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Mining Supply Chain Governance and Water Quality Outcomes in Illegal Mining Regions in Ghana: The Role of Intelligence-Led Policing and Community-Oriented Policing

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Abstract
Illegal artisanal and small-scale mining (ASM), locally known as galamsey, is a major driver of water pollution in Ghana's mining regions, yet limited empirical evidence exists on how governance systems and policing strategies influence water quality within illegal mining supply chains. This study examines the relationship between Mining Supply Chain Governance (MSCG), Intelligence-Led Policing (ILP), Community-Oriented Policing (COP), and water quality across the Western, Western North, Ashanti, and Eastern regions of Ghana using a mixed-methods approach. Laboratory analyses of river water samples were combined with qualitative interviews involving 251 stakeholders, including regulators, police officers, miners, community leaders, and residents, with thematic analysis conducted using NVivo. Results revealed extremely high turbidity levels and contamination by toxic elements such as mercury, cadmium, and lead in several river systems. Four key themes emerged: water quality degradation, governance failures, mining supply chain dynamics, and policing constraints, highlighting weak institutional coordination and limited enforcement capacity that enable illegal mining activities to persist. Drawing on Institutional Theory and Routine Activity Theory, the findings demonstrate that governance failures and policing gaps significantly contribute to environmental degradation, while emphasizing the complementary roles of ILP and COP in strengthening environmental governance and improving water monitoring systems, ultimately offering practical policy insights for sustainable mining governance in Ghana and similar resource-dependent contexts.

Keywords: Illegal mining (galamsey); Mining supply chain governance; Intelligence-led policing and community-oriented policing; Water quality degradation; Environmental governance

1.0 INTRODUCTION

Illegal mining in Ghana, commonly referred to as galamsey, involves artisanal mining operations conducted without adherence to legal, environmental, and institutional regulations (Hilson & Maconachie, 2020). It is typically characterized by lack of formal authorization, unsafe mining practices, environmental violations, and weak institutional oversight. Galamsey has significantly contributed to environmental degradation across Sub-Saharan Africa, resulting in serious challenges such as river contamination, deforestation, soil erosion, and widespread water pollution (Agyei, 2022; Blay, 2022; Sunkari et al., 2022; Donkor et al., 2023; Agyei et al., 2026). Illegal mining in Ghana involves complex connections between financiers, equipment brokers, gold buyers, and transportation systems, making regulation difficult (Gaisie, 2024; Twumasi-Anokye, 2024; Achamah, 2025). Studies have linked pollution of major river basins like Pra, Offin, Ankobra, and Birim to sediments, mercury amalgamation, and cyanide leaching from uncoordinated artisanal mining (Akabzaa et al., 2007; Donkor et al., 2015; Hilson and Maconachie, 2020; Sunkari et al., 2022). These impacts compromise governance systems by undermining public trust and regulatory effectiveness, creating sustainability challenges affecting community livelihoods.

The environmental effects of illegal mining are global. Studies from Asia, Latin America, and Europe show uncontrolled mining causes increased turbidity and pollution, harming human health and freshwater environments (Oelofse & Turton, 2008; Abiye & Ali, 2022; Adeniyi et al., 2022). Surveys have found widespread river pollution by arsenic, lead, cadmium, manganese, and mercury, posing ecological risks in mining-dependent areas (Candeias et al., 2015; da Silva et al., 2025).

While literature on environmental effects of illegal mining grows, it typically separates ecological deterioration from governance failures. Environmental analysis focuses on water quality indicators, while governance analysis examines regulatory inefficiency and policy implementation (Mensah et al., 2015; Asuamah Yeboah, 2023; Chen and Ding, 2023). Few studies combine enforcement measures with environmental impacts, and none systematically investigate relationships between mining supply chain governance, policing approaches like Intelligence-Led Policing (ILP) and Community-Oriented Policing (COP), and water quality measures in

developing nations where illegal mining is prevalent.
Environmental sustainability means that the river systems and ecological processes remain active despite mining pressures (Dunham et al., 2018; Grabowski et al., 2022; Vercruysse et al., 2022). The results of water quality relate to the measurable factors of freshwater situation (Tavakoly Sany et al., 2014; Mosley, 2015; Guerra-Garcia et al., 2021). The gap identified is that no studies combine illegal mining, water quality and policing frameworks in an analytical way. Previous research on Ghana has not utilized a combined concept of water tests, stakeholder interviews, and governance, which restricts the knowledge of the policymakers on the relations of enforcement mechanisms and the water quality results.
The gap in the existing research is that it provides a complete filling to the research gap because it takes a mixed-method approach, involving the laboratory analysis of the water samples, the theoretical analysis of the interview of stakeholders using the NVivo, and the theoretical conceptualization of the ILP and the COP into the mining supply chain governance. The study is conducted in the four principal mining regions, including Western, Western North, Ashanti, and Eastern regions, and focuses on a variety of different conditions of illegal mining, ecology, and interactions between the enforcement.
This study has two objectives. First, the research evaluates environmental impacts of illegal mining on freshwater systems in affected communities by integrating scientific water quality data and stakeholder perceptions. This goal specifically evaluates measurable indices of water degradation, such as turbidity, sediment loads and heavy metal pollution linked to artisanal and small-scale mining. Second, the paper examines the impacts of enforcement methods, particularly ILP and COP, on water quality results in mining supply chain governance.
The analysis aims to determine how institutional coordination, intelligence-based enforcement and community-police partnership regulate illegal mining and preserve freshwater ecosystems. The research has two main questions. First, how do illegal mining activities impact water quality in Ghanaian mining communities, regarding laboratory-based environmental indicators and stakeholder perceptions? Second, what are the effects of ILP and COP interventions on water quality outcomes under mining governance through Ghana's mining supply chain? The theory of the study presupposes institutional coordination, regulatory oversight and supply chain transparency influence water quality via ILP, and COP mediates these effects by facilitating or diminishing community-police cooperation. It is a unique approach that integrates environmental science and policing research, which has been tested using both laboratory and qualitative findings.

2.0 LITERATURE REVIEW

The illegal and artisanal mining activities continue to play a major role in the destruction of freshwater ecosystems both in the developed and developing world (Armah et al., 2013; Githiria & Onifade, 2020; Ouma et al., 2022). The mining activities destroy riverbeds and discharge suspended sediments and toxics, including mercury, arsenic, and cyanide, hence adding ecological pressure and creating severe
health hazards to the local communities (Candeias et al., 2018; Talukder et al., 2024).
In Ghana, a problem of illegal mining, also known as galamsey, has exacerbated these effects, and research has shown that there is more turbidity, sedimentation, and heavy metal pollution in large river basins because of this problem, making the water undrinkable, unproductive, and useless (Yirenkyi Fianko, 2021; Darko et al., 2023; Donkoh). This part reviews the literature on water quality degradation, environmental crime and crime control, lack of governance, policing theories, and supply chain governance of mining and finds gaps that clarify the use of a mixed-method attitude in the present study.

2.1 Mining and Water Quality Degradation

Water quality degradation is defined as the reduction of the physical, chemical, and biological characteristics of surface or ground water, which is mostly caused by heavy metals, acidic drainage, cyanide, and suspended solids (Omer, 2019; Akhtar et al., 2021; Zhang et al., 2023). Studies have associated mining processes with water turbidity, changes in the PH, high levels of dissolved metals, and bioaccumulation of toxic substances in the river ecosystem (Byrne et al., 2012; Ouma et al., 2022).
Mercury contamination in areas of artisanal gold mining in Peru and in the Brazilian Amazon has caused neurological diseases and environmental harm by accumulating in food chains (Dórea & Marques, 2016; de Bakker et al., 2021). Similar tendencies could be observed in Africa, where ore processing on the banks of rivers leads to the increase of the level of suspended solids and turbidity (Okolo et al., 2018; Ouma et al., 2022, Nunoo et al., 2022).
Even in extremely controlled settings, the occurrence of pollution incidences is intermittent; the recent collapse of the Sino-Metals leach dam in Zambia is evidence that mining-related water pollution is persistent despite the presence of environmental protection (Chama et al., 2026; Muimba-Kankolongo et al., 2026). It has been indicated that mining as a cause of water quality opposite is an extensive and systemic phenomenon, especially in areas where governance is weak like in Ghana.

2.2 Environmental Crime and Enforcement Approach: The Role of Policing

Environmental crime constitutes criminal acts that harm the ecosystem, such as unauthorized mining, water pollution, illegal logging, and wildlife trafficking (White, 2021; 2022; Koci, 2023). Illegal mining is a significant issue, as reported to take place in isolated regions, organized gangs, and worsened by institutional vulnerability, corruption and lack of resources (Zabyelina & Van Uhm, 2020; Modise, 2025). The solution to this problem is unified governance, community participation and special methods of policing that aim at environmental protection.
Two main models of policing are being discussed in the context of environmental enforcement. ILP focuses on

gathering intelligence, information-driven decision-making, and focused enforcement to break down the illegal networks (Amos et al., 2022; Elias, 2022; Dolan, 2026). COP is focused on the establishment of trust and cooperation between law enforcement and community members and the development of local stakeholders to take part in monitoring and prevention activities (Santana, 2021; Buçpapaj, 2024; Awoyemi et al., 2025).
Cases of Brazil and Indonesia demonstrate that the combination of ILP and COP can be used to better locate the illegal mining locations and reinforce the environmental monitoring frameworks (Tacconi et al., 2019; Rohman et al., 2024; Arlianto et al., 2026). Nonetheless, peer-reviewed studies have not yet found any connection between ILP and COP models and measurable environmental impacts, including laboratory-measured quality of water. It is one of the literature gaps that the current study aims to fill.

2.3 Illegal Mining, Governance Failures, and Water Pollution
In Sub-Saharan Africa, the problem of illegal and artisanal mining is one of the primary contributors to the pollution of water, which is mainly caused by the weak system of environmental governance (Justice et al., 2017; Mimba et al., 2023; Mulenga et al., 2024). Governance gaps (such as fragmentation in institutional roles, political interests, inadequate surveillance and corruption) facilitate the growth of illegal mining (Campbell, 2006; Spiegel, 2012; Adom & Simatele, 2025). Studies in Mali, Burkina, Faso, and the Democratic Republic of Congo point out that there are continued problems of sedimentation, mercury pollution, and chemical discharge along rivers where institutions have failed to effectively control mining operations (Otamonga & Poté, J2020; Heydari et al., 2025). Such governance failures lead to the lack of confirmed data, which makes it much harder to regulate the ecological changes or create evidence-based interventions. Although governance is an important factor that influences environmental outcomes, research studies on African mining practice seldom relate governance failures to evaluations of water quality or enforcement measures. The lack of understanding of the linkage between governance and environmental matters in the context of illegal mining is brought about by this disconnect.

2.4 Illegal Mining in Ghana: Water Degradation and Institutional Weaknesses
Galamsey mining, which is a common mining activity in Ghana, still impacts negatively on the key river systems such as the Pra, Birim, Offin, and Ankobra. The studies have reported high concentrations of heavy metals, pollutants, and alterations in the color and transparency of water (Boye et al., 2023; Musah, 2025). Locally, it has been reported that there has been a decrease in fish population, rising costs of water treatment, and decreased agricultural production (Ogwu & Kosoe, 2024; Adebayo, 2025). The absence of the coordination between the Minerals Commission, Environmental Protection Agency (EPA), Water Resources Commission, and local governments worsens these environmental issues (Appiah & Abass,2014; Eduful, 2024; Siakwa, 2023). The literature notes that environmental management should be effective through accountability, transparency, and cooperation between various stakeholders, but these aspects are not uniformly implemented in Ghana because of political interference and shortage of resources. Despite all the research available on water pollution and environmental governance in Ghana, there is limited systematic study that considers the role of ILP and COP in water quality outcomes and combines laboratory-validated findings with qualitative information of enforcement officers and societies. The importance of the present mixed-method research can be explained by this gap.

2.5 Mining Supply Chain Governance and Environmental Impact
Regulatory, institutional, and enforcement mechanisms that regulate mineral extraction, processing, transportation, and trading are known as Mining Supply Chain Governance (MSCG) (Bilham, 2021; Rangel, 2021; Cardona Vallès, 2024). MSCG is effective, promotes inter-agency coordination, compliance, and transparency. In cases of weak governance structures, which may be fragmented mandates, political interference, or lack of enforcers, the illegal mining networks take advantage of the loopholes in the regulations, compound environmental destruction, and avoid being tracked down (Spiegel, 2012; Asuamah Yeboah, 2023; Adom, & Simatele, 2025).
Research indicates that participants of the supply chain often contravene environmental rules by emptying the chemical-contaminated tailings into rivers or employing insecure mining methods (World Nuclear Association, 2006; Lowry, 2008; Agyei et al., 2026). Similarly, in Ghana, illegal mining networks support their activities with the latest logistics and informal networks to avoid the policing process, which shows how a breakdown in governance contributes to environmental destruction (Asuamah-Yeboah, 2023; Adom & Simatele, 2025; Agyei et al., 2026). Although there are strong theoretical connections between MSCG and environmental outcome, to the best of our knowledge, empirical research incorporating governance structures with laboratory-tested and measured water quality data are limited, so this study can act as a bridge to this gap.

2.6 Policing in Mining Regions: ILP & COP as Environmental Enforcement Mechanisms
ILP is a strategic concept that focuses more on intelligence gathering, threat assessment, and precise operations in order to break down the criminal gangs, including the illegal mining (Ratcliffe, 2016; 2025). ILP pinpoints the mining hotspots, tracks the equipment movement, and maps supply chains in Ghana. It is effective due to the collaboration of the agencies, logistics, technological solutions (drones), and community collaboration. COP is an expansion of ILP that helps include greater levels of trust, information sharing, and the ability to report mining sites (Skogan, 2018; Braga and Weisburd, 2020).
COP enhances area of enforcement through local ability to understand terrain, river association, and mining structure. ILP and COP can be combined to create a framework in which ILP is a source of operational intelligence and COP is a source of strong local guardianship and legitimacy. Though ILP and COP have been successfully used to solve illegal logging and wildlife trafficking (Humphreys,2016; Stewart, 2016), none of the studies

considers the collective impact of these two on the water quality in the mining areas. The gap highlights the novelty of bringing in ILP and COP in the field of environmental governance studies.

2.7 Theoretical Foundations of the Study

The paper is grounded in the Institutional Theory, Routine Activity Theory (RAT), Governance Network Theory (GNT), and the practical philosophical paradigm that presents a complementary viewpoint to explain the interconnection that exists between mining supply chain governance, policing strategies, and water quality outcomes. The Institutional Theory explains the way in which loose institutional structures, disjointed institutional responsibilities, and uncertain policy implementation provide situations that favour unlawful mining activities (Spiegel, 2012; Chiu, 2018). In this paper, it forms the basis of Mining Supply Chain Governance (MSCG) especially the poor performance of institutional coordination and regulatory controls, which contributes to negative environmental impacts such as water pollution. The Routine Activity Theory (RAT) views illegal mining as an environmental crime, which occurs when the motivated offenders (illegal miners), appropriate targets (mineral-rich areas), and ineffective guardians (lack of effective enforcers) meet (Williams, 2014; Espin & Perz, 2021; Modise et al., 2025).

RAT, in this respect, explicitly explains how the ILP functions as the tool that increases guardianship by collecting intelligence and identifying hotspots, followed by appropriate enforcement, as the means of reducing the effects of illegal mining and the quality of water as the results. Governance Network Theory (GNT) highlights the importance of multi-actor governance that is collaborative and that includes regulators, law enforcement agencies, the local authorities and the communities (Stewart, 2004; Falayi et al., 2020; Feng et al., 2025). It explains that COP is more effective in governing through trust building, better sharing of information, and a greater contribution of community in checking the activities of illegitimate mining. In this perspective, COP is placed as a mediating process that enhances the success of ILP and other wider governance interventions. Lastly, the pragmatic philosophical paradigm allows combination of quantitative information about the environment (e.g., qualities of water turbidity and heavy metals) with qualitative information provided by the stakeholders, which will help understand the way in which the governance and policing strategy translate into a specific ecological result (Wilson, 2018; Supangkat et al., 2024).

This paradigm supports why the proposed study employs a mixed-methods design and guarantees that the theoretical concepts relate to the practical solutions that can be implemented in the policy. These theoretical views combined can explain the structure of governance (MSCG) and explain the mechanisms of enforcement (ILP), collaborative processes (COP), and pragmatism can combine to determine the overall impact of the combination of these factors on water quality outcomes.

Conceptual Framework: Assessing MSCG Influence on Water Quality

The framework suggests that Mining Supply Chain Governance (MSCG) has an impact on environmental outcomes with the change mediated by COP as shown in Figure 1 and Table 1 below. Good governance is an effective way to improve ILP through better clarity of regulations, allocation of resources, and coordination among institutions (Arman & Rafi, 2025, Davies, 2025). The effects of ILP are a reduction in illegal mining due to higher surveillance, limitation of opportunities to criminals, and better hotspots detection (Mertens, 2021; Simbolon & Pratama, 2025). COP improve ILP through the establishment of trust, monitoring, and promotion of reporting of illegal mining (Harimbawa et al., 2022; Arlianto et al., 2026). The effectiveness of governance nexus-policing is observed in the Water Quality Outcomes such as turbidity, heavy metals and sediment loads. According to Environmental Governance Theory, ecological conditions are determined by the interaction of state institutions, enforcement systems, and communities (Partelow et al., 2020; Bodin, 2017). The framework hypothesizes that well-functioning ILP and COP improve the quality of water, whereas institutional weakness, poor policing, and low civic engagement cause ecological degradation (Cachalia, 2022; Mliless, 2024).

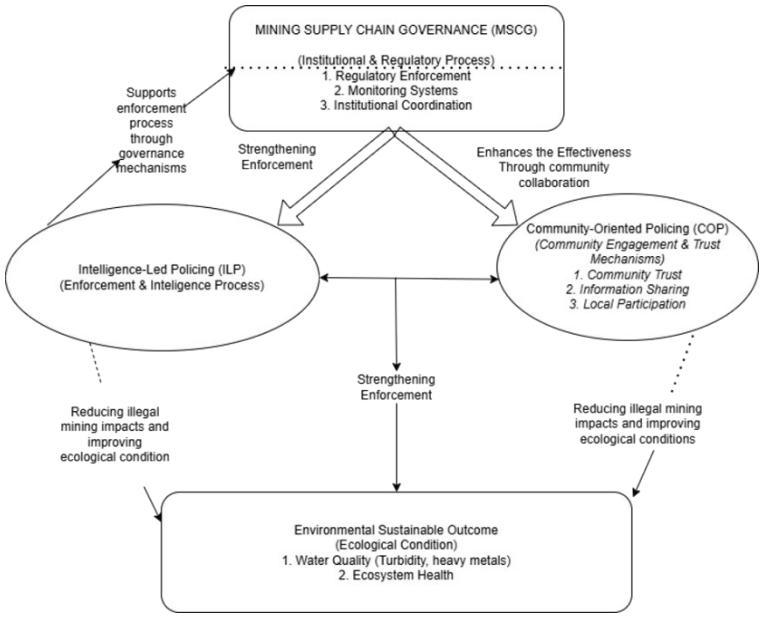


Figure 1: Conceptual Framework linking Mining Supply Chain Governance, Policing Strategies, and Environmental Sustainable Outcome. Source: Authors' own generation (2026)

Table 1: Operational Definition and Measurement Indicators of Key Variables

Variables	Definition	Measurement
MSCG	Institutional coordination in mining governance	Regulatory coordination, Transparency
ILP	Intelligence-based enforcement	Hotspot mapping, Intelligence sharing
COP	Community engagement	Reporting behaviour
Water quality	Ecological condition	Turbidity, Hg, Arsenic

Source: Authors' own compilation (2025)

3.0 RESEARCH METHODOLOGY

3.1 Research Design

The proposed study will be of a convergent parallel mixed-methodology (Creswell and Plano Clark, 2018; Bhana, 2024), as it will combine a laboratory-based water quality examination with a qualitative thematic investigation of the governance and policing approaches to illegal mining in Ghana. This choice of design is based on the main goal of the study, which is to comprehend the scientific scope of water degradation, as well as the institutional and policing processes that inform the environmental results. This design involves the simultaneous collection of quantitative and qualitative data, analysis done separately and finally, during interpretation, synthesis. This allows triangulating the results, increases validity, and a more holistic view of the interaction of Mining Supply Chain Governance (MSCG), Intelligence-Led Policing (ILP), and Community-Oriented Policing (COP) in determining the water quality in the illegal mining-impacted areas. The convergent mixed-method design is particularly appropriate to the research of environmental governance in which empirical ecological data has to be embedded into the context of institutional, social, and enforcement processes (Mahmood et al., 2018; Adam et al., 2025).

3.2 Study Area

The study was carried out in the four mining areas of Ghana namely Western, Western North, Ashanti and Eastern, and they were identified as vulnerable and problematic in terms of governance because of artisanal and small-scale mining (ASM) and illegal mining (galamsey). These areas were chosen due to their (i) the presence of illegal mining activities, (ii) the serious degradation of the river systems, (iii), complicated policing and governance relations, and (iv) the peculiarities of community and state relations in the process of implementation of environmental regulations. The traits give a proper background to the analysis of impacts of MSCG, ILP and COP on water quality results.

3.3 Research Setting

Ghana is a country in West Africa with a latitude of 11.5 0 N and a longitude of 3.5 0 W and a longitudinal range of 1.3 0 E, it is made up of sixteen regions and has an area of about 238,535 km (Osei et al., 2018). The mining industry is also a major contributor to the economy of the country as it is a leading sector in the industry and contributed to 29.7 percent of the GDP in early 2025. By comparison, agriculture was 23.5% and services 46.8 (Ghana Statistical Service, 2025).

With Ghana being the largest producer of gold in Africa, in 2024, the country produced approximately 136 tons of gold, almost 40 percent of which is as a result of artisanal and small-scale mining (Ndikumana et al., 2023; Hunter & Ofosu-Peasah, 2025; Achamah, 2025; Ayelazuno & Aziabah, 2025). Western, Western North, Ashanti and Eastern regions are marked by rich mineral resources, fertile farmland and a high level of socioeconomic reliance on waterways. Their records of mining, issues of enforcement and environmental stress, make them suitable to study the governance-policing-environment nexus on the focus of this research.

3.3.1 Study Site Characteristics

The spatial layout of the study areas is as shown in Figure 2 and Table 1. All four regions are typified by a dual

mining economy as a combination of formal mining and large-scale unregulated artisanal and illegal mining activities. These regions are the agro-ecological hotspots of the gold mining sites along major rivers, even though they have high agro-ecological potential.

The following reasons were used to choose these regions: they represent large river basins with turbidity, heavy metal pollution, and sedimentation problems; they have different institutional structures, law enforcement practices, and community governance models; they have a diverse range of ILP and COP strategies; they enable a comparative framework to relate the results of water quality and governance and enforcement practices.

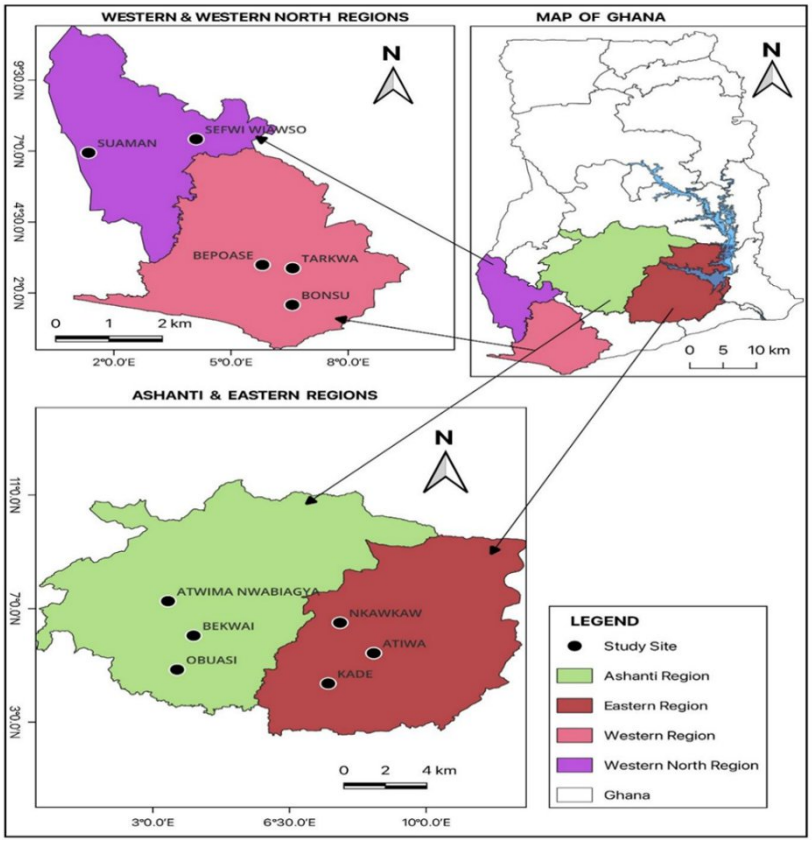


Figure 2: The Study Site. Source: Authors own construct (2025)

Table 2: Unique Characteristics of the Four Mining Regions

Region	Population	Land Area (km²)	Economy	Agro-Ecological Zone	Mean Annual Raindall	Rainfall Pattern	Temperature (°C)	Relative Humidity	Mining Activities (Legal & Illegal)
Western Region	2.6 million	23,921	Cocoa farming, timber, fishing, &mining (Tarkwa Nsuaem, Wassa, Prestea)	Evergreen &Semi-deciduous forest zone	1,500–2,000 mm	Bi-modal (Major: Apr–Jul; Minor: Sep–Nov)	25-30	70-85%	Large-scale: Gold Fields Tarkwa, AngloGold Iduapriem. Illegal mining: widespread along Bonsu, Subri, Beposo rivers, Tarkwa-Nsuaem and Wassa areas.
Western North Region	880,000	5,447	Agrarian (cocoa, food crops), logging, and ASGM	Moist Semi-deciduous forest zone	1,500–2,000 mm	Bi-modal	24–29	70-80%	Legal concessions in Sefwi-Wiawso, Suaman. Illegal mining along Kramo and Sui rivers, with significant ASGM encroachment.

Ashanti Region	5.4 million	24,389	Agriculture (cocoa, maize, cassava), trading, gold mining (Obuasi, Bekwai, Atwima Nwabiagya)	Semi-deciduous forest zone	1,200–1,800 mm	Bi-modal	25–32	65–80%	AngloGold Ashanti (Obuasi). Illegal mining along Offin and Oda rivers, Bekwai, Atwima Nwabiagya districts.
Eastern Region	3.6 million	19,323	Cocoa, oil palm, cassava, trading, and mining (Akyem, Kade, Nkawkaw)	Semi-deciduous forest zone	1,250–1,750 mm	Bi-modal	26–30	65–75%	Newmont Akyem Mine (Birim North). Illegal mining along Birim and Pra rivers, Kade, Atiwa, and Nkawkaw areas.

Source: Ghana Statistical Service (2021); Environmental Protection Agency (2020); Minerals Commission (2023); World Gold Council (2023); Ofosu-Mensah (2017).

3.3.2 Western Region (Tarkwa–Nsuaem, Wassa, Bonsaso)

The Western Region of Ghana (having 13,842 km 2) is considered the richest mining district in the country. Its population is 2,060,585 (GSS, 2021), and it contains major manganese mining fields, including Tarkwa, Iduapriem, and Wassa Mines, as well as manganese mining at Nsuta (Kusimi & Kusimi, 2012; Coakley, 2003; Ghana Chamber of Mines, 2022; Ndikumana et al., 2023). Tarkwa Nsuaem, which lies in the southwestern mineral belt within Ghana is a strategic area in gold production.

Although the Tarkwa and its surroundings are home to multinational corporations, there is a large amount of artisanal and small-scale mining (ASM) and illegal mining along the Pra, Ankobra, Beposo, Bonsu, and Subri rivers. Such informal activities are performed through mechanized dredging, amalgamation of mercury and arsenic, and washing of ores, causing a significant level of turbidity in water, mercury and arsenic pollution, biodiversity loss, and ecological deterioration (Obiri, 2009; Eshun, 2019; Gbeli, 2024). Agriculture and especially cocoa, cassava, and timber production are still crucial to the region, but land-use conflicts and water shortage have been caused by competition with mining (Awotwi et al., 2018; Asamoah, 2025; Donkoh, 2025).

Lack of proper coordination, militarization of actions, including Operation Vanguard, and political interference only serve as short-term solutions to control illegal mining, as they hinder governance and environmental enforcement (Yeboah et al., 2024; Adom & Simatele, 2025; Emmanuel & Kobla,2026). That economic potential, poor governance, and the destruction of the environment present a juxtaposition that makes the Western Region an important region to study how ILP and COP can be used to restore environmental accountability.

3.3.3 Western North Region (Sefwi-Wiawso, Suaman, Sui)

The Western North Region, which is part of the Western Region, covers a size of 20,570 km 2 and registered a population of 880,921 in 2021 (GSS, 2021). Although agriculture, especially cocoa production is the major economic activity, artisanal and illegal gold mining activities have also increased in the forests and rivers, such as Sui, Kramo, and Suaman (Adjei, 2017; Donkor et al., 2023; Donkoh, 2025). Informal mining activities are encouraged by the thick forests and isolated mining terrain in the region that makes it difficult to regulate the activities. The inability to stop illegal mining can be explained by the lack of resources, the fragility of enforcement, and the permeable nature of boundaries between the communities (Asuamah Yeboah, 2023; Ayambire et al., 2024; Donkoh, 2025).

According to the Water Resources Commission (2021), there are high levels of mercury, arsenic, and sediment, which are very dangerous to the ecosystem, agriculture, and drinking water supplies. Such pressures lead to the worsening of the conflicts between the agriculturalists and the miners and rural poverty (Okoh & Hilson, 2011; Hilson & Garforth, 2012; Hilson & Garforth, 2013). The weaknesses of the new region in governance, as well as the weak institutions and the lack of trust of the community in governmental bodies, weaken the effectiveness of COP (Adu-Baffour et al., 2021; Kasimba & Lujala, 2022; Araujo & De Tomi, 2025). These environmental and governance issues make Western North an urgent field to study ILP and COP in terms of environmental conservation.

3.3.4 Ashanti Region (Obuasi, Bekwai, Atwima Nwabiagya)

The Ashanti Region is a region of 24,389 km 2 and about 5.4 million people, making it the second most populous region in Ghana (GSS, 2021). It is labelled as the leading gold-producing region in the country, and significant amounts of formal mining activities contribute to it, including the AngloGold Ashanti Obuasi Mine, and large volumes of artisanal and small-scale mining (ASM) in Bekwai and Atwima Nwabiagya (Hilson, 2012; McQuilken & Hilson, 2016; Hilson & Maconachie, 2017; AngloGold Ashanti, 2022). Obuasi mining history shows that although the multi-national companies supported the growth of industries, the declining workforce in the 1990s

and 2000s prompted former workers and migrants to engage in informal mining (Okyere, 2013; Mensah & Okyere, 2014; Adonteng-Kissi & Adonteng-Kissi, 2017). The presence of ASM activity in the river basins of Offin and Oda led to an increase in water turbidity, mercury pollution, and the loss of biodiversity (Nunoo et al., 2022; Mulenga et al., 2024; Yirenkyi-Fianko & Ottou, 2024; Anoyege & Alatinga, 2025).
The main part of the economy is agriculture, especially growing cocoa, cassava, plantain, and yam, which leads to the confrontation between agriculture and mining industries (Siaw et al., 2023; Sadick et al., 2025; Boachie-Mensah, 2025). Turning cocoa plantations into illegal mines has helped to upset rural life (Adjei, 2017; Appiah et al., 2024). Attempts to control such activities as Operation Vanguard have been having little success as a result of lack of resources and political interference. The Ashanti Region would therefore be used as a case study to analyze how the Integrated Land Planning (ILP) and COP needs to be applied to improve mining governance and environmental performance.

3.3.5 Eastern Region (Kade, Nkawkaw, Birim Basin)
Eastern Region occupies an area of 19,323 km 2 and a population of 2,917,039 in 2021 (GSS, 2021). The area has had a great historical interest in the Ghanaian mining industry and is home to Newmont Akyem Mine and several small- and medium-scale mining operations located within the Atiwa, Kwaebibirem, and Birim North Districts (Baddianaah et al., 2023; Amofah, 2024; Biney et al., 2025).
The use of mechanized dredging machines, also known as Chang fans, to engage in illegal mining operations in the Birim and Pra Rivers has caused siltation, increased turbidity of water, and the presence of mercury (Dwamena, 2013; Hain, 2020; Yirenkyi Fianko, 2021). These operations are a great threat to the quality of water, negatively influence the agricultural productivity, and worsen soil health (Okorogbona et al., 20218; Xing et al., 2025).
In Kade, Nkawkaw and Atiwa, people are suffering diseases related to water and reduced yield of crops. The governance problematic issues are disjointed institutional mandates, insufficiency of capacity at EPA, and ad hoc anti-galamsey campaigns that hardly lead to sustained deterrent (Teschner, 2012; Hilson & Maconachie, 2017; Amoah & Eweje, 2022). The Eastern Region is one of the examples of the difficulty in balancing legal mining activities and suppressing illegal mining operations. The challenges present the need to find a way of ILP to detect illegal networks and COP to strengthen community enforcement.
Illegal mining in all the four regions has had a considerable impact on governance, increased pressures on the law enforcers, and a negative impact on the sustainability of the environment. The ecological vulnerability, fractured leadership, and policing difficulties of mining routes in these regions make them especially pertinent to the analysis of the influence of ILP, COP, and MSCG on the outcomes of the water quality. Moreover, the diversity on the regional level increases the external valiity of the study and generalizability of the results.

3.4 Population of the Study
The term population in the research methodology means a complete group of people with characteristics of interest in the study out of which a sample is taken (Buchstaller & Khattab, 2014; Casteel & Bridier, 2021; Willie, 2024). The population to use in this work was major stakeholders' groups in or affected by mining, mining supply chains governance, environmental degradation, and law enforcement in the Ghana mining areas as indicated in Table 3. The sample population was acquired by the four regions, the Western, Western North, Ashanti, and Eastern regions, which were known to be the key centres of artisanal and small-scale mining (ASM) and the related environmental degradation. Some districts that have widespread illegal mining include Tarkwa-Nsuaem, Wassa, Sefwi-Wiawso, Suaman, Obuasi, Bekwai, Atwima Nwabiagya, Kade, Nkawkaw and Kibi (Owusu-Nimo, 2017; Owusu-Nimo et al., 2018; Owusu, 2023). The largest river basins, such as the Pra, Offin, Ankobra and Birim have been severely affected by illicit mining that has caused a significant ecological change. Five main groups of stakeholders (community leaders (n = 85), ILP/COP officers (n = 45), environmental regulators (n = 25), small-scale miners (n = 40), and youth groups (n = 65) were also used to select 251 respondents. Both categories of groups affect governance, enforcement, and socio-ecological contacts in mining societies.
The biggest category is the community leaders including chiefs, members of an assembly, and opinion leaders since they are the ones who govern the community and have relations with the enforcement agencies. The state enforcement institutions are ILP and COP officers. They added environmental regulators, EPA, WRC and Minerals Commission, in their duties of monitoring the quality of water and imposing standards. Small-scale miners were selected because their activities impact on river systems, and the youth participants are a vulnerable group of people who are involved in illegal mining. These governance actors indicate the socio-political, economic, and environmental aspects of illegal mining.

Table 3: Study Population and Sampling

Stakeholder Group	Western	Western North	Ashanti	Eastern	Total
Community Leaders	25	20	20	20	85
ILP/COP officers	15	10	10	10	45
EPA/WRC/Minerals Commission	10	5	5	5	25
Small-Scale Miners	10	10	10	10	40
Youth Groups (18–35)	20	15	15	15	65
Total	-	-	-	-	251

Source: Authors' own compilation (2025)

3.5 Sampling Method and Sample Size

The study used purposive sampling, which is one of the most common techniques in qualitative and mixed-methods studies, to identify the participants with the necessary knowledge or experience regarding the topic of interest to the research (Dawadi et al., 2021; Haq & Yasin, 2025; Lyaka et al., 2026). The sample was chosen through direct participation or exposure of the participants in the following issues: illegal mining activities, environmental governance, policing strategies and water resource management. The final sample included 251 respondents, who represented the five groups of stakeholders mentioned above. This sampling methodology guaranteed representation of a variety of views of governance authorities, enforcement agencies, mining stakeholders and the communities impacted. The study does not pursue statistical generalization and instead pursues an analytical one, offering theoretically informed conclusions on the governance processes affecting environmental outcomes (Newig & Fritsch, 2009; Bennett & Satterfield, 2018). The sample was determined to be sufficient to reach thematic saturation, in which no new information is added with the help of new interviews (Guest et al., 2020; Chitac, 2022).

3.6 Data Collection Methods

To enhance methodological triangulation and strengthen the validity of the findings, a wide range of data collection methods was employed.

3.6.1 Sampling and Laboratory Analysis of Water Quality.

In all the four study areas, specific rivers were sampled to obtain water samples in areas close to areas of illegal mining activities. In the choice of the sampling sites, such factors as indicators of observable pollution, key to the proximity to mining, contamination reported by the community, and hydrological flows were considered. The samples were maintained and sent to certified laboratories to be analyzed. The main parameters that were checked were turbidity, heavy metal concentrations, level of sediment and chemical pollutants. The results of these laboratory tests provided quantitative measurements of the water quality, and thus it was possible to say how the unlawful mining activities affect the environment.

3.6.2 Semi-Structured Interviews

The main source of qualitative data was the semi-structured interviews. These were interviews with members of all stakeholder groups based on a framework to discuss illegal mining operation, governance and regulatory, enforcement, relationship between the community and the police and how they felt the water quality had changed. The interviews took 30 to 60 minutes and were either in English or Twi, depending on the preference of the participants. Interviews were either recorded on audio tape or recorded in elaborate field notes with permission.

3.6.3 Focus Group Discussions

The focus group discussions were held to get communal views on environmental degradation concerning the community and the response of the law enforcement in illegal mining as indicated in Figure 3. A focus group consisted of 10-20 participants, youth groups, local residents and leaders of the community. The topics from the discussions included seen pollution of a river, how communities respond to illegal mining, and whether the policing strategies were effective and community cooperation with the enforcers. The focus groups were informative on the social processes that govern the environment amongst the mining communities.



Figure 3: Focus group discussion session in Suaman, and Atwima Nwabiagya, participants responding to interview during focus group discussion with community members, Suaman, and Atwima Nwabiagya (March 2025)

3.7.4 Transect Walks and Field Views.

Direct assessment of the environmental conditions on riverbanks and in regions that have been largely impacted by mining operations was done using transect walks as a method to support data gathered through interviews and focus group discussions as shown in Figure 4. Such observations in the field allowed the research team to record observable evidence of environmental destruction related to illegal mining exercises. In these walks, evidence of sedimentation, turbidity of water, abandoned mines, dredging equipment used in illegal mining processes, and other types of land degradation on the surrounding lands were carefully noted by the researchers.

These walks were conducted with the assistance of local guides who were also conversant with the terrain and

mining areas, and thus the hot spots of mining that were important as well as the parts of rivers that were polluted were fully explored. To improve the validity of the observations the researchers photographed, took GPS positioning of the sites of the affected places, and made field notes of the observed conditions of the environment and mining practices of the sites that they visited. These observations were used to supplement laboratory analyses of water, as well as qualitative interviews, to enable triangulation of the evidence, and to gain a better vision of the environmental effects of illegal mining on river systems.



Figure 4: Transect walk near riverbanks and affected areas of illegal mining activities in Dominase Nkwanta (Kramo River), and Suaman (Bia River). Source: Authors' own field capture (2025)

3.8 Qualitative Data Analysis

The qualitative data gathered through semi-structured interviews, focus group discussion and field observations were transcribed and analyzed using NVivo qualitative data analysis software. To explore tendencies and recurring patterns in the text, the thematic approach was applied in the analysis, which is usually applied when conducting qualitative research. To start with, recording all the interview and focus group tapes were transcribed verbatim and checked severally to be conversant with the data. The coding procedure was initiated by the open coding during which the important statements and meaningful pieces of texts were selected and classified.

These preliminary codes were further classified into larger themes that capture key issues that have arisen out of the data like drivers of environmental degradation, failure of governance in mining regulation, the problems affecting law enforcement agencies in fighting illegal mining, and socio-environmental consequences of water pollution on the local communities. The analysis was conducted in an iterative process where the themes were refined continuously and a relationship that existed between them was analyzed. Through such systematic analytical process, the study was able to get a wide range of stakeholder views about mining supply chain governance, policing approaches and environmental sustainability and as such this offered greater insights into the institutional and socio-ecological processes that determined water quality performance in Ghana illegal mining areas.

3.9 Integration of Mixed Methods Data

The analysis of quantitative and qualitative data followed a convergent mixed-method design, thus differentiated and then combined during the interpretation. The results of the environmental data on the water samples were contrasted with the stakeholder reports on the pollution of the river, mining, and enforcement. This combination allowed the research to determine whether localities with the highest water contamination were associated with the lack of governance or enforcement problems. Combining scientific data on water quality with institutional and community perspective, the research gives a broad picture of the environmental consequences of illegal mining and the efficiency of the policing efforts.

3.10 Research Integrity and Ethical Issues.

The research was conducted by the author as part of his doctoral work and the institutional research ethics committee of the school of management at Sir Padampat Singhania University granted the ethical approval of the study. The research also followed internationally accepted ethical principles of conducting research on human subjects. Before data collection, an informed consent was taken out of all the participants. They were put in the know of the study purpose, voluntariness of the study, and they had the right to pull out of the study at any point in time without consequences.

To ensure the privacy of the participants, all the responses of the interviews were anonymized and stored in a secure location. Issues concerning illegal mining were addressed carefully because of sensitive nature of the topics that need to remain confidential and safe of respondents. There were no personal identifiers used in the analysis, and all the data were utilized with the purpose of study. The field researchers also learned to conduct ethical research, such as protection of confidentiality, responsible data handling and respectful interaction with the local communities.

3.11 Interviews with illegal miners as key informants.

To gain an insight into illegal mining and its effects on the environment, semi-structured interviews were held

with purposely selected artisanal and small-scale miners (ASM) in four regions of the study Western, Western North, Ashanti, and Eastern. These miners were one of five key stakeholders (n = 40) and hold key points in the informal mining supply chain. Their views were relevant towards perceiving the degree to which mining activities cause environmental degradation such as sedimentation, turbidity, and gold mining contaminated with mercury and gold mining chemicals.

The purposive sampling was meant to ensure that the sampled participants had first-hand experience on artisanal and illegal mining work such as excavation, dredging of riverbanks, ore washing and the use of mechanized equipment. The campaigns brought on board varying perspectives through incorporation of the miners in various ages, experience and positions in informal mining networks. The small-scale operators, previously licensed and unlicensed artisanal miners were added, to get a balanced view of mining operations, issues of governance and environmental impacts.

Interviews were also held at mining areas, settlements along the riverbanks and the immediate communities. The interviews took up to 30 to 45 minutes in duration and were based on an open-ended interview guide that revolved around the topics of mining supply chain governance, ILP, COP in policing illegal mining as well as the perceived changes in water quality. Interviews were either audio-taped or detailed field notes made of responses; where prohibited, responses were recorded. Perceptions of environmental risks and interactions with law enforcement, experiences of miners with law enforcement, relations between the community and the police, and socio-economic factors that drive illegal mining were discussed. The participants gave information about operational activities such as the dredging of the rivers, release of sediments, use of mercury, movement of the equipment and impacts of policing activities.

The interviews were also continued until thematic saturation was attained where new relevant information was not produced with the additional interviews (Bowen, 2008; Saunders et al., 2018). Transcription and analysis of interviews were done with NVivo software. Coding and grouping the data on the main topics, such as drivers of environmental degradation, lack of governance, and challenges of policing and socio-environmental effects of water pollution. The views of ASM miners formed a vital qualitative source of data, which enhanced the interpretation of the findings of the water quality and improved the analysis of the mining governance and environmental sustainability.

3.12 Interview questions and responses of stakeholders.

Semi-structured interviews with key stakeholder groups that participated in or are impacted by the mining supply chain governance in all four study areas were used to explore the links among illegal mining, policing practices, governance structures, and water quality outcomes as shown in Table 4. These interested groups were artisanal miners, illegal miners, community leaders, the security agents, environmental regulators of Environmental Protection Agency (EPA), Water Resources Commission (WRC), and Minerals Commission, the youth groups, and the district authorities. A questionnaire guide covered the lives and perception of the participants concerning the environmental degradation caused by the illegal mining venture, the success of policing measures in controlling mining and how the local river systems and water quality have changed.

The questions were formulated to attain institutional insights and experiences within the community to enable the study to address governance dynamics at numerous viewpoints. Among the questions that participants considered were the causes of illegal mining, the challenges of enforcement that are encountered by regulatory bodies, the cooperation of the communities with the law enforcement agencies, and the environmental effects caused by mining operations on the river ecosystems. The answers were informative in terms of qualitative data on the socio-institutional processes that influence environmental performance in mining areas. The narratives served to put into context scientific findings of water sample analyses and give more insight into governance and policing regimes that affected the quality of water in the illegally mined zones. Table 4 shows the main interview questions and some of the main answers given by the stakeholder groups and how various actors understand the environmental, governance, and enforcement aspects of illegal mining in Ghana.

Table 4: Interview Questions and Stakeholders Responses Across All Groups

Stakeholder Group	Interview Question	Representative Responses (Verbatim Quotes)
Illegal Miners (ASM/Galamsey)	Can you describe how illegal mining activities operate in this community? How do your activities affect water bodies near your mining sites? What happens to the pits and ponds created after mining? Have these abandoned pits affected the community? How does mining affect neighbouring farmlands? Do metal detector ('kwee-kwee') operators create additional risks?	***"Galamsey is not just boys digging; there are sponsors, equipment suppliers, fuel suppliers, and buyers waiting."*** ***"The washing goes straight into the river… after ten minutes the water turns brown."*** ***"We move quickly to new sites, so the pits remain. They fill with water and become dangerous."*** ***"Children fall into the holes… snakes and crocodiles now live in the ponds."*** ***"When the water overflows, it destroys cocoa and food crops. Farmers sometimes lease the land to us because crops keep dying."*** ***"They are mostly outsiders… they dig everywhere. If you challenge them, they can attack you."***
Licensed Small-Scale Miners (LSM)	How does illegal mining affect your operations? What challenges do you face in complying with regulations?	***"Illegal miners pollute the river and make the work harder for us who follow the rules."*** ***"The process is too slow… while we wait, galamsey boys are already mining at the site."***
Community Leaders (Chiefs, Assembly Members, Elders)	How would you describe the environmental changes caused by illegal mining? What dangers do abandoned pits and ponds pose? How has illegal mining affected farming activities? Do miners collaborate with community members? How do governance and leadership dynamics influence mining control?	***"Our rivers used to be clean enough to drink; now the water is like mud soup."*** ***"Women and children fear passing through farm paths. People have died falling into pits."*** ***"Our cocoa farms are destroyed, roads are spoiled, and polluted water kills our crops."*** ***"Some local youth assist them because of money, but the community suffers in the long run."*** ***"Sometimes we oppose mining, but powerful outsiders override community authority."***
ILP Officers (Intelligence-Led Policing)	How does ILP identify hotspots and mining networks? What are the main constraints hindering ILP enforcement? How does information flow from the community to ILP? Are there cases of political or internal interference? How does ILP influence water protection efforts?	***"We know where they operate… intelligence gives us exact locations."*** ***"We lack vehicles, drones, protective gear. Sometimes we can't respond quickly."*** ***"People report, but fear of retaliation reduces cooperation."*** ***"Yes… sometimes information leaks before operations. Miners escape."*** ***"Whenever we sustain operations, the river becomes clearer."***
COP Officers (Community-Oriented Policing)	How do you build trust with the community? Does trust improve environmental reporting? What challenges affect COP effectiveness? How do COP and ILP complement each other?	***"We engage them, visit homes, listen to complaints. Trust grows gradually."*** ***"Yes. When people trust us, they tell us about galamsey activities."*** ***"Fear of reprisals… and limited resources to maintain regular patrols."*** ***"We get the community intelligence; ILP uses it to plan operations."***
Environmental Agencies (EPA, WRC, Minerals Commission)	What water quality changes have you observed in affected rivers? What causes heavy metal contamination? Are institutional coordination challenges affecting enforcement? Does political interference affect regulatory enforcement? How does sustained enforcement relate to water quality?	***"Turbidity keeps increasing… aquatic life is disappearing."*** ***"Direct washing of ore into rivers introduces mercury and other chemicals."*** ***"EPA and Minerals Commission sometimes work separately. This weakens action."*** ***"Yes. Sometimes calls come from above stopping operations."***

		"When police clamp down, water quality improves within weeks."
Youth Groups (18–35)	Why are many youths involved in illegal mining? Are you aware of the environmental consequences? How do abandoned mining pits affect your daily activities? Does illegal mining reduce future livelihood opportunities?	***"Farming doesn't pay anymore. Mining gives quick money."*** ***"Yes… but there are no jobs. People must survive."*** ***"We are scared to use some paths; snakes and pits make it dangerous."*** ***"If the land and water spoil, our future suffers… but for now, we need money."***
Local Government Officials (District Assembly, NADMO, Environmental Health)	What governance gaps worsen illegal mining activities? How do institutional conflicts affect regulation? How do community complaints reach the Assembly? What role does the Assembly play in protecting water bodies?	***"Weak monitoring, lack of resources, and overlapping mandates make enforcement difficult."*** ***"Agencies sometimes act independently, causing confusion and delays."*** ***"People report issues, but our capacity to respond is limited."*** ***"We try to enforce bye-laws, but miners relocate quickly."***

Source: Authors own compilation (2025).

3.13 Thematic Analysis of Legislative Framework Effectiveness

All the transcripts of the interviews were introduced to NVivo 14 as a text file and were sorted and arranged to be analysed. All transcripts were assigned metadata (such as participant category e.g. regulator, community leader, miner, or enforcement officer) and location of interview to facilitate comparison of all stakeholder groups in a systematic way. The initial examination of the transcripts contained recurring issues on poor enforcement, lack of policy awareness, and non-compliance with the environment in the mining areas.

An inductive approach was used to come up with thematic codes by focusing on the recurring concepts based on the responses of the stakeholders. The main codes were sensitivity to legislative frameworks, governance issues, discretionary authority, and gaps in implementation. NVivo coding tools were used to assign relevant excerpts to these categories.

One respondent mentioned, under the theme of policy awareness and implementation, the following:

"The policies are indeed good, really good on paper, but the fact remains that they are not being implemented as they are on paper".

Likewise, the issues of environmental compliance were reflected in such statements as: ***"According to the laws, you are not supposed to destroy water bodies, however, a lot of the operators are not following this".*** These coded responses indicate a steady gap between the presence of regulatory frameworks and their actual implementation in mining settings.

NVivo query functions such as word frequency and text search were employed to determine the prevailing themes and also to have a full range of stakeholder responses covered. The patterns that were identified through the analysis were the notable patterns of poor enforcement mechanisms, institutional fragmentation, and community participation in the mining governance. As an example, some of the respondents focused on the issue of monitoring: ***"The monitoring regime is also very poor since the officers have not been increased despite the increased activities in the mining activities".***

Also, the problem of institutional coordination was mentioned severally: ***"There is lack of clear cooperation between regulatory bodies, police and district authorities in order to implement policies effectively".*** These trends verify that the issue of governance inefficiencies is structural rather than institutional, and it cuts across institutions that regulate the mining industry.

The identified themes were discussed concerning the study purposes and theoretical framework. The results show that Ghana has a reasonably broad legislative framework which includes the Minerals and Mining Act and environmental laws, however, the implementation is limited due to the issues of the application. The discretionary powers in the regulatory system also became the concern of the stakeholders: ***"The president has the powers to allocate portions of forest reserves to mining when the need arises which is most of the time abused by the law".***

This is an indication of larger governance issues associated with Institutional Theory, where rules exist but are undermined through political and institutional processes. In addition, the results are in agreement with Routine Activity Theory, where low enforcement and a lack of monitoring will decrease the institutional guardianship; hence giving rise to illegal mining as an opportunity.

Table 5 below summarises the above themes, codes and illustrative responses of the stakeholders discussed and provides the NVivo-based thematic analysis of the effectiveness of Ghana legislative framework in supporting sustainable mining practices and adherence.

Table 5: Thematic Analysis of Ghana's Mining Legislative Framework and Sustainable Compliance

Themes	Code	Description	Illustrative Excerpts
Awareness of Legislative Frameworks	Limited Awareness	Lack of full understanding of mining laws and policies by the stakeholders.	"Yes, I do know a little bit of them". / "I know some policies, but not all of them".
	Moderate Awareness	General knowledge of the licensing procedures and environmental guidelines.	"I have a little bit of reasonable familiarity with the legislative tools and policies".
	Low/No Awareness	Inexperience in mining regulations and policy content.	"Not exactly. I do not know any government system of mining sector".
Knowledge of Specific Legislative Instruments	Regulatory Frameworks	Knowledge of the most important legal tools of mining practices.	Understanding of essential legal tools of mining activities.
	Environmental Regulations	Understanding of environmental conservation needs (e.g. forest reserve)	Mining in forest reserve should consider buffer areas around water bodies to avoid environmental deterioration.
	Legislative Instruments (LIs)	Knowledge of certain rules that govern mining in sensitive regions.	Consciousness of particular regulations of mining in sensitive regions.
Discretionary Powers and Governance Concerns	Presidential Authority	Seen excessive centralisation of discretion in assigning mining rights.	The LI authorizes mining of forest reserves, which leads to the destruction of the environment.
	Ambiguity in Legal Provisions	Absence of a clear definition of some important legal clauses especially on the definition of national interest which creates the possibility of inconsistency in application.	According to the law, the president has the freedom to designate forest reserves to be mined. National interest is not well defined and can be abused.
Implementation and Enforcement Gaps	Weak Monitoring Systems	Insufficient organizational capacity to appropriately monitor and enforce legislation pertaining to mining	"Despite the significant increase in mining activities in the past few years, the monitoring regime remains very weak."
	Institutional Fragmentation	Additional institutional disintegration and poor inter-agency coordination concerning the governance of mining	"Very little coordination exists between the regulatory bodies and the law enforcement agencies responsible for the monitoring of mining activities."
	Policy–Practice Gap	Comprehensive regulatory frameworks compromised by ineffective and unfulfilled implementation and enforcement absences	"On paper, the policies look robust, but in reality, the enforcement of the policies is very weak."

Environmental Compliance Challenges	Poor Enforcement of Environmental Laws	Insufficient enforcement of laws designed to protect water bodies from pollution related to mining activities	"Although the laws prohibit the destruction of waterways, most mining operators disregard the law."
	Rising Environmental Degradation	Continued pollution of river systems and environmental destruction as a result of mining	"Farmlands and waterways are still being illegally mined and are being polluted."
	Limited Community Involvement	Local community exclusion from participation in the governance of mining activities	"Local community consultations are rare; mining contracts are made without community input, and we only learn of them once contracts are signed."

Source: Authors' NVivo thematic analysis based on stakeholder interview data (2025)

3.14 Experiences and perceptions of Legal and illegal miners.

Western, Western North, Ashanti, and Eastern are the four regions that have been studied and in all of them miners have expressed elaborate views regarding the illegal mining and the environmental and socio-economic consequences. They touched upon the consequences of water quality, agricultural means of living, the security of the local community, and local government, thus demonstrating the complexity of illegal mining. The discussions indicate that illegal mining is part of a wider mining supply chain involving various actors and structured networks. Participants have noted that illegal mining has been incorporated in a well-organised chain of supplies that includes financiers, suppliers of equipment, operators of machines, purchasers of gold, transporters and workers. As one of the interviewees pointed out, "***galamsey is not only the boys who dig; it is a chain of sponsors, to buyers".*** This observation makes it clear that informal mining activities are actually complicated and that there is a need to study illegal mining in the context of MSCG.

One of the miners who is licensed said, ***"we are bound to meet the standards of the Minerals Commission and the Environmental Protection Agency. We attempt to keep off mining near the riverbanks, and we dispose our waste where we need to. The issue is that the illegal miners are not subjected to any of these rules. They are directly involved in the rivers and are washing the ore in the water. The rivers get so dirty and contaminated because of that and it is happening with all miners, including us, who are legally working".*** Small-scale miners that had been licensed stressed that they met the regulatory and environmental standards. They, however, noted that there are illegal operators who tend to compromise legitimate operations by avoiding supervision, litter dumping in rivers and performing their activities at night to ensure that they become undetected.

The practices undermine formal governance structures and make it difficult to monitor mining operations. One of the illegal miners said, ***"majority of us are not doing it to destroy the environment. We do so because we have no work in the villages. Agriculture is no more able to sustain our families since it is not productive and crops prices are not stable, many of us can only make money fast through mining".*** The illegal miners defended themselves by referring to economic policy, joblessness in the rural areas and agricultural inefficiency. Others pointed out that mining is among the limited sources of income in the rural set ups. This highlights the socio-economical forces of illegal mining and the role of poverty and the lack of livelihood opportunities in perpetuating galamsey.

In spite of these motives, miners admitted that their operations are a source of environmental degradation such as land destruction and discharge of sediments. According to one of the miners, ***"the pits are left because we move quickly to new sites; it is not intentional, but we need to survive".*** These descriptions were corroborated by field observations, which showed that there were abandoned mining pits and degraded landscapes that were causing stagnant water bodies that were ecologically hazardous and unsafe locations to the local population such as children and farmers accessing their immediate land and water resources.

One of the miners explained, ***"During cleaning up of the ore, the wastewater that is produced is released in the streams and sometimes the wastewater is released in the fields. We are aware of the effects that this has on the land, but we move in and out of place regularly. Some farmers go to an extent of inviting us to work their land since they are compensated instantly after the work"***. Miners also agreed that mining activities release contaminated runoffs into nearby farmlands and water bodies, which negatively impact cocoa plantations and food crops. This increases the rate of soil degradation and agricultural losses, as well as the insecurity of the livelihoods of the rural population.

Comprehensively, the views of the two groups of miners: the licensed and the illegal miners exhibit the in-depth socio-economic and governance predicaments that surround illegal mining in Ghana. Their experience shows that to resolve water pollution and environmental degradation, the increased enforcement of the ILP and COP is not sufficient, but a wider intervention on the economic factors and the supply chain organization of the illegal mining process is needed.

3.15 Perspective of Community Leaders (Chiefs, Assembly Members, and Elders)

"In the olden days, people could drink the river water because it was so clear. It is like muddy soup nowadays since miners wash the soil in the river itself," stated one of the traditional chiefs of the Western Region. The community leaders are blaming the uncontrolled ore-washing and mechanized dredging on the banks of the rivers as the sources of turbidity and sedimentation. Such activities disturb the riverbeds and add contaminants to water systems which are used by communities in their daily and agricultural activities. Chiefs have been very concerned about the artificial water bodies formed by the deserted mining pits which are very dangerous environmentally and health wise. These pits contain stagnant water which is a breeding place of mosquitoes and poses a threat to safety.

"There are numerous pits left uncovered by miners. These pits are filled up with water during rainy season and children occasionally fall in as it was reported by a community elder in the Ashanti Region.

"Animals have been lost due to wandering into these pits which they cannot escape. These pits have transformed the scenery of our societies, observed by one of the members of the assembly in the Eastern Region.

"Because mining leaves stagnant water, now we see snakes and crocodiles approaching the villages. This was not norm in the past when mining activities had not been intensified, as was the case," one of the traditional leaders in the Western North Region stated. The risks are mostly in old age farmers and women who walk through farmlands to get water supplies. The pits and waste have been blocking agriculture routes thus forcing the people to use dangerous ways. The effects of mining on agriculture have been highlighted by the community leaders as being detrimental. Mining activities lead to the release of polluted runoff that decreases the level of agricultural production. Plantations have experienced crop losses because of deposition of sediments and polluted water in Cocoa farms.

"When miners engage in the practice of washing soil in riverine environments, the resultant turbid water disperses onto agricultural lands, leading to detrimental effects". A cocoa farmer and community elder at the Eastern Region clarified that this process is leading to the gradual death of cocoa trees because the soil is flooded with sand.

A chief in the Ashanti Region noted that, ***"some farmers have given up farming practices in the region because of loss of soil fertility. They, therefore, engage in leasing their lands to mining operators in order to make ends meet".*** These situations represent a great paradox: farmers, who relied on agriculture since the times immemorial, are now forced to sell their land to miners as a source of their livelihood even though mining undermines the agricultural systems that support the rural livelihoods. In addition to the environmental impacts, the leaders in the community have expressed apprehension on the loss of traditional power and erosion in customary power in mining areas.

"Chiefs have highlighted their inability to control land use by other parties and mining operators of political interests. A classical leader in the Western Region wrote",

"We endeavor to curtail illegal mining activities, yet some miners possess influential patrons. When we resist, they disregard the authority of the chiefs." An assembly member in the Eastern Region stated.

"They give licenses without the approval of chiefs, yet we are the people who take care of the land. This has a debilitating effect on our authority and the control of activities". A traditional leader in Ashanti region. Such lack of connection between the state agencies and traditional forms of governance fosters institutional fragmentation in the mining areas. The need to strengthen the partnership between the traditional authority, the local government and law enforcement to increase the implementation of the mining rules has been highlighted by the community leaders. These views demonstrate that illegal mining is not only an environmental but also a socio-institutional menace, which affects the governance and stability of the communities. Their stories emphasize the need to incorporate traditional governance into the mining supply chain models, as well as the unified plans to enforce, including ILP and COP.

3.16 ILP and COP Officers' Responses on Environmental Challenges

The law enforcement officers involved in ILP have highlighted the important role of intelligence gathering in locating the hotspots of illegal mining and destroying the organized mining networks. According to the ILP officers, intelligence reports, surveillance information, and tips given by communities allow them to map mining supply chains and know where the illegal mining is concentrated. They are, however, faced with several operational challenges that hinder their effectiveness in responding. These obstacles can be summarized as low logistics, vehicle deficit, lack of protective equipment, slow operational rolling out, and untrained manpower. According to an ILP officer in the Ashanti Region, ***"the country has known of numerous illegal mining sites using intelligence, but the rapid response is difficult because there are no cars, mining equipment, and logistics to facilitate such an operation".***

Officers involved in COP have stressed that community collaboration is crucial for monitoring illegal mining activities and sharing local intelligence with enforcement agencies. They have observed that COP initiatives have strengthened relationships between police and community members, leading to increased willingness among residents to report illegal mining activities. ***"When the police collaborate closely with the community, people are more inclined to share information about illegal mining activities,"*** remarks by security officer in the Western Region. Despite these advancements, officers have pointed out that fear of retaliation from mining operators often deters community members from openly reporting illegal activities. They further emphasized that ongoing community engagement and regular patrols are more effective than sporadic enforcement raids in safeguarding environmental resources.

ILP officers have also expressed concerns about institutional challenges such as internal information leaks, political interference, and limited inter-agency coordination, which sometimes allow illegal miners to evade

enforcement actions. ***"Occasionally, miners receive advance notice before enforcement teams arrive, making it difficult to apprehend offenders or halt the activities,"*** explained an officer in the Eastern Region. These challenges highlight broader governance weaknesses within environmental enforcement systems and reinforce concerns raised by community leaders and regulatory agencies about the need for stronger coordination, improved logistics, and institutional accountability in combating illegal mining.

3.17 Environmental Agencies (EPA, WRC, Minerals Commission) Water Quality and Governance.

Illegal mining activities have consistently been cited as the cause of environmental degradation of river ecosystem by the environmental officials of the Environmental Protection Agency (EPA), Water Resources Commission (WRC), and Minerals Commission. Such actions include uncontrolled mining of ore, release of silt and the application of dangerous chemicals in extraction of gold like mercury. EPA Officers have noted that ***"Many rivers that communities rely on are now severely polluted because miners wash soil directly in the water and discharge waste into the streams".***

The failure of the agencies to coordinate in their agency roles of monitoring mining and environmental protection has also emerged as a problem by regulatory officers. Certain officials have complained that mining licences are sometimes issued without thorough environmental impact assessment or due consultation with the affected communities, hence compromising the control of regulating bodies and thus facilitating environmental destruction. Noted by a WRC officer in the Eastern Region, ***"licenses are granted even before proper environmental examination and it can be hard to deal with this matter later".*** Regulators have also cited operational constraints that hinder effective monitoring of the environment such as limited field logistics, lack of laboratory testing capacity, rugged environment in the mining region, and mobility of the illegal miners who tend to move frequently to avoid detection.

These obstacles notwithstanding, other officers have admitted that sustained enforcement processes that integrate ILP with COP have led to local environmental surveillance and adherence. In areas where ILP activities are supplemented by community reporting in COP structures, the environmental officer in the Ashanti Region has noted that ***"Where ILP operations are supported by community reporting through COP structures, we have observed some progress in controlling mining activities and protecting certain river sections"***. Such results suggest that better institutional coordination, increased monitoring capacity, and long-term collaboration between ILP and COP are the key to strengthening the environmental governance and the rehabilitation of the water quality in mining-impacted areas.

3.18 Youth Groups (18-35): Motivations and Observation

Youths, regardless of their direct participation in illegal mining activities, are lured into the venture mainly because of the monetary gains it presents. Many respondents have pointed out that the decline in agricultural productivity, rising input prices and mining activities that have taken over the farmlands has made farming less profitable. To these young people, illegal mining is a way of making quick money even though its effects are negative to the environment. One of the Western Region youths said: ***"Agriculture no longer feeds us the way it used to. Mining is destroying cocoa farms and fertilizers are so costly. In illegal mining, even though it is dangerous, it is possible to make money in a few days".***

This observation highlights the role of economic vulnerability and the diminishing agricultural yield as the force that drives young people towards illegal mining. These findings indicate that illegal mining is a challenge to the environment, as well as socio-economic survival strategies among the unemployed youth. Some respondents mentioned that mining pits and dredging ponds have turned agricultural lands into dangerous areas. One of the young ladies of the Ashanti Nation said: ***"Now we have to go to the farms through lots of pits that are left empty. Sometimes these pits are filled with water, and we cannot know the depth of them. We are afraid of falling in or seeing snakes in the bushes".***

This shows that the degradation of the environment caused by the illegal mining interferes with the livelihoods of the people and increases risks to the locals especially women practicing subsistence farming. Although young respondents may have recognized the harm to the environment, they were economically desperate because they could find few job opportunities. One of the members of the youth in Eastern Region remarked: ***"We know the rivers are being polluted with mining, but what can we do? No jobs here, no opportunities given to the youth by the government".***

This points to how unemployment as a structural problem drives the youth to be involved in illegal mining, and therefore enforcement actions might not be enough to solve the problem without economic interventions.

3.19 NVivo Qualitative-Base Thematic Validation and Stakeholder Coding

To accomplish this work NVivo 14 software was used to generate structured qualitative outputs including matrix coding queries, coding summary tables, and stakeholder response visualizations. NVivo played a crucial role in the logical organization, categorization, and authentication of qualitative interview data of various stakeholder groups within four mining regions. This method of analysis maximizes transparency, traceability, and analytical rigor by allowing researchers to code, compare, and visualize thematic relationships among respondents and categories systematically. The coding involved a multi-thematic analysis process, which consisted of open coding, axial coding and selective coding. Open coding was done through line-by-line review of transcripts to find patterns concerning illegal mining procedure, water quality loss, governance and enforcement issues.

The axial coding of these codes was later divided into wider analytical groups that aided in the discovery of the relationship between the governance systems, policing strategies and environmental outcomes. Lastly, a few themes were narrowed down and adjusted according to the conceptual framework of the study which is MSCG,

ILP, COP and water quality outcomes. NVivo was used in this research in order to confirm commonalities in themes of sufficiency and saturation. The use of coding frequency analysis and matrix queries helped to arrive at the predominant themes within the groups of stakeholders, so that the qualitative interpretation based on the results was based on the empirical data coded in a systematic manner, as opposed to the subjective viewpoints.

The NVivo Matrix Coding Query analysis indicated that there are clear variations in the priorities of thematic issues associated with the mining governance and environmental degradation among different stakeholder groups that are represented by Table 6. The matrix query will help to compare the categories of stakeholders and thematic issues and will also give a clue on how various actors view the concept of environmental degradation; lack of governance and enforcement issues related to illegal mining. The findings of matrix coding indicate that all stakeholders have differences regarding thematic focus. The highest number of references found were water quality impacts and mining operations, which means that residents and members of the community are exposed to the negative consequences of the environment caused by illegal mining. Most of the references that were also made about mining effects were reported by miners themselves, as they are directly engaged in the mining and they understand the mining operations in the informal networks.

Most regulatory bodies such as EPA, Water Resources Commission and Minerals Commission recorded greatest coding density on governance failures, which enforced coordination problems, regulatory, and enforcement restrictions in dealing with illegal mining. The highest references were found among police officers of ILP and COP units in the context of policing constraints, which are the inability to monitor remote locations, constraints of intelligence, and logistical difficulties during enforcement activities.

Table 6: Matrix Coding Query (Stakeholder Groups & Key Themes)

Stakeholder Group	**Water Quality Impact**	**Governance Failures**	**Mining Impact**	**Policing Constraints**	**Total Respondents**
Community Leaders (CL)	42	36	**49**	28	60
Regulators (EPA/WRC/Minerals Commission)	40	**51**	33	44	25
Security Agency (ILP/COP Units)	32	26	23	**58**	40
Residents/Community Members	63	44	**67**	41	90
Miners (ASM/LSM)	47	31	**72**	22	36
Total References	**223**	**188**	**244**	**193**	**251**

Source: Authors' own compilation from NVivo (2025)

A coding summary, provided in Table 7, explains the relative significance of all the thematic categories identified during the NVivo analysis. Mining impacts became the most frequently coded theme with 244 references, as it was evident that illegal mining activities are the major cause of environmental degradation in the areas being studied. Water quality degradation was the second most represented theme with heavy stress on the vast environmental impacts of illegal mining, especially the pollution of rivers by sedimentation, use of mercury and chemicals. The presence of governance failures also featured prominently in the coded data, suggesting problems with institutional fragmentation, weak enforcement of the regulations, and a lack of coordination between the environmental agencies. Policing constraints were commonly reported by the respondents, particularly ILP and COP operation constraints, which indicated that the enforcement issue continues to be a major challenge to effective governance of the environment in the areas where illegal mining has taken place.

The coded references are distributed across these themes, which highlights the interconnection between illegal mining, governance structures, and effects on the environment. This consistency supports the conceptual framework of the study that incorporates Mining Supply Chain Governance, ILP enforcement approaches, COP community engagement approaches, and water quality performance.

Table 7: NVivo Coding by Themes (Number of Participants & References)

Theme/Code	No. of Participants	No. of References
Water Quality Degradation	152	223
Governance Failures	141	188
Mining Impact	157	244
Policing Constraints (ILP&COP Limitations)	132	193

Note: Total participant counts exceed 251 due to multiple themes mentioned by individual respondents, Reference counts reflect frequency of coded text segments, not unique individuals. Source: Authors owns generation from NVivo 14 software (2025).

3.19.1 Stakeholder Priorities from NVivo Matrix Coding

The NVivo analysis was used to compare the priorities of the stakeholder groups to the environmental governance issues and policing interventions in illegal mining. This discussion gives a more profound understanding of institutional forces that affect environmental sustainability in the mining supply chains.

3.19.2 NVivo Thematic Patterns of ILP & COP in Environmental Governance

The thematic analysis of the data through NVivo coding revealed that ILP and COP is of interest to several stakeholders in matters concerning environmental governance in numerous ways. ILP had the highest coding

density in the governance themes of Governance Failures (64.6), Water Quality Degradation (58.5), Illegal Mining Activities (54.2) and Pollution Control (53.2) as shown in Figure 5. These results suggest that stakeholders regard ILP mostly as a tool of operational enforcement, emphasizing on gathering intelligence, tracking operations of illegal mining circles, and disrupting illegal supply chains. This view correlates with other concepts of Intelligence-Led Policing, according to which, to fight organized environmental crimes, it is necessary to focus on the analysis of intelligence, its evaluation, and targeted measures (Matsaeng, 2023; Tortorici, 2018).
Conversely, COP exhibited higher thematic concentration in Community Trust (64.2%) and Sediment Monitoring (53.2%). This trend is indicative of the participatory style of COP whereby the community is actively engaged in the monitoring, sharing of information and reporting of illegal mining. According to the NVivo results, ILP and COP play a complementary role in environmental governance. Whereas ILP can offer intelligence-led enforcement to detect and disrupt the illegal mining networks, COP can encourage participatory and trustful community relations, boosting intelligence collection and environmental surveillance. Such policing measures help to enhance Mining Supply Chain Governance in terms of enhanced institution coordination, effectiveness in enforcement and water resource protection in the areas that have fallen victim to illegal mining.

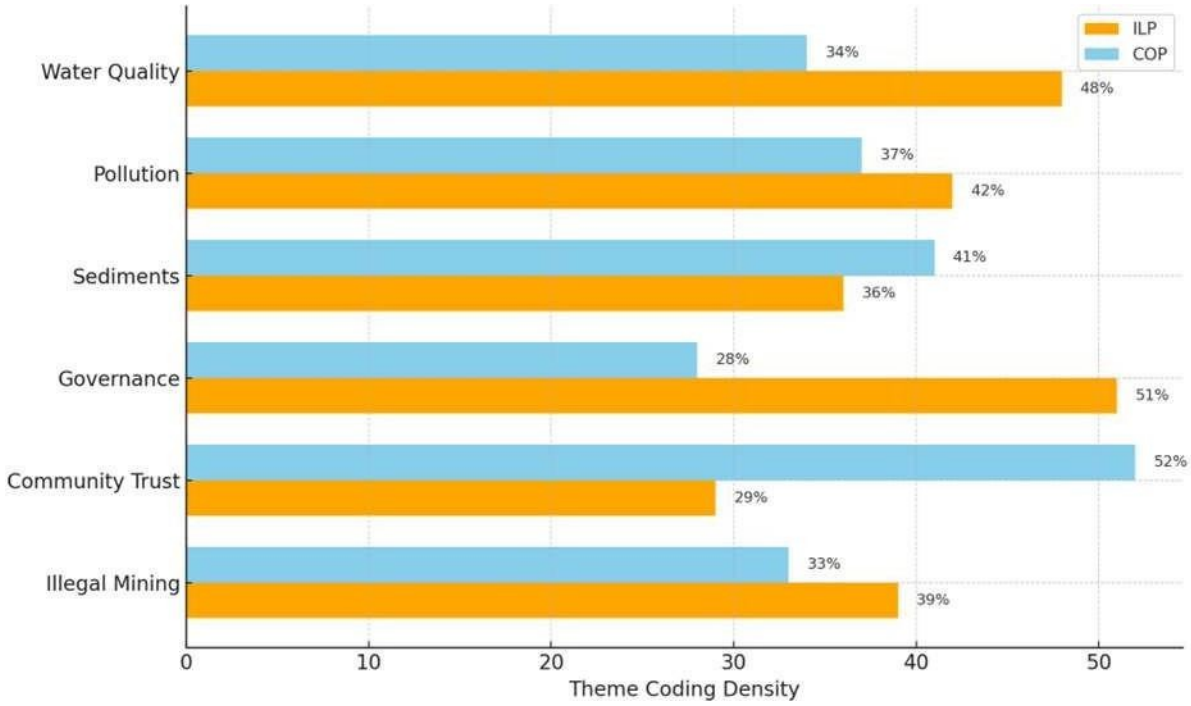


Figure 5: NVivo Coding Density Comparison of ILP and COP. Source; Authors own generation from NVivo 14 (2025)

3.20 Quantitative Analysis

3.20.1 Laboratory Analysis of Water Quality
Water samples were taken from river systems in Ghana and groundwater sources in areas of illicit mining. The purpose of this study was to examine physical and chemical characteristics and to quantify heavy metals and determine the effect of mining pollution on the following parameters: turbidity, mercury (Hg), arsenic (As), lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn), total suspended solids (TSS), and other pollution-related parameters. The average values for these parameters were statistically analyzed and compared to the World Health Organization (WHO) standard for drinking water (Table 8).
Water quality samples showed noticeable degradation at all sampling locations. Water quality turbidity values were on average 94.36 NTU, and > 5 NTU is the WHO standard for safe drinking water. For sampling points, turbidity values exceeded 400 NTU and were the result of sediment disturbances from mining activities. Water quality mercury concentrations were on average 0.0014 mg/L with a max of 0.0037 mg/L, and several locations exceeded the WHO standard for safe drinking water which is 0.001 mg/L, this was evidence of fortification with mercury in the gold amalgamation process. Cadmium was equally found to be above the WHO standard for safe drinking water of 0.003 mg/L with concentration levels of 0.0045 mg/L. Water quality samples were above the WHO standard of 0.01 mg/L for lead, with 0.12 mg/L being the highest concentration.
Iron levels were high, with an average of 2.81 mg/L, almost 9 times higher than the WHO level of 0.3 mg/L, which is evidence of disruption in mineral-rich deposits. The level of arsenic was found within the WHO limit of 0.01 mg/L though a peak of 0.009 mg/L was reached. Manganese levels were also within acceptable limits. The Total Suspended Solids was 8.09 mg/L, which is similar to the threshold of 10mg/L, but some sites had high values of up to 18mg/L, which shows there was a localized load of sediments by mining activities.
The laboratory tests highlight a clear evident of environmental degradation in the water bodies that were sampled, especially regarding turbidity, mercury, cadmium and iron concentration. The findings are indicative of the effects of the use of illegal mining on the water quality in the Ghana mining areas. In combination with NVivo-based

stakeholder analysis, the results indicate that inadequate governance, lack of enforcement, and monitoring are some of the factors leading to environmental degradation in illegal mining areas. This combined study will provide a multifaceted explanation concerning the role of governance deficiencies and social life on the environmental conditions within the Ghanaian mining supply chain.

Table 8: Water Quality Parameters of Concern Compared with WHO Standards

Parameters	WHO Standards	Mean	Max	SDV.	Interpretation
Turbidity	5 NTU	38	122	21.4	Severely Polluted
Mercury	0.001 mg/L	0.005	0.014	0.004	Dangerous contamination
Arsenic	0.01 mg/L	0.034	0.082	0.021	Exceeds WHO limit

Source: Authors own compilation from laboratory results (2025)

3.21 Regional Interpretation of Water Quality Results

Spatial comparison of water quality indicators shows that there are regional differences in environmental degradation due to illegal mining activities as shown in Table 9 below. The Western Region was the most affected with the highest turbidity of 124.8 NTU on an average that is twenty times higher than the recommended 5 NTU of the WHO. This goes hand in hand with extensive river dredging and alluvial mining of the Pra and Ankobra basins. High levels of mercury imply that a considerable amount of mercury was amalgamated in the process of extracting gold. There were high levels of sediment pollution and heavy metal in the Western North Region, indicating artisanal mining activities in the forest reserves and the river basins. The average concentration of mercury of 0.0013 mg/L is higher than WHO threshold and this shows that there are ecological and health hazards to people using the surface water without treatment.

Ashanti Region was less turbid than the Western Region, yet it had higher turbidity levels compared to international standards. These high sediment loads are a result of mining on the Offin and Oda rivers. Many of the sites had cadmium levels that were close or even higher than the WHO level of 0.003 mg/L, which showed that it had been contaminated by mineral processing. The lowest average turbidity was recorded in the Eastern Region, although still above natural background levels. In certain locations, the concentration of mercury approaches the WHO safety threshold, signifying environmental dangers from undocumented mining activities within the Birim River basin. The case-by-case analysis indicates that there is a general decline in the quality of water within the illegal mining zones of Ghana, although the degree of contamination depends on the intensity of mining, the type of minerals and the level of environmental regulation.

The higher the volume of illegal mining activities, the greater the turbidity and heavy metals contamination. These results confirm that poor governance of mining and the absence of regulation have serious adverse impacts on the environment in the regions where mining occurs.

Table 9: Regional Water Quality Comparison in Mining Areas

Region	Turbidity (Mean NTU)	Mercury Hg (Mean mg/L)	Cadmium Cd (Mean mg/L)	Lead Pb (Mean mg/L)	Iron Fe (Mean mg/L)	Interpretation
Western Reg.	124.8	0.0019	0.0068	0.013	3.42	Severe mining-related contamination
Western North Reg.	101.6	0.0013	0.0041	0.009	2.96	High sediment disturbance and moderate heavy metal contamination
Ashanti Reg.	84.5	0.0012	0.0037	0.007	2.51	Elevated turbidity linked to river dredging
Eastern Reg.	66.3	0.0010	0.0029	0.006	2.13	Moderate contamination but still above natural background levels

Source: Authors own compilation from laboratory analysis (2025)

4.0 FINDINGS AND DISCUSSION

4.1 Findings

This study explains that unlawful mining in four different parts of Ghana breeds multi-layered environmental, institutional and socio-economic issues, the most significant environmental impact of which is degradation of quality water. Quantitative lab results and qualitative information gathered using NVivo show that illegal mining plays an important role in the deterioration of the river ecosystems. The study offers both mixed-method validation of the harm caused to the environment by illegal mining in Ghana through the combination of water testing and the stakeholder views.

The laboratory tests reveal that there is a high level of turbidity and sediment disturbance in river systems located in the Western, Western North, Ashanti, and Eastern regions. The sampling sites were characterized by a high level of heavy metals, such as mercury, lead, cadmium, and iron, together with the concentration beyond the WHO recommended limit. The turbidity in some of the rivers was found to be multiple times greater than the WHO

recommended level of 5 NTU, indicating a serious disturbance of sediments which is due to dredging, excavation of riverbanks, and washing of ore used in artisanal mining. These data indicate that the nature of freshwater ecosystems is significantly altered by illegal mining processes. The environmental destruction that was discovered during the laboratory tests was supported by the testimonies of the local residents and stakeholders. The observed changes that were reported by the respondents included muddy and discoloured river waters, reduced fish populations, and the impossibility of using river water in domestic or agricultural activities. According to residents, rivers which were previously used to drink, to irrigate, and fish were no longer fit since they were sedimented and polluted. These observations compare the experiences of the community to the environmental indicators.

This research paper shows that illegal mining has a well-organized supply chain which includes the financial sponsors, supplying the mining equipment, laborers who are involved in the dredging process and the buyers of the gold in informal trading structures. The structure allows the perpetuation of illicit activities regardless of the restrictions leading to deterioration of the environment. This kind of coordinated network brings out the issue of governance in tracking illegal mining. Rural societies have been affected by illegal mining with a strong socio-economic effect. The pits left behind have caused groundwater pollution, land degradation, and loss of agricultural land whereas farmers claimed to have had low productivity caused by soil erosion and pollution of water. Women and older residents indicated that mining-impacted regions were more unsafe, whereas traditional leaders observed that community power declined and farmers engaged in rivalry with miners. These results show that the effects of the environment go further to general social and livelihood derailments.

4.2 Discussion

The research contributes both empirically and theoretically to understanding the governance of illegal mining and its impact on the environment. Rather than merely demonstrating the adverse effects of illegal mining on water quality, the findings illustrate that poor institutional governance provides opportunities for, and positively reinforces, the unregulated and uncontrolled destructive tactics of illegal mining networks. This view coincides with that of the Institutional Theory which assumes that weak institutional coordination, a divided regulatory power, and a lack of capacity to enforce these rules creates a space in which activities that negatively impact the environment flourish in the interests of the regulatory device.

The conclusions are also in line with the Routine Activity Theory (RAT) that holds that crime occurs when motivated offenders take advantage of opportunities when there is a lack of effective guardianship. With reference to illegal mining in Ghana, organized criminals, such as organized mining companies and machinery financiers, engage in activities in isolated river systems with limited enforcement. The institutional guardianship is weak, and this creates an environment where illegal mining networks can thrive without much interference.

Policing strategies have become relevant in this form of governance to break into the illegal mining practices and to protect the environmental resources. The results indicate that ILP can play a key role in detecting hotspots of illegal mining, monitoring equipment, and focusing on organized mining networks. According to ILP officers, the intelligence collection and surveillance technologies improved the enforcement activities by allowing the law enforcers to prioritize high-risk mines instead of randomly performing enforcement activities. This highlights the importance of type of intelligence-based strategies to deal with environmental crimes.

The findings, however, point to institutional coordination and logistical capacity as the determinants of the success of the ILP interventions. The issues reported by the enforcement officers included inadequate surveillance equipment, inaccessibility to remotely located places, and the lack of inter-agency coordination between the environmental regulators and the law enforcement. These constraints hinder the capacity of the enforcement strategies that are based on intelligence to attain long-term environmental protection results. As a result, water quality could be seen to have occasionally improved as long as enforcement was maintained but this meant that institutional coordination to maintain the environment was a longstanding process that needed to be sustained.

The COP has become a critical complementary governance tool that boosts enforcement with the help of community involvement and trust development. Communities that had COP initiatives in operation were more cooperative with law enforcement with activities such as reporting illegal mining, riverbank monitoring, and information on hotspots of mining. Results of laboratory of the said communities indicated reduced turbidity as opposed to the regions of poor community-police collaboration. These results imply that community participation and social trust enhance the governance of the environment.

The mediating effect of COP highlights the importance of social capital in environmental governance. Societies with greater trust between the residents and the law enforcement agencies are more likely to support enforcement activities and participate in environmental observation. This fact is aligned with the literature that points at the significance of community participation in the management of natural resources and the prevention of environmental crimes.

The mixed-methods approach contributes to the body of literature on illegal mining and environmental governance as a methodological contribution. Through the integration of water quality evaluation and qualitative stakeholder analysis, the research study is used to demonstrate the relationship between environmental degradation, the governance structures, and the implementation approaches in illegal mining supply chains. The approach offers a more comprehensive view of environmental crime dynamics relative to research aiming to collect only environmental monitoring data or analyse environmental governance.

Theoretically, the results highlight the co-relational impact of MSCG, ILP, and COP in defining the environmental conditions in the areas affected by illegal mining. MSCG offers an institutional framework through which regulatory oversight, inter-agency cooperation and enforcement policies are structured. In this context, ILP acts as a mediating force, converting the capacity of governance into practice enforcement, namely detecting the illegal

mining hotspots and interfering with the illegal networks of the supply chains. COP also influences this dynamic, by instilling community trust, improving exchange of information, and local monitoring of environmental violations. Together, these governance and policing approaches influence the ecological performance of river systems, with the enhancement in the institutional coordination and enforcement capacities, leading to the increased water quality, and the poor governance allows the sustenance of an illegal mining activity, thus damaging freshwater ecosystems.

4.3 Practical Implications

The study finding proposes that water contamination and environmental degradation caused by the mining activity through illicit mining take into consideration policy interventions that are not limited to technical environmental provisions. The analysis of samples collected in the laboratories and interviews with stakeholders show that the damages to the environment are associated with the lack of institutional coordination, enforcement processes, and management of the mining supply chain. The best policy responses should target the environmental effects as well as the institutional aspects that promote illegal mining. An important policy implication is that there is need to improve coordination between agencies that govern mining and environmental protection.

The absence of unity between Minerals Commission and EPA, Water Resources Commission, District Assemblies and security agencies also lead to inconsistency of inspections and low level of information sharing. The environmental impact of such coordination failures is highlighted by laboratory results of a high level of turbidity and heavy metals in rivers. Developing a Mining and Water Governance Taskforce would enhance monitoring and enforcement operations in mining regions.

A second significant policy implication is associated with the regulation of the illegal mining supply chain. The evidence presented in this paper suggests that illegal mining does not just persist due to the miners at the mining fields, but also due to a system of financiers, equipment distributors, fuel distributors, and gold purchasers. Regulation of the economic networks encompassing illegal mining activities by addressing these upstream actors by means of strict licensing regulations, equipment tracing systems and regulation of gold trading routes would thus help to disband the networks.

The water tests showed that there were high traces of heavy metals which show that they are contaminated through mining. Only extraction sites policies cannot suffice to achieve environmental policies. The policy frameworks are to be supported with the rest of the supply chain, which is financiers, equipment suppliers, and gold buyers. There is a possibility of weakening illegal mining networks through improving traceability systems and controlling mining equipment and chemicals. The results underline that there should be reforms in policing in environmental management.

There has been evidence that ILP can improve enforcement by highlighting the mining hotspots and monitoring the supply chains. It has been linked to the reduction of illegal mining and enhancement of water quality when it comes to ILP operations. Nevertheless, logistical issues have been reported by the enforcement officers, including inadequate surveillance equipment and transportation. To equip ILP with better surveillance technologies and better intelligence systems, policy reforms will be necessary.

On the community level, the research shows that COP has a significant complementary role in environment protection. Societies that had better COP participation stated that they were more willing to exchange information regarding illegal mining practices, such as operation of night-time dredges and transportation of equipment along banks of rivers. This was community-based intelligence that could be used to better monitor mining hotspots and facilitate enforcement. The establishment of COP programs by means of the community environmental monitoring system and organized reporting systems might enhance the relationships between communities and enforcement bodies.

Judicial enforcement has become an important issue of concern in policy. The stakeholders have noted that the deterrent effect of environmental regulation is compromised by lack of prosecution, dismissal of cases and political interference. The implementation of environmental courts as a way of improving judicial capacity may help in improving the enforcement of environmental laws. Moreover, clear sentencing policies concerning any offence regarding illegal mining would create a better reputation within the regulating authorities.

The results suggest that policies are needed to deal with the socio-economic drivers of illegal mining. The community members have cited low agricultural production and low levels of employment as forces that force people to take part in unlawful mining. Livelihood diversification policies, including agricultural rehabilitation projects and green mining small-scale exploration programs, can decrease the use of illegal mining but encourage sustainable development.

Finally, improving the sustainability of the environment in mining regions necessitates a holistic governance plan. Enhancing the institutional coordination, mining supply chain regulation, enhancing enforcement measures, judicial accountability, and support of alternative livelihoods will help to curb illegal mining and help control its effects on the river systems of Ghana. These combined policy interventions are crucial towards protecting the water resources in Ghana and the maintenance of sustainable mining governance in the country and other areas of Sub-Saharan Africa.

5.0 LIMITATIONS

The qualitative and quantitative research design of the study includes a thematic analysis with NVivo and laboratory analysis of river water samples to explore the environmental and governance effects of illegal mining in Ghana. The mixed-methods approach allows the research to present complementary evidence to show that there is a connection between the stakeholder viewpoints, governance problems, and water quality indicators, which increases the credibility of the research. However, there are various weaknesses to be mentioned.

To begin with, this study was done in the particular regions of mining in Ghana, which could prevent its externalization to other resource-dependent regions in sub-Saharan Africa. Although the observed environmental and governance issues are in line with the trends in other countries affected by mining, institutional frameworks may be different across jurisdictions. Secondly, the water quality evaluation relied on the samples made at a certain fieldwork, which meant that the results could be affected by the changes that might take place depending on the season. Future studies may include common sampling through the seasons to gain a deeper knowledge of the seasonal changes in water quality.

Thirdly, though the Institutional Theory and the Routine Activity Theory were used to explain the links between governance structures and environmental facilities, the cross-sectional nature of the research limits the possibilities to trace the evolution of the enforcement strategies with time. The effectiveness of the governance interventions would be better revealed through longitudinal studies that track changes in enforcement practices and environmental indicators.

Research work that may be pursued in the future can extend their geographical coverage to the comparative study of countries in sub-Saharan Africa, which have been impacted by the mining activities. Exploring countries like the Democratic Republic of Congo or Peru, the scholars could explain the impacts of variations of the governance framework, enforcement of regulation, and mining supply chains on the environmental performance.

There are several ways to improve integration of monitoring of environmental change, illegal mining, remote sensing and satellite data. Further interdisciplinary studies might be conducted on the social aspects of illegal mining, especially the gender and mining interplay, mining livelihoods and mining resilience in the mining affected communities. Recognizing the value of technological advancements, especially remote sensing, monitoring, and digital reporting, applied to ILP and COP can enhance environmental governance.

6.0 CONCLUSION

Although this study has its shortcomings, it adds value to the current body of knowledge by showing that environmental degradation due to illegal mining is very much related to governance systems, the capacity of enforcement, and the participation of the community. The combination of laboratory examination of the quality of water with qualitative data of the stakeholders enables the study to be descriptive of the overall effect of MSCG, ILP, and COP on the environmental results in the mining areas.

Results suggest that institutional cooperation, improvement of enforcement mechanisms, and community involvement are necessary to safeguard freshwater ecosystems and achieve sustainable mining governance in Ghana. Finally, the study underlines the importance of focusing on the environmental effects of illegal mining with the use of the combined tools of governance through regulatory, intelligence-driven, and community-driven monitoring. The strategies play an important role in the enhancement of water quality and sustainable management of the resources in the mining regions.

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