



When Rivers Become Mining Victims: Mercury, Illegal Gold Mining, and Ecological Injustice in West Sumatra

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Abstract

Rivers are essential sources of water, food, livelihoods, and ecological stability, yet they increasingly function as sites where the environmental costs of extractive activities become concentrated. This article examines the relationship between illegal gold mining, mercury contamination, river degradation, and ecological injustice in West Sumatra. Focusing on artisanal and illegal mining practices, the study explores how the use and release of hazardous substances can affect aquatic ecosystems, agricultural activities, fisheries, and community health. Beyond environmental contamination, the article investigates the social and political dimensions of mining conflicts, including intimidation, violence, unequal enforcement, and weaknesses in environmental governance. The persistence of illegal mining despite its ecological consequences suggests that environmental degradation cannot be understood solely as a technological or behavioral problem. It is also embedded in economic dependence, regulatory failures, unequal power relations, and limited livelihood alternatives. Using an environmental-justice perspective, the article examines who benefits from gold extraction, who bears the risks of contamination, and whose voices are recognized in decisions concerning river governance. It argues that effective responses require more than enforcement against illegal mining. They must also address the structural conditions that sustain extractive practices while ensuring remediation, community participation, health protection, and accountability. River protection, therefore, should be understood as both an ecological and social justice issue.

[Sungai merupakan sumber air, pangan, mata pencaharian, dan stabilitas ekologis yang sangat penting, namun semakin berfungsi sebagai tempat terkonsentrasinya biaya lingkungan dari kegiatan ekstraktif. Artikel ini mengkaji hubungan antara penambangan emas ilegal, kontaminasi merkuri, degradasi sungai, dan ketidakadilan ekologis di Sumatera Barat. Dengan berfokus pada praktik penambangan artisanal dan ilegal, studi ini mengeksplorasi bagaimana penggunaan dan pelepasan zat berbahaya dapat memengaruhi ekosistem perairan, kegiatan pertanian, perikanan, dan



kesehatan masyarakat. Di luar kontaminasi lingkungan, artikel ini menyelidiki dimensi sosial dan politik dari konflik pertambangan, termasuk intimidasi, kekerasan, penegakan hukum yang tidak setara, dan kelemahan dalam tata kelola lingkungan. Kegigihan penambangan ilegal meskipun memiliki konsekuensi ekologis menunjukkan bahwa degradasi lingkungan tidak dapat dipahami hanya sebagai masalah teknologi atau perilaku. Hal ini juga terkait dengan ketergantungan ekonomi, kegagalan regulasi, hubungan kekuasaan yang tidak setara, dan keterbatasan alternatif mata pencaharian. Dengan menggunakan perspektif keadilan lingkungan, artikel ini mengkaji siapa yang mendapat manfaat dari ekstraksi emas, siapa yang menanggung risiko kontaminasi, dan suara siapa yang diakui dalam keputusan mengenai tata kelola sungai. Artikel ini berpendapat bahwa respons yang efektif membutuhkan lebih dari sekadar penegakan hukum terhadap penambangan ilegal. Mereka juga harus mengatasi kondisi struktural yang mendukung praktik ekstraktif sambil memastikan perbaikan, partisipasi masyarakat, perlindungan kesehatan, dan akuntabilitas. Oleh karena itu, perlindungan sungai harus dipahami sebagai isu keadilan ekologis dan sosial.]

Keywords: mercury pollution, illegal gold mining, river degradation, ecological injustice, West Sumatra

Introduction

Rivers are among the most important ecological and social systems in human societies. They provide water for domestic consumption, support agriculture and fisheries, sustain biodiversity, and serve as the foundation of livelihoods for communities living along their banks. In many rural areas, rivers are not simply physical features of the landscape but are closely connected to food security, economic activities, cultural practices, and community life. Consequently, environmental degradation of rivers can generate consequences that extend far beyond the loss of water quality. When river systems are contaminated or physically altered, the environmental costs can be transferred directly to communities whose livelihoods and daily activities depend on them.

One of the activities that increasingly threatens river ecosystems in Indonesia is artisanal and small-scale gold mining (ASGM), particularly mining activities that operate without adequate licensing, environmental controls, or occupational safeguards. Indonesia has a long history of gold mining, and ASGM activities are distributed across numerous provinces. Although small-scale gold mining provides employment and income for many communities, a substantial proportion of these activities use rudimentary technologies and operate outside formal regulatory frameworks. As a result, ASGM can generate significant environmental, public-health, and socioeconomic consequences (Meutia, Lumowa, and Sakakibara 2022).

The environmental consequences become particularly serious when mercury is used in gold-processing activities. Mercury is traditionally employed to separate gold from ore through amalgamation, but its use can release mercury into air, soil, water, and sediments. The problem is not limited to the immediate mining site. Mercury can move through environmental systems and accumulate in aquatic food chains, creating risks for organisms and communities that depend on contaminated rivers and fishery resources. The Minamata Convention identifies artisanal and small-scale gold mining as the largest source of anthropogenic mercury emissions and releases and calls for the reduction and, where feasible, elimination of mercury use in this sector (Minamata Convention on Mercury 2026).

In Indonesia, the environmental implications of ASGM have been documented in different mining regions. Research reviewing Indonesian ASGM has identified impacts that include water and sediment contamination, ecosystem degradation, deforestation, soil disturbance, and risks to human health. In the Batanghari River system, including areas of Dharmasraya Regency in West Sumatra, gold-mining activities have been associated with severe ecological damage and deterioration of river-water conditions (Meutia, Lumowa, and Sakakibara 2022). Research on mercury distribution in the Batanghari watershed has likewise demonstrated the importance of examining mercury pollution at the watershed scale rather than treating contamination as an isolated mining-site problem (Ratnaningsih et al. 2019).

West Sumatra provides an important context for examining these dynamics because illegal gold mining has emerged as both an economic activity and a source of social and environmental conflict. Communities may become economically dependent on mining because it offers income in areas where alternative livelihood opportunities are limited. This creates a difficult policy dilemma. Enforcement measures may be necessary to stop environmentally destructive activities, yet a purely punitive approach can also affect households that depend on mining for their economic survival. The persistence of illegal mining therefore cannot be explained simply by the willingness of individual miners to violate environmental regulations. It must also be understood in relation to poverty, employment opportunities, access to natural resources, local economic structures, regulatory capacity, and the distribution of political and economic power.

Recent research from West Pasaman illustrates the broader social dimensions of illegal gold mining in West Sumatra. Illegal mining has been associated with social conflict and economic disparities, while local customary, religious, and community institutions have attempted to mitigate some of its social consequences. At the same time, these institutions face limitations because they do not possess the same legal authority as formal state institutions to address criminal violations (Sahrul and Daulai 2025). This situation demonstrates that mining governance involves multiple forms of authority and that environmental problems cannot necessarily be resolved through state enforcement alone.

The problem is therefore not merely whether rivers are polluted, but also who benefits from mining and who bears the environmental costs of extraction. This question is central to the concept of environmental justice. Environmental justice is concerned not only with the distribution of environmental benefits and burdens but also with recognition, participation, political inclusion, and the capacity of affected communities to influence decisions that affect their environments (Schlosberg 2007). From this perspective, mercury contamination in rivers can be interpreted as a form of distributive injustice when the economic benefits of gold extraction are concentrated among particular actors while the environmental and health risks are transferred to miners, farmers, fishers, and other river-dependent populations.

The environmental-justice perspective also requires attention to questions of recognition and participation. Communities affected by mining may possess substantial knowledge about changes in river conditions, fish populations, agricultural productivity, and the social consequences of mining. Nevertheless, their experiences and knowledge may receive limited recognition within formal environmental decision-making processes. Similarly, communities may have limited influence over licensing, enforcement, remediation, and river-management policies. Environmental injustice can therefore emerge not only through unequal exposure to pollution but also through unequal political power and limited opportunities to participate in decisions concerning natural resources (Schlosberg 2007).

The West Sumatran case is particularly important because illegal gold mining creates a contradiction between immediate economic benefits and long-term ecological costs. Gold extraction can provide rapid cash income, while the consequences of environmental degradation may accumulate gradually and become visible only after ecosystems, agricultural land, fisheries, or human health have already been affected. This temporal dimension can make environmental governance more difficult. Individuals who depend on mining may prioritize immediate livelihood needs, while the broader community bears environmental costs that extend across time and space.

The persistence of illegal gold mining also raises questions about the effectiveness of environmental governance. If regulations formally prohibit environmentally harmful mining practices but illegal operations continue, the problem may involve more than insufficient legislation. It may reflect weaknesses in monitoring, enforcement, institutional coordination, political accountability, or access to alternative livelihoods. In such circumstances, environmental degradation becomes embedded within broader structures of inequality. The existence of regulation does not automatically produce environmental justice if regulatory implementation is selective, inconsistent, or inaccessible to affected communities.

This article therefore approaches illegal gold mining in West Sumatra as both an environmental and a social-justice problem. Rather than treating mercury contamination as a purely technical problem requiring technological solutions, the article examines how environmental degradation is connected to economic

dependence, livelihood insecurity, unequal power relations, governance weaknesses, and community participation. The central argument is that the environmental costs of gold extraction are unevenly distributed: while gold generates economic value for particular actors, river-dependent communities may bear disproportionate risks through degraded water resources, declining ecological productivity, health concerns, and social conflict.

Accordingly, this article addresses three main research questions. First, how does illegal gold mining contribute to mercury contamination and ecological degradation of rivers in West Sumatra? Second, how are the environmental, health, and socioeconomic risks associated with illegal gold mining distributed among river-dependent communities? Third, why does illegal gold mining persist despite its environmental consequences, and what does this persistence reveal about environmental governance and ecological injustice in West Sumatra?

The article aims to contribute to the study of environmental justice by connecting the ecological consequences of mercury pollution with the social and political structures that enable illegal gold mining to persist. It argues that effective river protection requires more than the removal of mining equipment or the prosecution of individual miners. A durable response must combine environmental enforcement with mercury reduction, ecological remediation, health protection, alternative livelihood opportunities, meaningful community participation, and institutional accountability. Protecting rivers from mining-related degradation should therefore be understood not simply as a matter of environmental management, but as a question of justice over resources, risks, recognition, and decision-making power.

Literature Review and Theoretical Framework

1. Artisanal and Small-Scale Gold Mining and Illegal Extraction

Artisanal and small-scale gold mining (ASGM) occupies an ambiguous position within rural economies. On the one hand, it provides employment and income opportunities, particularly in areas where formal employment and alternative livelihood options are limited. On the other hand, poorly regulated ASGM can produce substantial environmental and public-health consequences. Studies of ASGM in Indonesia indicate that mining activities may contribute to water and sediment contamination, deforestation, soil degradation, riverbank disturbance, and occupational and community health risks (Meutia, Lumowa, and Sakakibara 2022).

The distinction between artisanal and small-scale mining and *illegal gold mining* is analytically important. ASGM refers broadly to mining conducted on a relatively small scale, whereas illegal mining refers to activities that violate applicable licensing, land-use, environmental, or mining regulations. These categories can overlap but should not be treated as synonymous. A livelihood-oriented perspective is important because criminalizing miners without examining

their socioeconomic circumstances can obscure the structural factors that sustain illegal extraction.

Previous research in Indonesia demonstrates that ASGM can become an attractive livelihood strategy because entry barriers are relatively low and gold can generate relatively rapid income. Research in West Sumbawa, for example, found that ASGM offered an alternative livelihood for rural workers, while simultaneously creating substantial mercury-related environmental and health concerns (Suharno et al. 2018). This tension between livelihood security and environmental protection is central to understanding why illegal mining may persist despite regulatory prohibition.

From a political-ecology perspective, extraction should therefore not be understood simply as an individual decision to exploit natural resources. Extraction is embedded within economic relationships, institutional arrangements, markets, and political structures. Bebbington (2012) argues that mineral extraction is constituted by wider political, economic, and institutional arrangements, meaning that conflicts surrounding extraction cannot be adequately explained by examining the mine itself. This perspective is particularly relevant to illegal gold mining because it directs attention toward the relationships among miners, intermediaries, local communities, state institutions, markets, and natural resources.

2. Mercury Pollution and River Degradation

Mercury represents one of the most important environmental concerns associated with gold processing. In many ASGM operations, mercury is used to form an amalgam with gold, after which heating separates the gold from the mercury. Where adequate technologies and waste-management systems are absent, mercury can enter surrounding environmental media, including air, soil, sediments, and water. Research on Indonesian ASGM has documented multiple exposure pathways, including inhalation during amalgam processing and ingestion of contaminated food, while mercury can also be transported through rivers and accumulate in aquatic organisms (Meutia, Lumowa, and Sakakibara 2022).

The aquatic environment is particularly important because rivers can function simultaneously as ecological systems, transportation pathways, and recipients of mining waste. Mercury released near mining areas can become associated with sediments and subsequently be transported downstream. It can also enter aquatic food webs and accumulate in fish and other organisms. Research in Indonesia has documented mercury contamination in water, sediment, and fish associated with artisanal gold-mining areas (Limbong et al. 2003).

This ecological dimension is particularly relevant to West Sumatra. Research reviewed by Meutia, Lumowa, and Sakakibara (2022) reports severe ecosystem degradation associated with gold mining along the Batanghari River in Dharmasraya Regency, including substantial deterioration in water conditions and impacts on aquatic life. These findings suggest that mining impacts should not be conceptualized solely in terms of individual mining sites. River systems connect

upstream extraction activities with downstream communities, meaning that environmental risks can be geographically redistributed.

The concept of river degradation in this study therefore encompasses more than mercury contamination. It includes changes in water quality, sediment conditions, river morphology, aquatic biodiversity, and the capacity of rivers to support human livelihoods. Illegal mining may contribute to several of these processes simultaneously. Consequently, mercury should be examined as part of a broader system of extractive environmental degradation rather than as an isolated chemical pollutant.

3. Environmental Justice

Environmental justice provides the principal theoretical framework for this study. Traditional approaches to environmental management often emphasize pollution control, environmental standards, and technical remediation. Environmental justice expands this perspective by asking how environmental benefits and burdens are distributed and whether affected populations have meaningful opportunities to participate in decisions concerning their environments. Schlosberg (2007) conceptualizes environmental justice through interconnected dimensions that include distribution, recognition, participation, and capabilities. This multidimensional approach is particularly useful for analyzing illegal gold mining because mining-related injustice may occur in several forms simultaneously.

First, distributive justice concerns the distribution of environmental benefits and burdens. Gold extraction generates economic value, but the associated environmental costs may be borne by people who do not receive equivalent economic benefits. River-dependent communities may experience degraded water resources, declining fisheries, agricultural impacts, or exposure to pollutants even when they are not directly involved in mining. The central question becomes whether the distribution of economic benefits and environmental risks is equitable.

Second, recognition concerns whether different communities, identities, experiences, and forms of knowledge are adequately acknowledged. Mining governance can marginalize local experiences when technical or state-based knowledge is privileged over community observations of changing rivers, declining fish populations, or deteriorating agricultural conditions. Recognition is therefore essential because environmental injustice can occur even before an unequal distribution of pollution is measured: communities can be excluded from recognition as legitimate stakeholders.

Third, participation concerns the ability of affected populations to influence environmental decision-making. Decisions concerning mining regulation, enforcement, river management, remediation, and livelihood programs may be made through formal institutions in which affected communities possess limited influence. Environmental justice consequently requires more than consultation; it

requires meaningful opportunities for communities to shape decisions that affect their environments.

Fourth, the capabilities dimension directs attention toward whether individuals and communities possess the practical conditions necessary to live healthy and secure lives. In the context of illegal mining, environmental degradation may reduce communities' capabilities by undermining access to clean water, productive fisheries, agricultural resources, and safe livelihoods.

This framework allows the study to move beyond the question of whether mercury contamination exists. Instead, it asks who is exposed, who benefits, who is recognized, who participates in decision-making, and who possesses the capacity to respond to environmental harm.

4. Political Ecology of Extraction

Environmental justice is complemented by a political-ecology perspective. Political ecology examines environmental change through the interaction of ecological processes with economic, political, and social relations. Rather than treating environmental degradation as the inevitable result of population growth, technological failure, or individual behavior, political ecology asks how access to resources and control over environmental decisions are structured by power.

Bebbington's (2012) analysis of extractive industries is particularly relevant because it emphasizes the relationship between subsoil resources and wider political-economic and institutional arrangements. From this perspective, gold is not simply a physical resource waiting to be extracted. Its extraction involves property rights, markets, labor relations, state authority, local institutions, and competing claims over territory.

Applied to West Sumatra, political ecology helps explain why environmentally harmful mining can continue even when its consequences are widely recognized. Mining may provide income to workers, profits to intermediaries, and economic opportunities to other actors. At the same time, environmental costs may be distributed across a much larger population through degraded rivers and landscapes. The resulting conflict is therefore not simply a disagreement over whether mining should occur; it is a conflict over access to resources, economic opportunities, environmental risks, and political authority.

This perspective also prevents the analysis from placing responsibility exclusively on individual miners. Individual miners make decisions, but those decisions occur within broader structures. Limited employment opportunities, gold prices, access to mining equipment, local market networks, weak regulatory capacity, and expectations concerning resource access can all influence mining practices. Understanding these structures is necessary if policy interventions are intended to address the persistence of illegal mining rather than merely its visible manifestations.

5. Environmental Governance and the Persistence of Illegal Mining

Environmental governance refers broadly to the institutions, rules, actors, and processes through which environmental resources are managed. In the context of illegal gold mining, governance includes licensing systems, environmental regulation, law enforcement, monitoring, local government, customary institutions, community organizations, and livelihood policies.

A key problem is the potential gap between formal regulation and practical enforcement. A government may prohibit illegal mining and mercury use while lacking sufficient capacity to monitor remote mining areas, coordinate agencies, prosecute violations, or provide economically viable alternatives. The existence of environmental regulations therefore does not necessarily mean that effective environmental governance exists.

Research on Indonesian ASGM demonstrates that environmental degradation and health risks are closely associated with the legality and regulatory conditions under which mining takes place. A 2023 comparative study of Indonesian ASGM sites found that illegal mining activities can generate significant environmental and public-health problems, particularly where hazardous processing methods such as mercury use remain present (Meutia et al. 2023). Governance must consequently be understood as a multidimensional process. Effective responses require not only enforcement but also monitoring, remediation, public-health interventions, alternative livelihoods, and community engagement. A narrow enforcement approach may remove mining temporarily without changing the economic conditions that motivate its return.

6. Integrating Environmental Justice and Political Ecology

The theoretical framework of this study combines environmental justice with political ecology to explain the relationship between illegal gold mining, mercury contamination, and river degradation. The relationship can be conceptualized as follows:



Political ecology explains why extraction and environmental degradation occur within particular political and economic structures, while environmental justice explains how the resulting benefits and burdens are distributed and experienced by different social groups. The integration of these approaches is important because neither perspective alone fully captures the complexity of the West Sumatran case. Environmental justice provides a framework for evaluating fairness, while political ecology provides an explanation of the power relations and institutional structures that produce unequal environmental outcomes. Together, they allow the river to be understood not merely as a contaminated ecosystem but as a contested social and ecological space.

7. Research Gap

Existing research on Indonesian ASGM has established important evidence concerning mercury exposure, environmental degradation, health risks, and the socioeconomic significance of small-scale mining (Meutia, Lumowa, and Sakakibara 2022; Meutia et al. 2023). However, much of the literature emphasizes either environmental-health impacts or the socioeconomic characteristics of mining communities. Less attention has been given to integrating these dimensions into a single environmental-justice analysis focused specifically on the relationship between river degradation, unequal environmental burdens, and governance.

This study addresses that gap by treating the river as the central site where ecological degradation, livelihood dependence, public-health risks, and political contestation intersect. It moves beyond the question of whether illegal gold mining causes environmental damage and instead examines the distribution of risks and benefits, the recognition and participation of affected communities, and the governance conditions that allow environmentally harmful extraction to persist.

The study consequently conceptualizes illegal gold mining not simply as an environmental violation but as a structural environmental-justice problem. Such a conceptualization provides a basis for evaluating policy responses according to not only their capacity to reduce pollution but also their ability to address livelihood dependence, protect vulnerable communities, ensure participation, and establish accountability.

Methods

1. Research Design

This study employs a qualitative case study approach to examine the relationship between illegal gold mining, mercury pollution, river degradation, and ecological injustice in West Sumatra. A qualitative case study is appropriate because the research questions focus on how and why environmental degradation occurs within a particular social, economic, and institutional context rather than on measuring a single environmental variable in isolation. Case study research is particularly useful when a phenomenon is closely intertwined with its real-world context and involves multiple actors, institutions, and processes (Yin 2018).

The study treats illegal gold mining in West Sumatra as a socio-ecological case rather than as a purely technical pollution problem. The case encompasses interconnected processes of mineral extraction, mercury use, river degradation, livelihood dependence, environmental risk, social conflict, regulatory enforcement, and community participation. This approach makes it possible to examine how ecological processes and social relations interact and how environmental risks are distributed among different groups. The study does not claim to provide an independent laboratory measurement of mercury concentrations or a statistical estimate of the prevalence of illegal mining. Instead, it synthesizes and critically interprets existing empirical evidence concerning mining activities, mercury contamination, river degradation, community livelihoods, health risks, and environmental governance. This distinction is important because the purpose of the study is primarily analytical: to connect existing environmental and socioeconomic evidence through an environmental-justice framework.

2. Study Context and Case Selection

West Sumatra was selected as the geographical context because the province contains areas where small-scale and illegal gold-mining activities have intersected with river systems and rural livelihoods. Particular attention is given to mining-related pressures within the Batanghari watershed, including areas of Dharmasraya Regency, where previous research has documented environmental degradation associated with gold mining (Meutia, Lumowa, and Sakakibara 2022). The case is approached at the watershed and community level rather than being restricted to a single mining site. This is important because rivers connect upstream mining activities with downstream ecological and socioeconomic systems. Mercury and other mining-related pollutants may therefore create environmental consequences that extend beyond the location where extraction and processing occur.

The selection of West Sumatra also allows the study to examine the relationship between environmental degradation and local socioeconomic dependence on mining. Small-scale mining can function as an important livelihood strategy while simultaneously generating environmental risks. Research on Indonesian small-scale gold mining has demonstrated that mining livelihoods are shaped by the physical characteristics of gold deposits as well as by broader political-economic conditions and patterns of inequality (Libassi 2023). Consequently, the study does not conceptualize mining communities simply as perpetrators of environmental degradation but as actors operating within complex livelihood and governance structures.

3. Sources of Data

The study relies primarily on secondary qualitative data. The documentary materials include peer-reviewed academic articles, scientific reports, government and institutional publications, environmental and mining policy documents, and

other credible sources relevant to illegal gold mining, mercury pollution, river degradation, public health, livelihoods, and environmental governance.

Academic literature constitutes the principal source for establishing empirical and theoretical claims. Studies concerning Indonesian ASGM provide evidence concerning mercury use, environmental degradation, health risks, and the socioeconomic significance of small-scale mining (Meutia, Lumowa, and Sakakibara 2022; Meutia et al. 2023). Research concerning mercury in Indonesian mining contexts is also used to understand the environmental pathways through which mercury can enter aquatic systems and affect ecosystems and human populations.

Policy and institutional documents are used to examine the regulatory dimension of the problem. These materials are particularly important for understanding the gap between formal environmental rules and their implementation. The study also considers relevant international frameworks, particularly the Minamata Convention on Mercury, because artisanal and small-scale gold mining is recognized internationally as a major source of anthropogenic mercury releases. Document analysis is appropriate for this study because documents can provide evidence concerning institutional policies, historical developments, environmental conditions, and competing representations of environmental problems. Bowen (2009) emphasizes that document analysis can function as a systematic qualitative research method and can complement other forms of evidence through processes of comparison and triangulation.

4. Data Selection and Inclusion Criteria

Sources were selected according to four principal criteria. *First*, sources had to address one or more of the central themes of the study: illegal or artisanal and small-scale gold mining, mercury pollution, river or ecosystem degradation, community livelihoods, health impacts, environmental conflict, or environmental governance. *Second*, priority was given to research concerning Indonesia and, where available, West Sumatra and the Batanghari watershed. International literature was incorporated when it provided established theoretical concepts or comparative insights relevant to the Indonesian context. *Third*, preference was given to peer-reviewed academic publications and authoritative institutional sources. Scientific studies reporting environmental or health findings were prioritized for empirical claims, while theoretical literature was used to construct the environmental-justice and political-ecology framework. *Fourth*, sources were evaluated according to their relevance, methodological transparency, and ability to support the specific claim for which they were cited. This approach reduces the risk of relying on unsupported generalizations or treating media reports and institutional claims as equivalent to peer-reviewed scientific evidence.

5. Data Analysis

The study uses thematic analysis to identify recurring patterns across the documentary evidence. The analysis was organized around themes derived from both the research questions and the environmental-justice framework. The first analytical theme concerns environmental degradation, including mercury pollution, water-quality deterioration, sediment disturbance, riverbank degradation, and impacts on aquatic ecosystems.

The second theme concerns livelihood and socioeconomic effects, including dependence on mining, impacts on agriculture and fisheries, economic opportunities, and the availability of alternative livelihoods. The third theme concerns health and environmental exposure, particularly the pathways through which mercury and other mining-related hazards may affect miners, households, and river-dependent populations.

The fourth theme concerns distributional injustice, focusing on the relationship between those who obtain economic benefits from gold extraction and those who bear environmental and health risks. The fifth theme concerns recognition and participation, examining whether affected communities are recognized as legitimate stakeholders and whether they have meaningful opportunities to participate in decisions concerning mining and river governance. The sixth theme concerns governance and power, including regulatory implementation, enforcement capacity, institutional fragmentation, conflict, and unequal power relations among miners, communities, government agencies, and other actors.

The thematic analysis follows an iterative process. Relevant passages and findings from the selected literature were first organized according to the major themes. These themes were subsequently compared across sources to identify similarities, differences, and relationships. The analysis then connected empirical findings to the theoretical concepts of environmental justice and political ecology.

6. Analytical Framework

The analysis combines environmental justice and political ecology as complementary theoretical perspectives. Environmental justice is used to examine four interconnected questions: How are environmental burdens distributed? Whose experiences and knowledge are recognized? Who participates in environmental decision-making? And what capabilities do affected communities have to respond to environmental harm? These dimensions allow the study to move beyond the simple identification of pollution and evaluate whether environmental risks and decision-making opportunities are distributed equitably (Schlosberg 2007).

Political ecology is used to examine the structural conditions that shape environmental outcomes. In particular, it directs attention toward economic dependence, resource access, labor relations, political authority, regulatory institutions, and power relations surrounding gold extraction. Research on mercury use in Indonesian ASGM demonstrates that mercury pollution is influenced not only by technological practices but also by socioeconomic processes, labor relations,

and power dynamics within the mining economy (Spiegel et al. 2018). The combined analytical framework can be expressed as:



This framework enables the study to analyze environmental degradation as both a material ecological process and a socially differentiated outcome.

7. Triangulation and Reliability

To strengthen analytical credibility, the study uses source triangulation. Claims concerning environmental contamination are compared across scientific studies and institutional reports, while claims concerning socioeconomic and governance dimensions are examined across academic research and relevant policy literature.

Triangulation is particularly important in qualitative case studies because complex environmental problems rarely have a single source of evidence. Different documentary sources may emphasize different dimensions of the same phenomenon. Scientific studies may focus on contamination levels, for example, while social research may emphasize livelihoods, conflict, or institutional arrangements. Comparing these perspectives allows the analysis to identify patterns that might not be visible within a single source.

The study also distinguishes between documented empirical findings and analytical interpretation. Where previous research has directly measured mercury contamination or documented specific environmental effects, those findings are presented as evidence from the original study. The present article does not represent those measurements as original observations. Interpretations concerning ecological injustice, unequal risk distribution, or governance failures are explicitly developed through the theoretical framework and supported by multiple sources where possible.

8. Scope and Limitations

This study has several limitations. First, because it relies primarily on secondary sources, it cannot provide the same level of firsthand insight as an ethnographic

study or interview-based field investigation. The perspectives of miners, farmers, fishers, local officials, health workers, and affected residents are represented only to the extent that they have been documented in existing research. Second, evidence concerning mercury contamination may vary according to location, sampling period, environmental medium, and analytical technique. Findings from one mining site should therefore not automatically be generalized to all rivers or communities in West Sumatra. Third, illegal mining is inherently difficult to measure because activities may occur outside formal registration and reporting systems. Official statistics may therefore underestimate the actual scale of extraction. For this reason, the study emphasizes patterns and relationships documented across multiple sources rather than claiming a definitive estimate of the total extent of illegal gold mining. Fourth, the study's environmental-justice interpretation is analytical rather than a legal determination. Describing a situation as ecological or environmental injustice does not by itself establish that a particular actor has violated a specific legal provision. Instead, the concept is used to evaluate the distribution of environmental burdens, recognition, participation, capabilities, and power.

Despite these limitations, a qualitative, document-based case study is well suited to the central objective of this research: understanding how mercury pollution and river degradation associated with illegal gold mining become embedded in broader socioeconomic and governance structures. The approach provides a basis for connecting environmental evidence with questions of livelihood, power, participation, and justice that may otherwise remain analytically separated.

Results and Discussion

1. River Degradation, Mercury Contamination, and the Legal Construction of Environmental Harm

Illegal gold mining in West Sumatra represents more than a violation of mining licensing requirements; it constitutes a transformation of riverine environments through which ecological risks become embedded in landscapes and communities. The distinction is important because the legal status of an activity and its ecological consequences are related but analytically different questions. An unlicensed mining operation is prohibited because it lacks the authorization required for mineral extraction, but its environmental consequences may additionally trigger obligations and liabilities under environmental law. Indonesia therefore regulates the problem through overlapping legal regimes rather than through mining law alone. The current regulatory framework includes the Minerba Law as amended most recently by Law No. 2 of 2025, the Environmental Protection and Management Law No. 32 of 2009 as amended, and Government Regulation No. 22 of 2021. Together, these instruments establish that mineral exploitation cannot be separated from environmental protection, pollution control, and accountability.

The ecological evidence from Dharmasraya demonstrates why this integrated legal perspective is necessary. Research on the Batanghari River has identified mercury (Hg) and lead (Pb) in river sediments in areas affected by illegal gold-mining activities. Mawardi et al. (2022) specifically linked the presence of these metals to mining activities along the river, including the use of mercury in gold processing and fuel-related sources of lead. Their findings are important because contamination in sediments should not be interpreted merely as a temporary deterioration in water quality. Sediments can retain contaminants and subsequently interact with the water column and aquatic organisms. Thus, the ecological consequences of mining may continue even when individual mining operations cease. This creates a temporal dimension of environmental harm: the economic benefits generated during extraction can be realized rapidly, whereas contamination and ecological restoration may require long-term intervention.

The problem becomes more significant when river degradation is understood through the concept of ecological connectivity. A mining site occupies a specific geographical location, but a river functions as a connected hydrological system. Sediments, pollutants, and altered flows can move beyond the immediate extraction area, potentially affecting downstream environments and communities. Research on Batanghari River pollution in Sitiung, Dharmasraya, for example, has examined physical and chemical parameters including pH, temperature, conductivity, total dissolved solids, mercury, and lead, demonstrating that river quality must be assessed through multiple interacting indicators rather than through visual observation alone (Rani and Afdal 2020). The analytical implication is that environmental harm cannot be reduced to the physical boundaries of an illegal mining site. A watershed perspective is necessary because the ecological system affected by extraction is spatially larger than the legal location of the offense.

This distinction between the mining site and the affected ecosystem exposes an important limitation in conventional enforcement. Law enforcement tends to identify a particular offender, location, and prohibited act, whereas ecological processes operate cumulatively across space and time. A miner may be prosecuted for extracting minerals without authorization, but prosecution alone does not automatically restore a contaminated river. Likewise, closing an extraction site does not necessarily remove mercury already present in soil or sediments. The legal system must therefore distinguish between cessation of unlawful activity and restoration of ecological function. Government Regulation No. 22 of 2021 provides a broader environmental-management framework covering water quality, environmental damage, hazardous and toxic waste, environmental supervision, and administrative sanctions. This framework is important because it moves environmental governance beyond the question of whether an activity is permitted toward the question of whether ecological functions have been protected and restored.

The environmental significance of mercury is particularly important within this framework. Mercury is not simply another pollutant generated incidentally by

mining; in amalgamation-based gold processing it can become integral to the production process. Indonesian research has repeatedly demonstrated that mercury associated with ASGM can contaminate environmental media and create exposure pathways for communities. Arifin, Sakakibara, and Sera (2015), for example, found elevated mercury concentrations in river sediments and fish in Gorontalo Utara and reported elevated mercury concentrations in human hair among inhabitants of mining areas. Earlier research in North Sulawesi similarly documented mercury in water, sediments, and fish associated with artisanal gold mining (Limbong et al. 2003). These studies do not establish equivalent contamination levels in West Sumatra, but they demonstrate a scientifically established mechanism through which mercury released by ASGM can move from mining processes into aquatic ecosystems and subsequently into human exposure pathways.

Evidence from other Indonesian mining regions further demonstrates why mercury contamination should be considered a long-term ecological problem rather than a localized occupational hazard. Research in Poboya, Central Sulawesi, found substantial mercury contamination in soils surrounding small-scale gold-processing areas, with contamination extending spatially beyond the immediate mining center (Sari et al. 2016). Research in Palu similarly identified high atmospheric mercury concentrations around gold-processing facilities and demonstrated the potential for mercury vapor to disperse beyond processing sites (Sakakibara et al. 2011). These findings reinforce a central argument of political ecology: environmental effects are shaped by the spatial organization of production. Pollution is not necessarily retained within the physical location where economic value is produced. Instead, environmental systems can redistribute risks toward populations that are geographically or economically separated from the extraction process.

The Indonesian experience also challenges the assumption that mercury contamination can be addressed simply by instructing miners to adopt safer behavior. Spiegel et al. (2018) demonstrate that mercury use in Indonesian ASGM is embedded within economic and labor relations, mercury supply structures, and power dynamics. Mercury can remain attractive because it is relatively accessible and compatible with existing production arrangements. Consequently, its persistence is not adequately explained by ignorance of toxicity. This point is theoretically important because it shifts the analysis from individual behavior to political economy. If mercury use provides an economically viable processing method within a low-capital mining system, individual miners face structural incentives to continue using it. A regulatory strategy that focuses only on individual compliance therefore risks addressing the symptom rather than the institutional conditions that reproduce mercury dependence.

Indonesian law, however, has moved considerably further than merely recognizing mercury as an environmental concern. Indonesia ratified the Minamata Convention through Law No. 11 of 2017, thereby incorporating international commitments concerning mercury into the national legal framework. This was

subsequently reinforced by Presidential Regulation No. 21 of 2019 concerning the National Action Plan for Mercury Reduction and Elimination (RAN-PPM). The RAN-PPM explicitly identifies artisanal and small-scale gold mining as a priority sector and establishes strategies involving intergovernmental coordination, community participation, alternative technologies, livelihood transition, and law enforcement. This is significant because the legal framework itself recognizes that mercury elimination cannot be achieved through prohibition alone. The regulation incorporates technological, institutional, social, and enforcement dimensions, reflecting the multidimensional character of the problem.

The legal architecture therefore supports an interpretation of mercury pollution as a problem of preventive environmental governance, not merely post hoc criminal enforcement. The RAN-PPM requires strategies involving alternative mercury-free processing technologies and livelihood transition, while the Minamata framework emphasizes reduction and elimination of mercury use in ASGM. Government Regulation No. 22 of 2021 further establishes mechanisms concerning environmental quality, hazardous substances, monitoring, and administrative enforcement. Taken together, these rules indicate that the state has formally recognized three connected responsibilities: preventing mercury releases, controlling activities that generate environmental risks, and addressing environmental consequences when damage occurs. The analytical problem lies in implementation. The existence of a comprehensive legal architecture does not guarantee that regulations are translated into effective local governance. The persistence of illegal mining suggests a gap between normative environmental protection and practical environmental control.

The same gap can be observed in the relationship between mining law and environmental law. The Minerba framework establishes licensing requirements and criminalizes mining without authorization. The current statutory framework derives from Law No. 4 of 2009 as amended by Law No. 3 of 2020, Law No. 6 of 2023, and most recently Law No. 2 of 2025. The prohibition of mining without the required authorization remains central to the legal framework, and recent judicial and legal analyses continue to identify Article 158 as the principal provision for unauthorized mining. Yet a purely Minerba-centered approach is insufficient where illegal mining produces pollution or ecological damage. Environmental law addresses a different dimension of responsibility: whether the activity has caused pollution, environmental degradation, or failure to meet environmental obligations. The two regimes should therefore be understood as complementary rather than interchangeable.

This legal interaction has important implications for ecological justice. Environmental justice theory emphasizes that environmental harm should be examined in terms of distribution, recognition, participation, and the ability of affected groups to secure environmental protection (Schlosberg 2007). In the West Sumatran context, the legal question is consequently broader than whether miners possess permits. It is also whether communities that depend upon rivers have their

interests adequately recognized and protected when extraction takes place. The Environmental Protection and Management Law explicitly recognizes a right to a good and healthy environment, reflecting the constitutional principle embedded in Article 28H of the 1945 Constitution. The BPK's legal database identifies this right as one of the foundational considerations of Law No. 32 of 2009. Consequently, environmental protection is not merely a discretionary policy preference; it is connected to a legally recognized entitlement to environmental quality.

The significance of this right becomes clearer when the ecological evidence is considered alongside the social organization of mining. In Dharmasraya, research on former gold-mining land has identified degraded soil conditions and mercury contamination, indicating that environmental impacts persist beyond the active extraction phase (Manullang, Gusmini, and Rezki 2021). This finding challenges the conventional temporal boundary of mining regulation. If environmental responsibility ends when miners leave a site, the remaining contamination becomes an unassigned liability. From the perspective of the polluter-pays principle, however, environmental costs should not simply be transferred to communities or future governments. The remediation problem therefore becomes part of the governance problem. The state must determine who is responsible for assessment, remediation, monitoring, and financing. This is especially important in illegal mining because the absence of a formal permit does not eliminate the ecological damage produced by the activity.

The problem is ultimately one of institutional capacity and accountability rather than the absence of environmental norms. Indonesia possesses a relatively extensive legal framework governing mining authorization, environmental protection, mercury reduction, water quality, and hazardous substances. Yet studies of Indonesian ASGM repeatedly identify weaknesses in enforcement, formalization, technology transition, and coordination. A review by Meutia, Lumowa, and Sakakibara (2022) emphasizes that ASGM involves intertwined environmental, health, economic, and legal problems, while their later study finds that illegal mining sites can generate simultaneous environmental degradation, health threats, and legality problems (Meutia et al. 2023). These findings support the argument that the West Sumatran problem should not be conceptualized as a simple regulatory vacuum. Rather, it represents a governance implementation gap in which formal legal commitments coexist with persistent informal extraction. The key challenge is therefore translating legal principles into institutional practices capable of protecting rivers, reducing mercury, and distributing environmental risks more fairly.

The evidence from West Sumatra makes this governance gap particularly visible because illegal gold mining intersects with established local economic and social structures. Research on illegal mining networks in Sijunjung and South Solok identifies rent-seeking relationships involving mining entrepreneurs, capital owners, and individuals within official structures (Anggraini, Fajri, and Islami 2023). Although this study concerns political-economic relationships rather than mercury

contamination itself, it is highly relevant to understanding why environmental regulation can fail. If extraction generates economic rents that are distributed among multiple actors, enforcement becomes more difficult than a simple confrontation between the state and individual miners. The mining economy may become embedded within networks of interest that have incentives to preserve access to gold-bearing resources. Political ecology therefore provides a useful interpretive framework: environmental degradation is not simply an unintended consequence of economic activity but can be reproduced through unequal power relations surrounding access to natural resources.

The resulting picture is therefore more complex than the conventional narrative of “illegal miners damaging rivers.” The empirical evidence shows ecological degradation and mercury contamination; the legal framework establishes prohibitions and environmental obligations; and the political-economic literature demonstrates that extraction can be sustained through livelihood dependence, institutional weakness, and rent-seeking relationships. These elements interact. Mercury pollution persists not simply because mercury is toxic, but because particular production arrangements make its use economically meaningful. River degradation persists not simply because miners lack environmental awareness, but because ecological costs are externalized from the extraction economy onto broader communities and future users. The central argument of this subsection is consequently that river degradation in West Sumatra constitutes a legally recognizable environmental harm whose persistence reflects a governance and political-economy problem rather than a simple failure of individual compliance. This interpretation provides the foundation for examining who bears these environmental risks and why those burdens are distributed unequally.

2. Unequal Exposure, Livelihood Dependence, and Environmental Justice

The ecological consequences of illegal gold mining become an environmental-justice problem when exposure to environmental risk is distributed unequally among social groups. The central issue is therefore not simply whether mercury or other pollutants are present, but who is exposed, through which pathways, and with what capacity to avoid or respond to that exposure. Schlosberg’s environmental-justice framework is particularly useful because it moves beyond a narrow conception of justice as equal distribution and incorporates distribution, recognition, participation, and capabilities (Schlosberg 2007). In West Sumatra, these dimensions intersect because mining generates economic opportunities for some actors while potentially transferring environmental risks to workers, farmers, fishers, households, and downstream communities. The resulting inequality is not necessarily produced by a single intentional decision. Rather, it emerges from the organization of extraction itself: benefits tend to be monetized and concentrated around mining activities, whereas ecological costs may be dispersed across communities that depend upon the same river system. This makes illegal mining simultaneously an economic and environmental-justice issue.

The distribution of mercury exposure illustrates this asymmetry particularly clearly. Individuals involved directly in amalgamation or gold processing may face occupational exposure, but exposure does not necessarily stop at the processing site. Mercury can enter surrounding environmental media and food systems, creating pathways through which people who do not participate in mining may nevertheless encounter contamination. Research from Sijunjung provides important West Sumatran evidence. A 2026 study by Novirsa et al. assessed potential mercury exposure through rice consumption among communities living near gold-mining areas and found that estimated intake from rice remained within the tolerable daily intake level, while emphasizing that other exposure pathways, including inhalation and consumption of other foods, require further investigation (Novirsa et al. 2026). The finding is analytically important precisely because it prevents overstatement: available evidence does not establish widespread mercury poisoning through rice in Sijunjung, but it demonstrates the existence of an exposure pathway requiring continued surveillance.

The Sijunjung evidence also illustrates why environmental risk should not be reduced to a binary distinction between “safe” and “contaminated.” Risk depends on dose, pathway, duration, population characteristics, and the interaction of multiple exposure routes. A population may have a calculated exposure below a particular tolerable threshold through one food pathway while simultaneously experiencing exposure through inhalation, occupational contact, fish consumption, or other environmental media. Consequently, a single environmental-health measurement cannot adequately characterize the social distribution of mercury risk. Research in other Indonesian ASGM locations demonstrates why this precaution is warranted. Baeuml et al. (2016), examining a mining community in Cisit, documented mercury contamination in air, fish, and rice and found elevated mercury levels among individuals presenting neurological symptoms. Their findings cannot be transferred directly to Sijunjung or Dharmasraya, but they establish a scientifically documented mechanism through which mining-related contamination can become a community-wide health concern rather than merely an occupational hazard.

The distinction between occupational and community exposure is fundamental to environmental justice because miners and non-miners occupy different positions of choice and vulnerability. A miner may accept occupational risk because mining provides income, whereas a child consuming locally produced food does not make an equivalent economic choice. Similarly, farmers and fishers may be unable to avoid environmental exposure without abandoning livelihoods that have existed independently of mining. This creates what can be termed involuntary risk transfer: economic activity undertaken by one group can generate environmental risks that are experienced by another group without equivalent participation in the decision to generate those risks. Such a pattern corresponds closely with the distributive dimension of environmental justice identified by Schlosberg (2007). It also complicates conventional cost-benefit approaches because the people receiving

economic benefits and the people bearing environmental risks may not be the same population. The distribution of environmental burdens must therefore be examined alongside the distribution of economic gains.

This issue becomes especially relevant for food systems. Rivers and surrounding agricultural landscapes are not merely ecological spaces; they are productive infrastructures supporting household subsistence and income. Where mining affects water quality, sediments, soils, or aquatic organisms, the consequences can extend into food production and consumption. Research in Dharmasraya has documented mercury and lead in Batanghari River sediments in areas associated with illegal gold mining (Mawardi et al. 2022), while research on former mining areas has identified persistent mercury contamination in soils (Manullang, Gusmini, and Rezki 2021). These findings matter because soil and river contamination can transform environmental resources that previously functioned as livelihood assets into potential sources of risk. The injustice is therefore not limited to exposure itself. It may also involve the loss of safe access to resources that communities depend upon for food and income.

The relationship between environmental degradation and livelihood dependence creates a particularly difficult policy dilemma. Illegal gold mining may provide cash income that is difficult for agriculture, fishing, or informal employment to match in the short term. Yet mining can simultaneously weaken those alternative livelihood systems through environmental degradation. This produces a potential dependence-degradation cycle: households enter mining because alternative income is inadequate; mining degrades ecological resources; degraded resources reduce the productivity of non-mining livelihoods; and declining livelihood alternatives increase dependence on mining. Meutia, Lumowa, and Sakakibara (2022) emphasize precisely this dual character of Indonesian ASGM, in which mining provides economic opportunities while generating environmental and health risks. The policy implication is significant: eliminating mining without addressing economic dependence may create new forms of social vulnerability, while tolerating mining indefinitely may progressively undermine the ecological foundations of alternative livelihoods. Environmental justice therefore requires policies capable of addressing both dimensions simultaneously.

Political ecology provides a stronger explanation for this contradiction than approaches that treat environmental degradation as the unintended result of individual behavior. Political-ecology scholarship emphasizes that environmental change is shaped by relations of power, access, and control over natural resources (Bebbington 2012). In an illegal gold-mining context, the relevant question is therefore not merely why an individual miner chooses to enter a river but how economic institutions make extraction profitable and alternative livelihoods comparatively less attractive. Gold possesses a readily monetizable value, while ecosystem services such as clean water, fish habitats, soil fertility, and landscape stability are often weakly represented in market transactions. The resulting valuation asymmetry can make environmental destruction economically rational at the

individual level even when it is socially costly. Illegal mining thus illustrates a classic externalization problem: the private return from extraction can remain attractive because substantial ecological costs are transferred to others and to the future.

The distribution of benefits within the mining economy must also be distinguished from the simplistic image of “miners versus communities.” Gold extraction can involve miners, landholders, financiers, machinery owners, processing operators, intermediaries, traders, and other actors. The distribution of income among these groups is unlikely to be equal. Research examining illegal mining in Sijunjung and South Solok has identified rent-seeking relationships involving mining entrepreneurs, capital owners, and actors connected with official structures (Anggraini, Fajri, and Islami 2023). This finding is important for environmental justice because it suggests that economic benefits may extend beyond the workers who are most visible at mining sites. If enforcement concentrates exclusively on individual miners, it may therefore impose the greatest legal costs on actors with relatively limited economic power while leaving broader structures of extraction intact. The resulting pattern would constitute not only distributive environmental injustice but also accountability injustice, because responsibility would not correspond proportionately to economic power and organizational control.

Health vulnerability further complicates the distribution of mining risks. Exposure is not experienced equally because individuals differ in occupation, diet, age, mobility, economic resources, and access to health services. Children, pregnant women, workers directly involved in processing, and households relying heavily on locally produced food can face different exposure profiles. The 2026 Sijunjung study is useful here because its authors explicitly identify the need to investigate exposure pathways beyond rice consumption (Novirsa et al. 2026). This supports a precautionary analytical approach: where evidence is incomplete, the appropriate conclusion is not that communities are necessarily suffering widespread poisoning, but that exposure should be assessed comprehensively. Environmental justice requires particular attention to populations with fewer resources to reduce exposure. A wealthy household may purchase alternative food or water, relocate, or access private medical services; a poorer household may have considerably fewer options. Economic inequality can therefore translate directly into unequal capacity to respond to environmental risk.

The concept of capability adds another dimension to this analysis. For Sen and subsequent environmental-justice scholars, justice concerns people's substantive ability to achieve valuable forms of life, rather than simply the distribution of material goods. Schlosberg (2007) incorporates this capability perspective into environmental justice by emphasizing the relationship between environmental conditions and people's ability to function within their communities. Applied to West Sumatra, a degraded river can reduce capabilities even without producing immediately measurable disease. A farmer may face declining agricultural

productivity; a fisher may lose access to productive fishing grounds; households may lose confidence in local food or water sources; and communities may experience increasing uncertainty about the safety of their environment. Environmental degradation therefore reduces the range of choices available to people. This is particularly significant where rural livelihoods depend strongly upon ecological resources, because environmental damage can constrain economic and social opportunities simultaneously.

Recognition is equally important because affected communities are not homogeneous victims. West Pasaman provides evidence of local institutions attempting to respond to the social consequences of illegal mining. Sahrul and Daulai (2025) document the involvement of indigenous communities, religious leaders, and intellectuals in addressing social conflict, economic disparities, and other consequences associated with illegal gold mining. Their findings demonstrate that communities possess institutional resources of their own and should not be represented simply as populations awaiting intervention from the state. Recognition justice requires acknowledging the social institutions, cultural values, and environmental knowledge through which communities interpret and respond to mining. At the same time, recognition should not romanticize customary authority or assume that local institutions are internally equal. The analytical point is more limited and more defensible: environmental governance becomes incomplete when policies recognize only formal administrative actors while ignoring legitimate community institutions that influence behavior and social acceptance.

Participation consequently becomes a substantive component of environmental protection rather than a procedural formality. If communities affected by mining are consulted only after decisions have already been made, participation has little capacity to redistribute power. Meaningful participation would require communities to influence environmental monitoring, livelihood planning, remediation priorities, and decisions concerning river protection. This is particularly important because local residents may possess long-term observations of changes in water, fish populations, agricultural productivity, and mining patterns that are not captured by periodic scientific sampling. Such knowledge should complement rather than replace scientific evidence. The environmental-justice literature treats participation as important because distributive outcomes are partly determined by who has access to decision-making institutions (Schlosberg 2007). In West Sumatra, strengthening participation could therefore address not only procedural injustice but also the information gap that makes environmental regulation less responsive to local ecological conditions.

The cumulative evidence indicates that illegal gold mining produces a layered structure of environmental inequality rather than a single category of harm. Workers can experience occupational hazards; surrounding households may experience environmental exposure; farmers and fishers can face declining ecological productivity; and future generations may inherit contaminated soils and sediments. Meanwhile, the economic benefits of extraction may be distributed among a

different set of actors. This separation between benefit, exposure, and decision-making power is the defining analytical feature of the environmental-justice problem. It explains why simply measuring mercury concentrations or counting illegal mining sites is insufficient. Scientific measurements establish environmental conditions, but environmental justice asks what those conditions mean socially and politically. The relevant unit of analysis is therefore not the pollutant alone but the relationship between ecological risk, economic dependence, institutional authority, and social vulnerability.

The evidence also demonstrates why the West Sumatran case should not be framed as a conflict between environmental protection and poverty reduction. Such a binary is analytically misleading because environmental degradation can itself become a mechanism through which poverty and dependence are reproduced. If mining destroys or degrades alternative livelihood resources, communities may become more economically dependent on the same activity responsible for environmental degradation. Conversely, a sudden prohibition without viable livelihood alternatives can expose miners and their households to serious economic insecurity. The appropriate analytical objective is therefore livelihood security without ecological destruction. This requires recognizing miners as economically vulnerable workers while simultaneously recognizing the rights of non-mining communities to safe environmental conditions. Environmental justice provides a framework capable of holding these interests together because it does not define justice as protecting one group at the expense of another; rather, it asks whether institutional arrangements distribute environmental opportunities, risks, recognition, and capabilities fairly.

Taken together, the findings establish that environmental injustice in West Sumatra operates through at least four interconnected mechanisms: unequal exposure, unequal economic benefit, unequal decision-making power, and unequal capacity to respond. Mercury provides a particularly clear example because its risks can move through occupational, environmental, and food pathways. River degradation broadens the problem because ecological resources support livelihoods beyond the mining economy. Political-economic structures further complicate the distribution of benefits, while differences in wealth and institutional access shape the capacity of households to avoid or respond to environmental harm. The central argument of this subsection is therefore that illegal gold mining should not be evaluated solely according to whether miners comply with legal requirements. It must also be evaluated according to whether the broader mining economy produces an unjust distribution of environmental risks and livelihood opportunities. This provides the conceptual bridge to the next subsection, which examines how power relations, rent-seeking, institutional fragmentation, and selective enforcement shape the persistence of illegal mining despite the existence of formal legal prohibitions.

3. Illegal Mining, Power Relations, and the Limits of Law Enforcement

The persistence of illegal gold mining in West Sumatra demonstrates that illegality cannot be explained solely by individual miners' decisions to violate mining regulations. Illegal mining operates through a broader institutional and political-economic structure involving miners, landowners, financiers, equipment owners, gold traders, local authorities, and, in some cases, law-enforcement actors. A study of illegal gold mining in Indonesia identifies six major determinants of persistence: financial incentives, low barriers to entry, regulatory and policy conditions, availability of supporting resources, political and power relations, and psychosocial factors (Yunianto et al. 2021). This finding is particularly relevant to West Sumatra because it challenges the conventional assumption that enforcement fails simply because miners are unwilling to obey the law. Instead, illegal mining persists because an economic and institutional environment makes extraction possible and profitable. Law enforcement consequently confronts not a collection of isolated offenders but a networked socio-economic activity in which different actors occupy different positions of power, responsibility, and vulnerability.

The distinction between miners and the wider mining network is especially important in Sijunjung and South Solok. Anggraini, Fajri, and Islami (2023) identify rent-seeking relationships involving mining entrepreneurs, capital owners, landowners, officials, bureaucrats, and law-enforcement actors. Their findings indicate that some actors allegedly facilitate the movement of mining equipment or otherwise enable operations, while insufficient governmental oversight creates opportunities for the mining network to continue operating. The theoretical significance of this evidence can be understood through rent-seeking theory. In its classical formulation, rent seeking involves attempts to obtain economic advantage through control or manipulation of public institutions rather than through productive economic activity (Krueger 1974). Applied to illegal mining, the concept shifts analytical attention from the visible act of digging toward the institutional relationships that protect access to valuable resources. Illegal mining therefore becomes not merely an underground economy but potentially a political economy in which regulatory authority itself can become a resource.

The existence of rent-seeking relationships also complicates the meaning of “illegal” within resource governance. Formally, mining without the required authorization constitutes a legal violation, but the practical operation of illegal mining may depend upon informal arrangements that reduce the probability of enforcement. Anggraini, Fajri, and Islami (2023) report that relationships between entrepreneurs and officials can facilitate mining operations in Sijunjung and South Solok. This does not mean that all officials or institutions are involved, nor does it justify attributing corruption to the entire local government. The analytical point is narrower: where regulatory enforcement can be selectively weakened through personal, political, or economic relationships, the expected cost of illegality declines. Becker's (1968) economic theory of crime provides a useful complementary explanation because the deterrent effect of law depends partly

upon the probability and severity of sanctions. If the probability of detection or prosecution is perceived as low, even substantial statutory penalties may have limited deterrent effects. Illegal mining can consequently become rational from the perspective of actors who calculate expected returns against uncertain enforcement.

This problem is visible in the structure of enforcement documented in Sijunjung. Jailani and Rosadi report that law-enforcement actions against illegal gold mining have tended to capture workers while owners of capital or alleged protectors remain outside the immediate enforcement process. Although such findings should not be generalized to every enforcement operation, they reveal an important structural weakness. A mining worker is often the most visible and accessible actor at the extraction site, whereas financiers, equipment owners, intermediaries, and beneficiaries may be more difficult to identify. Consequently, enforcement can become concentrated at the lowest level of the production chain. From an environmental-justice perspective, this is problematic because legal vulnerability becomes inversely related to economic power: those with fewer resources may face direct criminal sanctions, while actors controlling capital and networks may be better positioned to avoid detection. Effective enforcement should therefore follow the organization of responsibility rather than simply the physical visibility of mining activity.

Indonesian mining law provides a strong normative basis for addressing unauthorized extraction. The Minerba regime, originally established through Law No. 4 of 2009 and subsequently amended by Law No. 3 of 2020, Law No. 6 of 2023, and Law No. 2 of 2025, requires mineral and coal mining activities to operate within the authorization system established by law. Article 158 remains central to the criminal regulation of mining without authorization. The legal significance of this provision is straightforward: mineral resources cannot be appropriated privately merely because they are physically accessible. However, the existence of Article 158 does not resolve the environmental dimension of the problem. A mining operation may simultaneously constitute unauthorized extraction and produce pollution or environmental damage governed by the Environmental Protection and Management Law. The legal problem is therefore cumulative rather than alternative: enforcement must address both the unlawful acquisition of mineral resources and the ecological consequences produced through extraction. This supports the argument that criminal prosecution should be integrated with environmental restoration rather than treated as an endpoint.

The Environmental Protection and Management Law No. 32 of 2009 reinforces this broader conception of responsibility. Article 98 establishes criminal liability for intentional acts causing environmental quality standards or environmental-damage criteria to be exceeded, while Article 99 addresses comparable consequences resulting from negligence. These provisions are analytically important because they demonstrate that environmental law does not conceptualize pollution merely as an administrative irregularity. Under specified circumstances, serious environmental

harm can generate criminal liability independently of the underlying mining offense. The implication for illegal gold mining is significant: where mining activities cause demonstrable environmental damage, enforcement should not stop after establishing that the operator lacked a mining permit. Investigators and prosecutors should also consider evidence concerning pollution, environmental damage, causation, and affected communities. This integrated approach would better reflect the actual social harm produced by illegal mining because it recognizes that the offense concerns both unauthorized extraction and the degradation of ecological systems.

Nevertheless, the existence of multiple legal provisions can itself generate institutional fragmentation. Mining authorities, environmental agencies, police, prosecutors, local governments, and community institutions may possess different mandates, information, and enforcement capacities. An illegal mining operation can therefore fall simultaneously within several regulatory domains without any single institution possessing complete responsibility for the entire problem. Research on Indonesian mining governance has identified insufficient monitoring infrastructure, limited transparency, and weaknesses in interinstitutional accountability as continuing problems (Suci 2022; Suarni et al. 2025). Suci (2022), for example, concludes that enforcement against unlicensed mining can be ineffective when punishment is disconnected from broader environmental objectives. The consequence is a governance paradox: the state may possess extensive legal authority but still lack the institutional coordination necessary to translate that authority into consistent control. Illegal mining therefore illustrates the difference between legal capacity and governance capacity.

Legal culture provides another explanation for the persistence of illegal mining. Jati et al. (2025), examining illegal gold mining in Paningkaban, argue that formal law enforcement alone has been insufficient because illegal mining is embedded within local social and economic conditions. Their analysis connects environmental non-compliance with legal culture and broader social acceptance of mining practices. This perspective is relevant to West Sumatra because an activity can remain formally illegal while becoming socially normalized when it provides employment, income, or access to valuable resources. Once mining becomes part of ordinary economic life, state enforcement may encounter resistance not because communities reject environmental protection in principle but because prohibition threatens established livelihoods. The analytical consequence is that compliance cannot be produced exclusively through coercion. Durable compliance requires institutions to change the incentives and social expectations surrounding extraction. Otherwise, enforcement may temporarily suppress mining while leaving the social conditions that reproduce it untouched.

The role of local institutions further complicates the governance landscape. Research in West Pasaman shows that indigenous communities, religious leaders, intellectuals, and other local actors have participated in efforts to mitigate the social consequences of illegal gold mining (Sahrul and Daulai 2025). Such institutions

possess forms of social legitimacy that formal government agencies may not always possess. Yet their authority does not necessarily include the formal power to investigate, prosecute, or impose criminal sanctions. This creates an important distinction between legal authority and social authority. Effective governance should not force a choice between them. Instead, customary and community institutions can contribute to early warning, social mediation, environmental monitoring, and livelihood programs, while state institutions retain responsibility for criminal enforcement and statutory environmental obligations. This model is consistent with Ostrom's (1990) argument that sustainable management of common-pool resources can depend upon polycentric institutions and locally embedded rules. However, local participation must remain accountable and inclusive rather than becoming a substitute for formal legal responsibility.

The problem of selective enforcement also has implications for corruption and institutional legitimacy. If mining operators perceive that connections with officials, politicians, or enforcement actors can reduce regulatory risks, then the law ceases to function as a predictable constraint. The literature on mining governance in Indonesia has documented relationships between political authority and resource extraction in which regulatory decisions can generate opportunities for private rent capture (Ammelia, Intan, and Idiani 2024). Such dynamics are particularly damaging because they transform environmental regulation from a public-good mechanism into a potential source of private advantage. The environmental consequences are substantial: when enforcement can be weakened through political or economic influence, communities bearing environmental risks have fewer effective mechanisms for protection. This produces what may be termed institutional environmental injustice, in which unequal political access becomes a mechanism through which environmental burdens are distributed unequally.

The legal framework concerning mercury illustrates why enforcement must also extend beyond the mining pit. Indonesia ratified the Minamata Convention through Law No. 11 of 2017 and subsequently adopted Presidential Regulation No. 21 of 2019 concerning the National Action Plan for Mercury Reduction and Elimination (RAN-PPM). The latter remains in force and specifically provides a national framework for reducing and eliminating mercury use. Ministerial Regulation No. 81 of 2019 further establishes implementation mechanisms for the RAN-PPM, including monitoring and reporting of mercury-reduction and elimination activities. The legal implication is that mercury governance is not simply a matter of prosecuting miners after contamination occurs. It involves prevention, monitoring, technological transition, coordination, and evaluation. Consequently, a law-enforcement strategy that ignores mercury supply chains, processing practices, and alternative technologies addresses only one component of the governance problem.

This point is reinforced by research on Indonesian ASGM showing that illegal mining has a complex actor structure. The study of Yuniarto et al. (2021) identifies financial incentives, low barriers to entry, supportive resources, regulation, politics, and power as mutually reinforcing determinants of illegal gold mining. (Spiegel et

al. (2018) similarly demonstrate that mercury use is embedded within economic and labor relationships rather than being merely an individual technological preference. These findings suggest that enforcement directed exclusively toward miners is structurally incomplete. If financiers continue to provide capital, equipment remains available, gold buyers continue purchasing output, and alternative livelihoods remain inadequate, removing individual miners may simply create replacement labor. The mining system possesses a degree of organizational resilience because different actors can substitute for one another. Effective enforcement must therefore target the conditions of reproduction of illegal mining, including financial flows, equipment supply, market access, institutional protection, and environmental consequences.

The limitations of conventional enforcement are particularly visible when criminal sanctions are prioritized over ecological restoration. Indonesian legal scholarship has noted that enforcement against unlicensed mining often emphasizes punishment while providing insufficient clarity concerning responsibility for reclamation and post-mining environmental recovery. Suarni et al. (2025), examining unlicensed mining and reclamation, argue that existing regulatory arrangements remain insufficient in establishing clear responsibility for restoring illegal mining sites. This creates a critical policy problem. Even if a mining operator is convicted, contaminated soil, damaged riverbanks, altered landscapes, and polluted sediments may remain. Criminal punishment therefore does not automatically reverse environmental harm. From an environmental-justice perspective, remediation is essential because communities should not inherit ecological liabilities merely because the perpetrators have been prosecuted. Enforcement must consequently be evaluated not only through arrest and conviction statistics but also through whether environmental conditions are restored and affected communities are protected.

The same reasoning applies to public participation. Recent legal scholarship argues that Indonesian mining regulation has gradually expanded formal channels for community participation, yet substantial weaknesses remain in implementation, transparency, and the ability of communities to influence decisions (From Authoritarianism to Participatory Governance? 2026). This gap is particularly important for illegal mining because local communities are often the first actors to observe changes in river conditions, mining expansion, equipment movement, or conflicts surrounding extraction. If reporting mechanisms are weak or communities fear retaliation, local information may never become actionable regulatory intelligence. Participation should therefore be understood not merely as a democratic principle but as an enforcement resource. Community reporting, environmental monitoring, and local institutional knowledge can increase the state's capacity to identify illegal activity. Conversely, excluding communities can make enforcement more dependent on periodic raids and reactive operations, which are less capable of addressing a dispersed and adaptive mining economy.

The evidence ultimately indicates that the principal weakness of illegal-mining governance in West Sumatra is not the absence of law but the uneven translation of law into institutional practice. Indonesia has criminal provisions for unauthorized mining, environmental criminal provisions, mercury-reduction commitments, environmental-quality regulations, and mechanisms for public participation. Yet illegal mining persists because these legal instruments operate within a socio-economic system characterized by livelihood dependence, financial incentives, institutional fragmentation, limited monitoring, and unequal power. This produces a crucial distinction between rule-based legality and substantive environmental justice. A system may successfully arrest miners while failing to dismantle the networks that finance extraction, restore degraded rivers, protect exposed communities, or provide credible livelihood alternatives. The central argument is therefore that enforcement should be redesigned around the structure of the mining economy and the ecological consequences of extraction. The relevant question is no longer simply “How many miners were arrested?” but “Has the governance system reduced the capacity and incentive to reproduce illegal mining while restoring the environmental rights of affected communities?”

4. From Enforcement to Ecological Justice: Governance, Remediation, and Mercury Elimination

The preceding analysis demonstrates that illegal gold mining in West Sumatra cannot be addressed adequately through criminal enforcement alone. The central policy challenge is to construct a governance system capable of simultaneously reducing illegal extraction, eliminating mercury use, protecting livelihoods, restoring degraded ecosystems, and strengthening the rights of affected communities. This requires a shift from an enforcement-centered model toward an ecological-justice model of resource governance. Such a shift does not imply weakening the prohibition against illegal mining. Rather, it recognizes that prohibition becomes effective only when accompanied by institutional mechanisms that alter the economic incentives sustaining illegality and provide credible alternatives for communities dependent upon mining. Recent research on Indonesian ASGM similarly finds that enforcement-focused interventions can displace mining activities without necessarily producing sustainable changes in production practices, whereas formalization, financing, training, and technological transition can improve compliance when implemented together (Harun, Veronica, and Puluhalawa 2026).

A first requirement is to integrate mining governance with the national mercury-elimination framework. Indonesia ratified the Minamata Convention through Law No. 11 of 2017 and subsequently adopted Presidential Regulation No. 21 of 2019 concerning the National Action Plan for Mercury Reduction and Elimination (RAN-PPM). The latter remains in force and establishes mercury reduction and elimination as a national policy objective. The significance of this framework is that mercury elimination should not be treated as a separate environmental-health program

operating alongside mining regulation. In ASGM areas, mercury use is structurally connected to mineral processing, labor arrangements, gold markets, and livelihood strategies. Spiegel et al. (2018) demonstrate that efforts to eliminate mercury can be undermined when interventions ignore these socioeconomic relationships. Mercury governance in West Sumatra should therefore be incorporated into mining enforcement, local development planning, health surveillance, and livelihood programs. This integrated approach would make mercury reduction a structural transformation of the mining economy rather than a narrow campaign against individual users.

The second requirement is to make technological transition economically viable. The continued use of mercury cannot be explained simply by a lack of awareness regarding its toxicity. Mercury remains attractive within ASGM because it is compatible with existing processing practices, relatively accessible, and embedded in established labor and production relationships. Spiegel et al. (2018) show that socioeconomic inequalities and labor dynamics can hinder collective adoption of mercury-free technologies. Consequently, providing alternative technology without addressing ownership, financing, training, processing capacity, and gold-market access is unlikely to produce sustained adoption. A more effective strategy would establish community-based or cooperative processing facilities using mercury-free methods, accompanied by technical assistance and transparent purchasing arrangements. Such facilities could reduce individual miners' dependence on mercury while creating a regulated point at which production volumes, processing practices, environmental standards, and gold transactions can be monitored. Technology would thus become part of a governance mechanism rather than merely an environmental gadget.

Formalization should constitute the third component of this strategy, but it must be approached cautiously. Formalization is frequently presented as an automatic solution to illegal mining because obtaining legal recognition theoretically brings miners under regulatory supervision. Yet formalization without economic feasibility can simply reproduce informality. If licensing procedures are costly, access to legal mining areas is limited, environmental requirements are technically inaccessible, or legal production is less profitable than informal extraction, miners may continue operating outside the formal system. Harun, Veronica, and Puluhalawa (2026) therefore argue for livelihood-sensitive formalization involving cooperatives, financing, training, and technological transition. For West Sumatra, formalization should consequently be evaluated not only according to the number of permits issued but according to whether legalization produces measurable improvements in environmental performance. A successful formalization program should connect authorization with mercury-free processing, environmental monitoring, occupational safety, transparent gold marketing, and enforceable restoration obligations. Otherwise, legalization risks becoming an administrative exercise without substantive ecological improvement.

The legal framework already provides important foundations for such an approach. Government Regulation No. 22 of 2021 regulates environmental approvals, water-quality protection, environmental damage, hazardous and toxic waste, environmental information, supervision, and administrative sanctions. It also establishes mechanisms concerning guarantees for environmental-function recovery. This is important because ecological justice requires environmental governance to address the entire life cycle of environmental harm. Mining governance should therefore connect authorization, operation, monitoring, cessation, and restoration rather than treating them as separate regulatory stages. For illegal mining, this principle becomes especially important because the absence of a formal permit cannot logically eliminate the need to restore environmental functions. If an operator has degraded a river or contaminated land, the community should not be left with an environmental liability simply because the activity was illegal. The legal system should instead ensure that identifiable responsible actors are pursued for restoration while public resources are available for situations where immediate ecological intervention is necessary.

The question of reclamation is therefore central to ecological justice. Indonesian legal scholarship has identified uncertainty concerning responsibility for reclamation following illegal mining, despite the increasingly strong emphasis on environmental protection and post-mining obligations in mining legislation (Rohmadanti et al. 2023). This creates a practical contradiction. The state can prohibit illegal mining and prosecute offenders, yet contaminated soils, abandoned pits, unstable riverbanks, and altered landscapes may remain after enforcement operations. Criminal punishment does not itself restore ecological function. A stronger framework should establish a clear hierarchy of restoration responsibility: first, identify and recover costs from responsible operators, financiers, land controllers, or other legally accountable actors where evidence permits; second, use legally available environmental guarantees and recovery mechanisms; and third, deploy public restoration funds where immediate intervention is necessary to protect communities and ecosystems. Public expenditure should not, however, become an implicit subsidy for illegal extraction. Recovery mechanisms should seek to internalize environmental costs whenever legally and practically possible.

Restoration itself should also be defined more broadly than physical reclamation of mining pits. A river affected by mining is an interconnected ecological and social system. Restoration should therefore include stabilization of riverbanks, rehabilitation of soils, reduction of contaminant sources, monitoring of sediments and aquatic organisms, recovery of agricultural productivity, and long-term assessment of ecological health. Recent Indonesian literature on post-ASGM restoration emphasizes community participation, technological innovation, and institutional intervention as interconnected components of sustainable recovery (Sulaiman, Hatta, and Jufri 2025). This perspective is preferable to a narrow engineering model because ecological recovery can take place over different temporal scales. Some physical interventions may produce immediate

improvements, whereas mercury-related risks may persist and require long-term monitoring. Restoration should therefore be organized as an adaptive process in which scientific measurements are periodically reassessed and management strategies adjusted according to ecological outcomes.

Community participation should form another institutional pillar. Environmental justice theory emphasizes that people affected by environmental decisions should have meaningful opportunities to participate in determining those decisions, while recognition justice requires institutions to take community identities, knowledge, and social circumstances seriously (Schlosberg 2007). Indonesian research on mining reclamation likewise finds that community participation can be constrained by limited access to information, limited technical capacity, and weak monitoring mechanisms (Ramadhan 2025). In West Sumatra, community participation could be institutionalized through river-monitoring groups, participatory environmental mapping, public reporting systems, community representatives in restoration planning, and accessible disclosure of water and sediment monitoring results. Participation should not replace scientific or governmental authority. Its function should be complementary: communities provide local knowledge and oversight, scientists provide analytical capacity, and government institutions retain statutory responsibility for enforcement and environmental protection.

A particularly important reform would be the creation of a river-centered monitoring system rather than a mining-site-centered system. Conventional enforcement tends to focus on identifying illegal extraction locations, but ecological harm can travel downstream and persist after mining stops. Monitoring should therefore combine information about mining activity with indicators of environmental condition. Satellite imagery, drone surveys, river sampling, sediment analysis, biological monitoring, and community reports could be integrated into a spatial environmental-monitoring platform. Such a system would allow authorities to identify both active mining and ecological consequences. The approach is consistent with the logic of PP No. 22 of 2021, which emphasizes environmental information, supervision, and monitoring as components of environmental governance. More importantly, it would change the performance metric of enforcement. Authorities would no longer assess success only by the number of raids, arrests, or seized machines, but also by whether illegal mining decreases and river ecological indicators improve.

Health protection must similarly be integrated into mining governance. The evidence from Sijunjung demonstrates why monitoring should be pathway-specific. Novirsa et al. (2026) found that estimated mercury exposure through rice consumption in the studied gold-mining area remained below the relevant tolerable intake threshold, but the researchers emphasized the need to investigate other exposure pathways. This finding supports a precautionary but scientifically disciplined approach. Authorities should not characterize all residents of mining regions as poisoned without adequate biomonitoring evidence; equally, they

should not interpret the absence of elevated exposure through one pathway as evidence that communities face no mercury risk. Health surveillance should therefore combine environmental monitoring with targeted assessment of occupational exposure, dietary pathways, vulnerable populations, and communities located near processing areas. Such surveillance would also provide an empirical basis for evaluating whether mercury-elimination policies are producing measurable health benefits.

Livelihood transition represents perhaps the most difficult component of ecological-justice governance. A policy that removes illegal mining without creating alternative income opportunities may generate resistance, displacement, or re-entry into illegal extraction. This problem is not hypothetical: research on Indonesian ASGM emphasizes that livelihood dependence is one of the structural factors sustaining mercury use and informal mining (Spiegel et al. 2018; Harun, Veronica, and Puluhalawa 2026). Alternative livelihood programs should therefore be designed according to actual local economic conditions rather than standardized training packages. Agricultural intensification, fisheries, livestock, small enterprises, forest-based livelihoods, processing industries, or regulated mining employment may be appropriate in different locations. The relevant policy criterion should be whether households can obtain sufficiently reliable income without returning to environmentally destructive extraction. Livelihood policy is thus not an auxiliary social program; it is part of environmental enforcement because it directly influences the economic incentives that sustain illegal mining.

The governance model should also distinguish between small-scale miners and higher-level economic beneficiaries. Environmental justice requires proportional accountability. Miners who possess limited capital and few livelihood alternatives should not automatically bear the same legal burden as financiers, equipment owners, processors, gold buyers, or actors who organize and protect large-scale illegal operations. This does not mean exempting miners from legal responsibility. Rather, enforcement should follow the actual structure of control and benefit. Research on Indonesian illegal mining repeatedly demonstrates that extraction involves multiple actors and economic relationships (Yunianto et al. 2021; Anggraini, Fajri, and Islami 2023). Enforcement that targets only visible workers risks producing a revolving-door system in which arrested miners are replaced by others while the economic infrastructure remains intact. A more sophisticated strategy would investigate financial flows, equipment ownership, land control, processing facilities, gold-trading networks, and institutional protection. Such enforcement would be more consistent with the principle that those possessing greater control over environmental risk should bear greater responsibility for preventing and remediating it.

Accountability should additionally extend to government institutions themselves. Environmental governance cannot be credible if communities are expected to comply with regulations while regulatory institutions are not transparent about monitoring, licensing, enforcement decisions, or restoration

outcomes. Recent research on Indonesian mining regulation identifies weak transparency, inadequate public participation, and insufficient mechanisms for environmental and post-mining accountability as continuing structural weaknesses (Mineral and Coal Mining Regulatory Reform in Indonesia 2025). ([Journal UNNES](#)) A stronger governance framework should therefore publish information concerning mining permits, designated community-mining areas, environmental monitoring results, enforcement actions, restoration responsibilities, and progress toward mercury elimination. Transparency is particularly important in contexts where allegations of rent seeking or selective enforcement exist. Public information cannot eliminate corruption by itself, but it increases the informational costs of arbitrary decision-making and enables civil society, researchers, journalists, and affected communities to scrutinize institutional performance.

Finally, ecological justice requires the state to redefine what counts as policy success. The traditional enforcement model tends to measure success through outputs: arrests, prosecutions, equipment seizures, or the closure of mining sites. These indicators are useful but insufficient. An ecological-justice framework should add outcome indicators: reductions in mercury use, improvements in river quality, rehabilitation of degraded land, reduction in community exposure, restoration of livelihood security, participation of affected communities, and prosecution of higher-level actors who organize or profit from illegal extraction. This approach is consistent with the Minamata Convention's requirement for national action concerning ASGM where the sector is more than insignificant, including periodic review of progress. It also corresponds with Indonesia's RAN-PPM, which provides a national framework for mercury reduction and elimination. The decisive measure of governance should therefore be ecological and social recovery, not merely the visibility of state coercion.

The West Sumatran case ultimately demonstrates that river protection requires a transformation from reactive enforcement to integrated ecological governance. Criminal law remains necessary because unauthorized extraction and serious environmental violations cannot be normalized under the language of livelihood necessity. Yet criminal law must operate alongside formalization, mercury-free technology, livelihood transition, health surveillance, ecological restoration, community participation, transparent monitoring, and institutional accountability. The purpose is not to legalize environmental degradation but to change the socioeconomic conditions that make degradation reproducible. In this model, the river is treated not as an externality of mineral production but as a public ecological infrastructure whose protection is connected to constitutional environmental rights, environmental law, public health, and community livelihoods. The broader theoretical implication is consistent with environmental justice and political ecology: sustainable governance cannot be achieved simply by controlling individual behavior when environmental harm is structurally produced. Justice requires changing the distribution of risks, benefits, capabilities, decision-making power, and responsibility surrounding gold extraction.

Conclusion

This study has demonstrated that illegal gold mining in West Sumatra should not be understood merely as a problem of unauthorized mineral extraction or regulatory non-compliance. It is a multidimensional environmental-governance problem in which river degradation, mercury contamination, livelihood dependence, unequal exposure, institutional weakness, and power relations interact. The evidence reviewed in this article indicates that mining-related environmental harm can persist beyond the physical location and operational period of extraction, particularly where mercury enters sediments, soils, aquatic organisms, and agricultural environments. Research from Sijunjung further demonstrates the importance of examining specific exposure pathways rather than assuming uniform health impacts across affected populations. The environmental consequences of illegal mining must therefore be evaluated spatially and temporally, recognizing that ecological systems and human communities can continue to bear the consequences after mining activities have stopped.

The analysis also shows that the environmental consequences of illegal gold mining are distributed unevenly. Mining can provide income and economic opportunities to households with limited alternatives, while simultaneously imposing environmental risks on farmers, fishers, downstream communities, and future generations. This asymmetry is central to the concept of environmental injustice. The problem is not simply that pollution exists, but that the distribution of environmental benefits and burdens does not necessarily correspond to the distribution of economic benefits and decision-making power. Environmental justice therefore provides a more comprehensive analytical framework than a purely environmental or criminal-law approach. In the West Sumatran context, justice requires attention to distributional outcomes, recognition of affected communities, meaningful participation, and the capability of households to maintain secure livelihoods without depending upon environmentally destructive extraction.

A major conclusion of the study is that mercury contamination cannot be separated from the political economy of artisanal and illegal gold mining. Mercury use persists partly because it is embedded within existing production systems, labor relations, technological practices, and economic incentives. Research on Indonesia demonstrates that restricting mercury availability alone may be insufficient when socioeconomic conditions continue to make mercury-based processing attractive (Spiegel et al. 2018). Similarly, recent research emphasizes that mercury-free technologies have not yet been adopted at the scale required to achieve global mercury-reduction objectives. This suggests that mercury elimination requires more than prohibition. It requires technological accessibility, financing, training, institutional support, and economically credible alternatives. Otherwise, regulatory pressure may simply displace mercury use rather than eliminate the underlying production practices that generate contamination.

The persistence of illegal mining is likewise rooted in structural conditions that exceed individual behavior. Financial incentives, low barriers to entry, availability of equipment, market access, weak regulation, and power relations can collectively reproduce illegal mining even when formal prohibitions are well established. In West Sumatra, the literature further points to relationships involving capital owners, entrepreneurs, and institutional actors. This suggests that enforcement strategies focused primarily on visible workers are unlikely to dismantle the broader economic structure of illegal extraction. Criminal law remains necessary, particularly where mining occurs without authorization or produces serious environmental harm, but enforcement should follow the organization of responsibility and benefit. Financiers, equipment owners, processors, intermediaries, and other actors who exercise greater control over illegal production should receive appropriate scrutiny rather than allowing enforcement to concentrate disproportionately on economically vulnerable workers.

The legal analysis demonstrates that Indonesia does not lack formal environmental and mining regulations. The country has established a legal framework governing mineral extraction, environmental protection, hazardous substances, mercury reduction, environmental monitoring, and community rights. Indonesia's ratification of the Minamata Convention through Law No. 11 of 2017 and the subsequent establishment of the National Action Plan for Mercury Reduction and Elimination demonstrate a formal national commitment to reducing and, where feasible, eliminating mercury use in artisanal and small-scale gold mining. The international framework itself recognizes ASGM as a sector requiring specific national measures where its presence is more than insignificant. The central governance problem is consequently not the absence of legal norms but the gap between normative commitment and institutional implementation.

This implementation gap has significant consequences for ecological justice. Enforcement operations may close mining sites or apprehend individual miners, but such measures do not necessarily restore contaminated rivers, rehabilitate degraded land, reduce community exposure, or provide alternative livelihoods. The distinction between ending an illegal activity and repairing environmental harm is therefore fundamental. Ecological restoration should be regarded as an independent policy objective rather than an automatic consequence of criminal enforcement. Environmental governance must identify responsibility for remediation, establish monitoring mechanisms, and ensure that affected communities do not become the *de facto* bearers of restoration costs. In this respect, environmental accountability should extend beyond punishment toward the restoration of ecological functions and the protection of environmental rights.

The study consequently proposes an integrated governance approach built upon five mutually reinforcing elements. First, enforcement should target the organizational and financial structures sustaining illegal mining rather than focusing exclusively on workers at extraction sites. Second, mercury elimination should be linked to accessible mercury-free processing technologies and economic

incentives. Third, formalization should be designed around realistic livelihood conditions rather than treated as a purely administrative licensing process. Fourth, ecological restoration should include river systems, sediments, soils, agricultural environments, and other affected ecological functions. Fifth, communities should participate meaningfully in monitoring, decision-making, restoration planning, and environmental accountability. These elements are consistent with the broader direction of mercury governance research, which emphasizes that credible mercury-reduction policies require reliable baseline information, transparent monitoring, and measurable indicators of progress.

Community participation is particularly important in the West Sumatran context because local institutions already play roles in responding to the social consequences of illegal mining. Research in West Pasaman documents the involvement of indigenous communities, religious leaders, and intellectuals in mitigating social conflict and other consequences associated with illegal gold mining. Such institutions should not be regarded merely as informal substitutes for the state. Rather, they can complement formal environmental governance by contributing local knowledge, social legitimacy, environmental monitoring, conflict mediation, and livelihood planning. At the same time, participation must remain inclusive and accountable. Community involvement should not be used to transfer the state's statutory environmental responsibilities onto local populations. The appropriate model is therefore one of co-governance, in which state authority, scientific expertise, and community knowledge operate in complementary rather than competing institutional spaces.

The findings also have implications for how environmental success should be measured. Conventional law-enforcement indicators—such as arrests, seizures, prosecutions, and mine closures—are important but inadequate as measures of ecological recovery. A more meaningful assessment should examine whether mercury use has declined, whether river and sediment quality has improved, whether degraded land has been rehabilitated, whether community exposure has decreased, whether alternative livelihoods have become economically viable, and whether higher-level actors responsible for organizing illegal extraction are being held accountable. This approach would transform environmental governance from an activity-based model into an outcome-based model. Such a transformation is especially important because estimates of mercury use in ASGM can contain considerable uncertainty; researchers have emphasized that inconsistent baseline methodologies and limited transparency can undermine evaluation of national action plans.

Ultimately, the West Sumatran case demonstrates that river protection is inseparable from social justice. A river is not merely a physical recipient of mining waste. It is simultaneously an ecological system, a livelihood resource, a source of food and water, and a component of community well-being. When extraction generates private economic value while transferring ecological costs to communities that possess less political and economic power, river degradation

becomes a question of justice. Conversely, protecting rivers without addressing the livelihood conditions of mining-dependent households risks producing another form of injustice. Sustainable policy must therefore reconcile two legitimate objectives: the right of communities to secure livelihoods and the right of present and future generations to a healthy environment.

The principal conclusion of this article is therefore that illegal gold mining in West Sumatra represents a form of ecological injustice produced through the interaction of extraction, environmental externalization, economic dependence, and unequal institutional power. Mercury contamination is one of its most visible manifestations, but the underlying problem is broader. Effective intervention requires changing the conditions that reproduce illegal extraction rather than merely punishing its most visible participants. The appropriate policy direction is consequently not enforcement *or* livelihood protection, nor mining regulation *or* environmental restoration, but an integrated framework in which law enforcement, mercury elimination, livelihood transition, ecological remediation, public health protection, participatory governance, and institutional accountability reinforce one another.

From this perspective, the protection of West Sumatran rivers should be treated as a test of Indonesia's broader commitment to environmental justice. The existence of comprehensive legal instruments creates an important normative foundation, but the legitimacy of environmental governance ultimately depends upon whether those instruments produce tangible improvements in ecological conditions and social equality. A river ceases to be merely a “mining victim” when institutions recognize its ecological value, communities have meaningful power to protect it, polluters and beneficiaries are held accountable, and economic alternatives allow people to prosper without destroying the environmental systems on which their lives depend. The transition from illegal extraction toward ecological justice therefore requires not simply stronger enforcement, but a redistribution of responsibility, power, and environmental protection across the entire mining governance system.

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