	≤ 30
pH	6.65	0.212	6.95	0.071	7.2	0.141	6.5 – 8.5
Turbidity (NTU)	27.5	3.536	50	14.142	100	28.284	≤ 5
Conductivity (µS/cm)	210	28.284	485	49.497	910	84.853	≤ 1500
TDS (mg/L)	145	21.213	330	28.284	715	35.355	≤ 1000
Cyanide (mg/L)	0.002	0.000	0.008	0.001	0.023	0.004	≤ 0.07
Lead (Pb) (mg/L)	0.009	0.001	0.032	0.005	0.195	0.035	≤ 0.01
Copper (Cu)(mg/L)	0.006	0.001	0.021	0.001	0.048	0.004	≤ 2.0
Mercury (Hg) (mg/L)	0.001	0.000	0.006	0.001	0.009	0.001	≤ 0.006
Chromium (Cr) (mg/L)	0.009	0.001	0.025	0.001	0.044	0.002	≤ 0.05
Cadmium (Cd) (mg/L)	0.004	0.001	0.009	0.001	0.018	0.001	≤ 0.003
Arsenic (As) (mg/L)	0.004	0.001	0.010	0.001	0.017	0.001	≤ 0.01
Iron (Fe)(mg/L)	0.75	0.071	1.7	0.141	2.7	0.283	≤ 0.3

Table 4. 10: Mean Concentrations of physiochemical and heavy metals during the Dry Season

Parameter	**Kunsu**		**Nwini**		**Mankran**		**WHO Standards**
	Mean	**±SD**	**Mean**	**±SD**	**Mean**	**±SD**	
Temperature (°C)	26.45	0.354	27.35	0.212	27.9	0.141	≤ 30
pH	6.9	0.141	7.15	0.071	7.45	0.071	6.5 – 8.5
Turbidity (NTU)	17.5	3.536	35	9.899	80	21.213	≤ 5
Conductivity (µS/cm)	240	28.284	540	56.569	985	91.924	≤ 1500
TDS (mg/L)	165	21.213	380	28.284	785	35.355	≤ 1000
Cyanide (mg/L)	0.001	0.000	0.006	0.001	0.017	0.002	≤ 0.07
Lead (Pb) (mg/L)	0.007	0.001	0.022	0.003	0.135	0.021	≤ 0.01
Copper (Cu)(mg/L)	0.006	0.001	0.017	0.001	0.040	0.003	≤ 2.0
Mercury (Hg) (mg/L)	0.001	0.000	0.004	0.001	0.007	0.001	≤ 0.006
Chromium (Cr) (mg/L)	0.008	0.001	0.021	0.001	0.036	0.003	≤ 0.05
Cadmium (Cd) (mg/L)	0.003	0.001	0.007	0.001	0.013	0.001	≤ 0.003
Arsenic (As) (mg/L)	0.003	0.001	0.008	0.001	0.014	0.001	≤ 0.01
Iron (Fe)(mg/L)	0.85	0.071	1.9	0.141	3	0.283	≤ 0.3

Statistical comparison confirmed significant seasonal differences ($p < 0.05$) for turbidity, conductivity, TDS, Pb, Hg, and CN^-, while seasonal variation for Cu, Cr, Cd, and As was less pronounced ($p > 0.05$). The general pattern of higher contaminant concentrations in the wet season is attributable to increased leaching and transport of metals and cyanide into rivers during heavy rainfall, as also reported in the Ankobra and Pra basins (Asare-Donkor & Adimado, 2016). However, for Fe, dry season concentrations slightly exceeded wet season values, likely due to reduced dilution and higher residence time in low-flow conditions, consistent with findings by Zhang et al., (2022).

Overall, the observed exceedances (Tables 4.9 and 4.10), particularly for Pb, Fe, Hg, Cd, and CN^-, highlight the severe and ongoing impact of illegal mining on river water quality in Mankranso. Chronic exposure to these contaminants poses significant health risks to downstream communities that depend on untreated river water for domestic and agricultural use. Long-term ingestion of Pb, Hg, and As is associated with neurological impairment, cardiovascular disease, and cancers, while CN^- exposure affects respiratory and cardiovascular systems (WHO, 2022). Similar exceedance patterns have been observed in other ASGM hotspots in Ghana (Macdonald et al., 2015; Wilson et al., 2015) and elsewhere in sub-Saharan Africa (Leuenberger et al., 2021; Tuokuu, 2019). These findings emphasize the urgent need for integrated river basin protection strategies. This should include stricter enforcement of mining regulations, continuous water quality monitoring, and provision of alternative potable water sources during contamination peaks. Community sensitization on the risks of consuming untreated river water and the deployment of point-of-use treatment technologies, such as activated carbon or reverse osmosis for cyanide and Hg removal, are recommended. Without such measures, the persistence of illegal mining will continue to undermine water security and public health in Mankranso and beyond.

4.5 Land Use and Land Cover (LULC) Changes from 2015 to 2025

Analysis of land use and land cover (LULC) classifications for the years 2015, 2020, and 2025 revealed substantial changes in the spatial distribution of major land cover categories, namely dense forest, cropland, bareland, built-up, and water **(Table 4.10; Figure 4.1)**. The most notable trend was the rapid expansion of built-up areas at the expense of dense forest and cropland. Between 2015 and 2025, built-up cover more than doubled from 32% in 2015 to 78% in 2025, reflecting accelerated urbanisation and the influence of galamsey activities that attract population inflows and spur peri-urban sprawl.

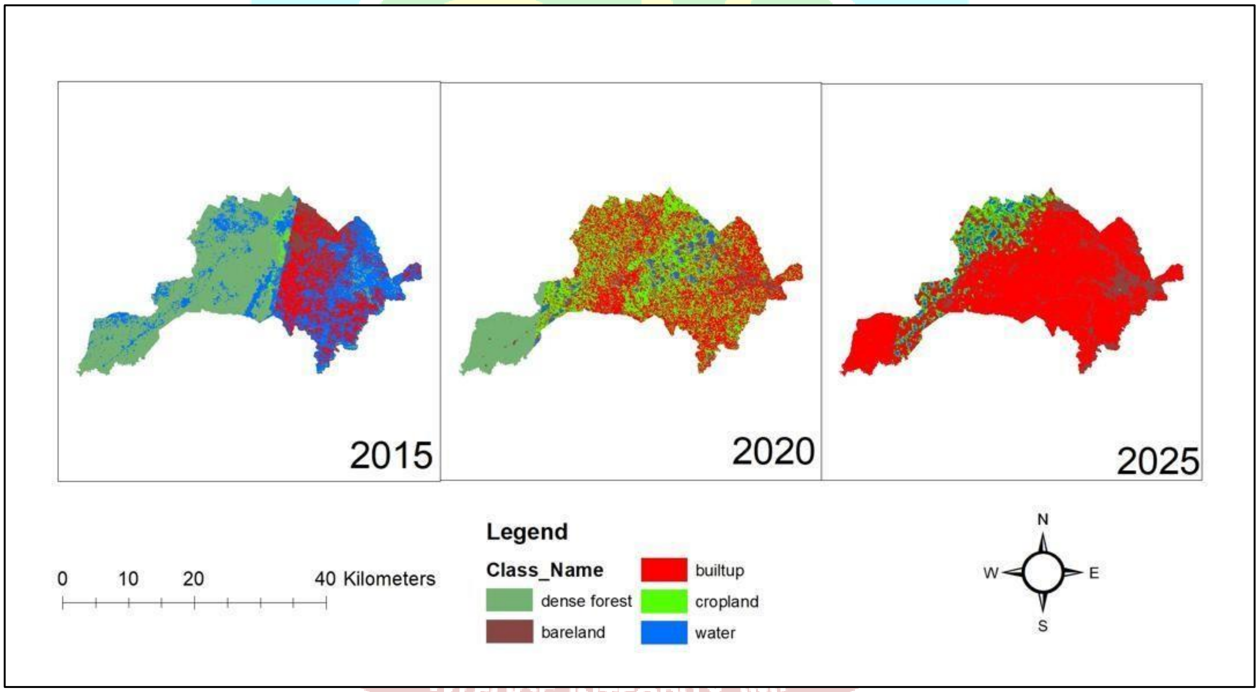

Figure 4. 1: Land Use Land Cover Change at Mankranso from 2015- 2025

Conversely, dense forest cover declined sharply from 48% in 2015 to just 10% in 2025, underscoring extensive deforestation and encroachment. Cropland exhibited modest fluctuations, increasing slightly from 12% in 2015 to 15% in 2020, before dropping to 6% in 2025, suggesting that agricultural land was progressively converted into built-up areas or degraded into bareland.

Bareland, though relatively small in proportion, showed minor increases from 5% in 2015 to 7% in 2020, followed by a decline to 4% in 2025 **(Figure 4.2)**, possibly reflecting temporary land clearance and subsequent conversion into settlement or mining activities. Water bodies remained the least affected category, maintaining 2–3% across all years, indicating relative stability, although slight reductions may be linked to sedimentation, siltation, and encroachment along riverbanks.

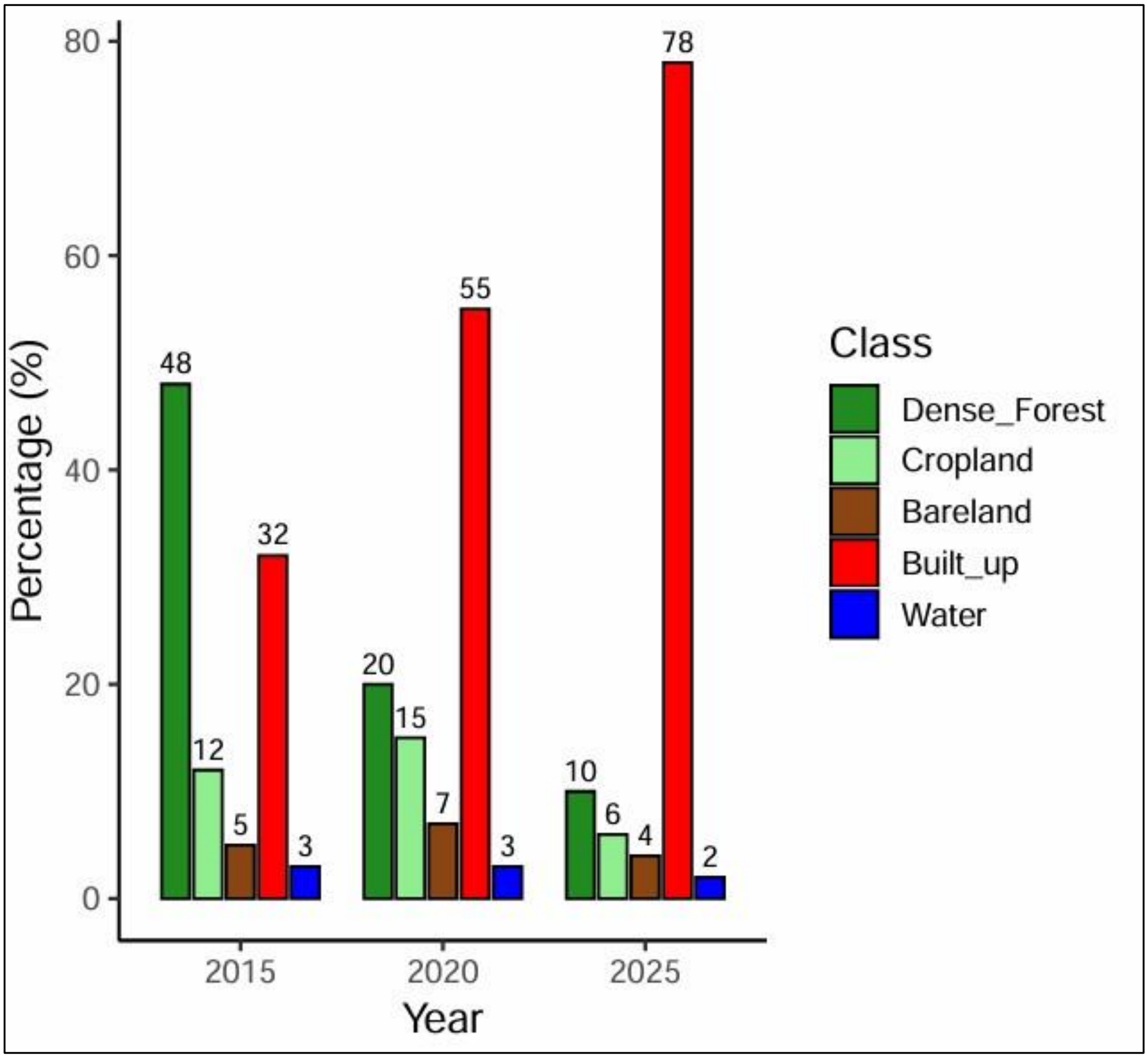

Figure 4. 2: Percentage distribution of Land Use Land Cover Classification from 2015 to 2023

These observed trends are consistent with previous studies in fast-growing Ghanaian towns, where illegal mining and urban expansion are major drivers of land cover transformation (Biney &

Boakye, 2021; Toure et al., 2020). For example, Abass et al., (2018) documented a 60% increase in built-up cover in Kumasi over two decades, accompanied by a corresponding decline in forest and agricultural lands. Similarly, Biney & Boakye, (2021) reported how population growth, weak land-use planning, and natural resource exploitation contribute to rapid forest loss in peri-urban areas of Accra and Takoradi.

Statistical analysis confirmed that built-up expansion between 2015 and 2025 was highly significant ($p < 0.01$), while reductions in water bodies were not statistically significant ($p > 0.05$), suggesting resilience of aquatic systems compared to terrestrial land covers. However, the drastic decline in dense forest is alarming due to its implications for biodiversity loss, reduced ecosystem services, and disruption of local microclimate regulation. Deforestation exacerbates the urban heat island effect, reduces carbon sequestration capacity, and increases vulnerability to flooding due to loss of natural infiltration (Nat et al., 2018).

The transition of cropland to built-up land raises further concerns for food security. As reported in similar agricultural belts of Ghana, such as Bono and Ahafo, rapid land conversion reduces crop yields and undermines the livelihoods of smallholder farmers (Ampim et al., 2021). The built-up surge of 46 percentage points within a decade represents one of the most rapid transformations recorded in Ghana, and if unchecked, could aggravate urban flooding, air pollution, and climaterelated vulnerabilities. The consequences of this transformation extend beyond the biophysical environment into social and economic domains. Uncontrolled urban growth often leads to informal settlements, poor sanitation, and inadequate infrastructure, thereby compounding environmental risks. Similar outcomes have been documented in mining regions of Nigeria (Omemu & Aderoju,

2008) and Kenya (Fayiga et al., 2018) suggesting that without proactive planning and regulation, Mankranso may face long-term sustainability challenges.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This section examines the environmental and socioeconomic impacts of illegal gold mining (galamsey) using an integrated mixed-methods design that combined hydrochemical analysis, GIS-based spatial assessment, and socioeconomic survey techniques. The study applied both descriptive and inferential statistical methods to assess the magnitude, pattern, and determinants of environmental degradation and its associated social consequences in the study area. The integration of these methods provided a multidimensional understanding of how illegal gold mining activities alter environmental systems, affect human livelihoods, and challenge governance and policy enforcement.

The results from the laboratory analysis revealed that concentrations of heavy metals, particularly iron (Fe), manganese (Mn), and arsenic (As), were significantly higher in areas closer to mining sites than in upstream or control areas. The inferential statistical analysis confirmed that proximity to mining sites had a statistically significant relationship ($p < 0.05$) with deteriorating water quality parameters such as electrical conductivity (EC), total dissolved solids (TDS), and turbidity. This implies that artisanal and small-scale mining (ASM) is a major driver of hydrochemical contamination in the study area. The variation of pollutant concentration across sampling locations further demonstrates that mining intensity and drainage connectivity directly influence the distribution of pollutants.

The GIS-based Land Use and Land Cover (LULC) analysis revealed that mining-disturbed lands expanded by approximately 25–30% between 2015 and 2025, while forest and agricultural areas experienced corresponding declines. The magnitude of LULC change, coupled with increased sediment load and soil exposure, indicates significant ecosystem degradation. The spatial pattern of change further corroborates the hydrochemical results, showing that areas of active mining correspond closely with zones of high contamination.

The socioeconomic analysis established that communities located near illegal mining sites have experienced considerable livelihood disruptions. Farmers reported reduced agricultural productivity due to topsoil removal, sedimentation, and loss of arable land. Water contamination has forced households to rely on alternative and often expensive water sources, increasing financial burdens. Health impacts were also evident, as respondents cited higher incidences of waterborne diseases and skin irritations. Statistical correlations between household distance from mining sites and livelihood indicators such as income, crop yield, and health expenditure further confirmed the cascading social impacts of environmental degradation.

Institutionally, the study found that regulatory enforcement remains weak due to overlapping mandates, inadequate logistics, and limited technical capacity among agencies such as the Environmental Protection Agency (EPA), the Minerals Commission, and local assemblies. The lack of coordination and real-time monitoring systems has created enforcement gaps that allow illegal mining to persist despite ongoing interventions. The absence of consistent environmental monitoring and public accountability mechanisms has also limited the ability of policymakers to evaluate the effectiveness of regulatory actions.

Although illegal mining was identified as the main driver of degradation, the study recognized other contributing factors such as agricultural runoff, natural geochemical weathering, and poor land-use management practices. Acknowledging these confounding influences enhances the scientific validity of the conclusions and reinforces the need for integrated management that considers all sources of environmental stress. Nonetheless, the inferential results indicate that mining remains the predominant contributor to heavy metal contamination and LULC change, confirming its primary role in the observed environmental deterioration

5.2 Recommendations

Based on the findings, the following recommendations are made to address the socioeconomic and environmental challenges associated with illegal gold mining in Mankranso:

i. Strengthen enforcement and institutional accountability.

Regulatory agencies such as the Environmental Protection Agency (EPA) and Minerals Commission should institutionalise real-time monitoring using GIS and remote-sensing systems, supported by periodic field inspections. Offenders should face stricter penalties under Act 703 to deter persistent illegal activity.

ii. Enhance inter-agency coordination.

A national inter-agency task force should be established to harmonise activities among the EPA, Water Resources Commission, Forestry Commission, and District Assemblies. Shared databases and joint reporting systems will improve transparency and resource sharing. iii. Establish community environmental watch committees.

Committees composed of trained volunteers should conduct local surveillance, report illegal activities, and assist with rehabilitation programmes. iv. Promote livelihood diversification and social resilience.

Alternative income schemes such as agroforestry, aquaculture, beekeeping, and eco-tourism should be supported through micro-credit and training initiatives.

v. Intensify environmental education and awareness campaigns.

Continuous sensitization in schools, churches, and community fora should focus on environmental stewardship, water safety, and sustainable practices. vi. Strengthen gender-inclusive participation.

Women and youth should be specifically targeted for capacity-building to enhance inclusivity in environmental decision-making. vii. Institutionalize periodic water quality monitoring.

Establish a standardized quarterly sampling schedule for all major water bodies in mining zones. Results should be compiled in an open-access database to promote transparency.

Indicator: Frequency of sampling; publication of annual water-quality bulletins.

viii. Adopt regular GIS and remote-sensing surveillance.

Conduct semi-annual analyses of satellite imagery to identify emerging mining sites and assess reclamation progress. ix. Rehabilitate degraded landscapes using adaptive technologies.

Employ phytoremediation and controlled backfilling techniques to restore mined-out pits and improve soil fertility.

x. Ghana Water Company Limited (GWCL) should provide boreholes and standpipes in downstream settlements where river water quality is critically compromised.
xi. Universities and research institutes should undertake longitudinal studies on water, sediments, and aquatic organisms to monitor heavy metal accumulation and ecological risks.
xii. The Ghana Health Service (GHS) should collaborate with academic institutions to carry out biomonitoring of vulnerable populations (children and women) to assess exposure to lead, mercury, and cadmium in mining-affected areas.

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APPENDIX: QUESTIONNAIRE

ASSESSING THE ENVIRONMENTAL AND WATER QUALITY IMPACTS OF ILLEGAL GOLD MINING IN MANKRANSO, ASHANTI REGION, GHANA: IMPLICATIONS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT.

Dear Respondent,

Please, a study is being conducted on the above topic and would be very grateful if you could respond to the questions developed below. Please, your identity would by no means be revealed in any form; therefore, be at liberty to complete the questionnaire with independent and objective judgment. Information provided shall be treated strictly confidential and for academic purpose only.

Thank you.

Instructions: Please tick [✓] the box that best represents your view or state where appropriate.

SECTION A: Demographic of Respondents

This section of the questionnaire refers to the background or biographical information. Although, the researcher is aware of the sensitivity of the questions in this section, the information provided would allow comparison of groups of respondents. Once again it is assured that your response would remain anonymous.

1. Gender: a. Male [ ] b. Female [ ]

2. Marital status: a. Married or living together [ ] b. Never married [ ] c. Previously married (divorced, separated) [ ] d. Not applicable (child < 16 years) [ ]

3. Age group: a. 18 – 30 [ ] b. 31 – 40 [ ] c. 41 – 55 [ ] d. 56 and above [ ]

4. Residential status: a) Native [ ] b) Migrant [ ]

5. Educational background a. Basic [ ] b. Secondary [ ] c. First Degree [ ] d. Post-Degree [ ] e. Others (specify)…………………………………………………………………

7. Name of your Community a. Mankranso [ ] b. Other [ ]

8. **Occupation:** a. Farmer [ ] b. Mining operator [ ] c. Self-employed [ ] d. Security service[ ]

e. Opinion Leader [ ], f. other:………..

9. Years of experience in the occupation

a. 1-5 years [ ] b. 6-10 years [ ] c. 11-15 years [ ] d. 16 years and above [ ]

SECTION B: ILLEGAL MINING ACTIVITIES

10. Are you aware of illegal gold mining activities in Mankranso?

a. Yes [ ], b. No [ ]

11. If yes, what is the main method used for illegal mining?

a. Surface mining (galamsey) [ ] b. Deep shaft mining[ ] c. Riverbed mining[ ] d. Other (Specify: ________)

12. What mining equipments are commonly used in illegal gold mining? (Check all that apply) a. Excavators [ ] b. Shovels & Pickaxes[ ] c. Mercury for gold processing[ ] d. Other (Specify: ________)

13. What are the main reasons for engaging in illegal gold mining? a. Unemployment [ ] b. High demand for gold[ ] c. Lack of strict law enforcement[ ] d. Quick financial gain[ ] e.Other

(Specify:………………………………………………………………………………..)

14. Has the illegal mining operations resulted in displacement of individuals from their habitations in your community?

a. Yes [ ] b. No [ ] c. Have no idea [ ]

15. Rank the level of agreements with the following negative effects of mining on the livelihoods of the people.

Negative Effects of Mining on Livelihoods	**Level of Agreement**				
	1	**2**	**3**	**4**	**5**
a. Increased cost of living					
b. Increased in school dropouts					
c. Increased in social vices					
d. Increased in flooding and communicable diseases					
e. Destruction of farmlands and crops					

Scale: 1 = Strongly Agree; 2 = Agree; 3 = Neutral; 4 = Disagree; 5 = Strongly Disagree

SECTION C: ENVIRONMENTAL IMPACTS OF ILLEGAL GOLD MINING.

16. What are the major environmental issues caused by illegal mining in Mankranso? (Check all that apply)

a. Deforestation [ ] b. Land degradation[ ] c. River and water pollution[ ]

d. Loss of biodiversity[ ]e. Air pollution f. Noise pollution g. Other (Specify: ________)

17. Have you observed changes in the quality of water sources due to illegal mining? a. Yes [ ] b. No [ ]

18. If yes, what kind of changes have you noticed?

a. Water color change (muddy, brown, or reddish) [ ]

b. Presence of chemicals (e.g., mercury, cyanide) [ ]

c. Reduction in aquatic life (fish, frogs, etc.) [ ]

d. Bad odor from water sources [ ]

Other (Specify: __________________)

19. Do you believe illegal mining has affected agricultural activities in the area?

a. Yes [ ] b. No[ ],

20. If yes, how has it affected farming?

a. Reduced soil fertility [ ] b. Destruction of farmlands[ ] c. Contaminated crop[ ] d. Reduced water supply for irrigation[ ] e. Other (Specify: ______________________)

21. Have the mining operations caused farmers to switch from farming to mining related occupations?

a.Yes [ ] b. No [ ] c. Have no idea [ ]

22. Are there any reported cases of health issues due to illegal mining activities?

a. Yes [ ] b. No [ ]

23. If yes, what health problems have been observed?

a. respiratory diseases (due to dust and chemicals) [ ] b. Skin diseases [ ] c. Mercury poisoning[ ] d. Waterborne diseases [ ] e. Other (Specify: ____)

SECTION D: WATER QUALITY IMPACTS

24. Which of the following sources of water are commonly used in Mankranso?
Rivers/Streams [ ] b. Borehole[ ] c. Wells[ ] d. Pipe-borne water[ ]

25. Do you think the water quality in the area is safe for drinking?
a. Yes [ ] b. No [ ].

26. How did you perceive the quality of water that you use for drinking and cooking 10 years ago?
A. Very safe [ ] b. moderately safe [ ] c. not safe [ ]

27. If not safe, why do you think it was not safe? A. Smell [ ] b. Color [ ] c. Upstream pollution [ ] d. Unsafe use of the source[ ] e. Lack of protection[ ] f. Other (specify)……………………………………………………………………………………………

28. Did you experience any disease, which you think is related to the poor quality of water?
Yes [ ] No [ ].

29. If yes, list or describe the diseases………………………………………………………………………………

30. Who was affected in the family? a. Children under 5years [ ] b. School going children (between 5 and 15years of age) [ ], c. Adult females (>18years) [ ] d. Adult males (>18years) [ ], e. Everyone in the family [ ]

31. 51. How often did people get affected? a. every day [ ] b. every week[

] c. every month[ ], other……………..?

SECTION E: SUSTAINABLE ENVIRONMENTAL MANAGEMENT STRATEGIES

32. Are you aware of any government policies regulating illegal mining?

a. Yes [ ] b. No [ ]

33. Have there been any local or national efforts to stop illegal mining in the area?

a. Yes [ ] b. No [ ]

34. Do you think law enforcement on illegal mining is effective?

a. Yes b. No

35. What alternative livelihood programs would you suggest for illegal miners?

a. Agriculture b. Vocational training c. Small-scale legal mining d. Other (Specify:________)

36. What measures do you think should be put in place to restore degraded lands?

a. Tree planting [ ] b. Reclamation of mined lands[ ] c. Enforcement of strict mining regulations[ ] d. Other (Specify: ________)

37. What role should the government play in controlling illegal mining? (Open-ended response)

………………………………………………………………………………………………

38. What role should the local community play in protecting the environment? (Open-ended response)

………………………………………………………………………………………………

………………………………………………………………………………………………

THANK YOU FOR ANSWERING THE QUESTIONS

Copy of Ethical letter

To:

The Community Heads and Hospital Administration, Mankranso
Community & Mankranso Government Hospital,
Ahafo Ano South District.
Ashanti Region, Ghana.

Dear Sir/Madam,

REQUEST FOR PERMISSION AND COOPERATION IN DATA COLLECTION FOR ACADEMIC RESEARCH.

I am Ms. Elizabeth Kwaa Afi, a final-year MSc student in Environmental Engineering and Management at the University of Energy and Natural Resources, Sunyani. I am conducting field research as part of my thesis titled:

"ASSESSING THE ENVIRONMENTAL AND WATER QUALITY IMPACTS OF ILLEGAL GOLD MINING IN MANKRANSO, ASHANTI REGION, GHANA: IMPLICATIONS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT."

The objective of this research is to assess the extent of water pollution and associated health impacts resulting from illegal gold mining (Galamsey) activities in the Mankranso area, and to provide evidence-based recommendations for sustainable environmental management.

As part of this study, I seek to:

1. Conduct field sampling and analysis of surface and groundwater sources in and around mining/pollution sites.
2. Administer questionnaires and interviews with community members and hospital staff to collect data on environmental conditions and health-related impacts.
3. Engage local stakeholders to understand community experiences and environmental concerns.

I respectfully request your permission and support to:

1. Access water sources and relevant mining sites for environmental sampling
2. Interact with members of your community and hospital staff
3. Administer surveys/questionnaires in a manner that respects the community's time, privacy, and consent.

All data collected will be used strictly for academic purposes and handled in accordance with ethical research guidelines. Participant anonymity and confidentiality will be maintained at all times.

I kindly seek your endorsement and any guidance necessary to ensure that my research is conducted in a culturally respectful and collaborative manner.

Thank you for your time and anticipated cooperation.

Yours faithfully,
…………………….

Elizabeth Kwaa Afi.

(UEMS0501323)