




Article

History, Current Situation and Challenges of Gold Mining in Ecuador's Litoral Region

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Abstract: Gold mining in Ecuador has been present in the country since Inca times; over the years interest in the mineral has increased, leading to the creation of legislation to control the mining sector in a safe manner. The Litoral region consists of seven provinces, six of which have registered gold concessions; the most affected provinces are El Oro and Esmeraldas. The objective of this study was to analyze the historical and current situation of artisanal and industrial gold mining in the Litoral region of Ecuador. Different methodologies were used for the elaboration of this study, including bibliographic review, grey literature, field interviews and a validation of expert judgment. The main results indicate that El Oro and Esmeraldas are essentially the most conflictive areas in the region, as they have sometimes had to establish precautionary measures due to the risks caused by illegal mining. In addition, in both areas there is a great socioeconomic impact ranging from lack of opportunities, forgetfulness, migration, emigration, and violation of rights, among others. With respect to environmental impacts, the study highlights the contamination of water sources (which leads to a lack of drinking water for people), and damage to aquatic and terrestrial ecosystems. Finally, the study concludes that the authorities should control the mining sector more by implementing more laws and carrying out inspections to put an end to illegal gold mining, in order to improve the situation in the areas.

Keywords: mercury; gold; socioeconomic impacts; political management; environmental management

1. Introduction

Gold mining and extraction dates back to ancient times, during the primitive era approximately 4000 years ago [1]. This economic activity has been transformed globally over the last two decades to such an extent that investment in developing countries has increased [2]. This event is of great significance, as millions of people depend on industrial, artisanal and small-scale gold mining for their survival [3]. In the context of world gold production, it is estimated that there will be a 5% reduction to a five-year low of 3359 t; an event related to the interruption of mining activities during the COVID-19 pandemic. On the other hand, the countries that have positioned themselves as the largest gold producers in recent years are China, Russia, Australia, United States, Canada, Peru, Ghana, South Africa, Mexico, and Brazil, among others [4].

In Ecuador, gold mining makes a great contribution to the country's economy, and in recent years laws and policies have been implemented to maintain a lower impact

on the environment. In Ecuador there are four types of mining according to the Mining Law: artisanal mining, small-scale mining, medium-scale mining and large-scale mining. This categorization has made it possible to maintain better control over mining, as these activities increase over the years [5]. Likewise, there has been an increase in illegality and informality in the gold mining sector, which is considered an obstacle to the development of an accurate record of all the gold produced and exported in the territory [6]. However, the Agency for Regulation and Control of Energy and Non-Renewable Natural Resources (ARCERNNR, for its acronym in Spanish) keeps a record of the economic aspects in the context of the mining activity of companies that exploit the mineral [7].

Mining activities can have a transformative effect on socio-economic development in the areas where it is carried out. It can produce compliance with high social, environmental and safety standards by offering employment opportunities. However, it can also give rise to false hopes of wealth and cause armed conflict [8]. In addition, it may include social conflicts such as lack of gender inclusion, labor exploitation and discrimination due to migratory status, lack of organization, child exploitation, alcoholism, citizen insecurity, and violence associated with illicit activity groups, among other things [9]. In recent years, measures have been proposed to promote mining investment, as it is believed that it can support the dollarization policy and move towards promoting a larger and more responsible mining sector [10].

Gold mining can cause serious environmental impacts. This is mainly related to illegal mining, since no technified methods are used to extract the mineral [5]. As a result, chemical pollution is produced on the banks of the water bodies that flow through the mining areas by processes that release substances such as mercury, cyanide, nitric acid, zinc, lead, arsenic, cadmium and manganese [11–14]. They can also affect aquatic diversity, terrestrial ecosystems and even people [15–18].

Five strategic mining projects and six second-generation projects are currently underway in Ecuadorian territory [19]. However, it is essential to bear in mind that mining exploitation always has repercussions in the socioeconomic and environmental spheres, generating serious impacts. In this sense, few studies have focused on analyzing these areas from a historical and current perspective with regard to gold mining in the coastal region of Ecuador. This has prevented a better understanding of the real situation of the sector, generating the urgent need to offer a real and updated vision. Based on the above, this study was based on the hypothesis that Ecuador does not currently have studies that provide decision-makers, local government administrators and scientists with updated information related to gold mining in the coastal region, which has prevented adequate socialization, technical and scientific assistance on the processes of formalization, regulation and environmental management of these activities.

Based on this hypothesis, the purpose of this research was to analyze the historical and current situation and the challenges of artisanal and industrial gold mining in the coastal region of Ecuador. The study focused mainly on the political sphere (laws applied), socioeconomic aspects (referring to population displacement, loss of livelihoods, changes in population dynamics, cost of living, water scarcity and health impacts) and finally environmental impacts (biotic and abiotic environments). For the development of this research, different methodologies were used: with respect to the historical context and the current situation, bibliographic and grey literature review techniques were used. In addition, field interviews were conducted for the current situation and, finally, expert judgment was used to establish the challenges of gold mining in the coastal zone.

2. Materials and Methods

2.1. Study Area

The Republic of Ecuador has a geographical area of 283,561 km² and is located on the equator in South America [5]. Its strategic location provides it with a privileged climate that benefits the development of economic activities in general, including mining [20]. Ecuador

is divided into four regions: Insular, Litoral, Andean and Amazonian [21]. However, the present investigation focuses on the Litoral region of the country (Figure 1).

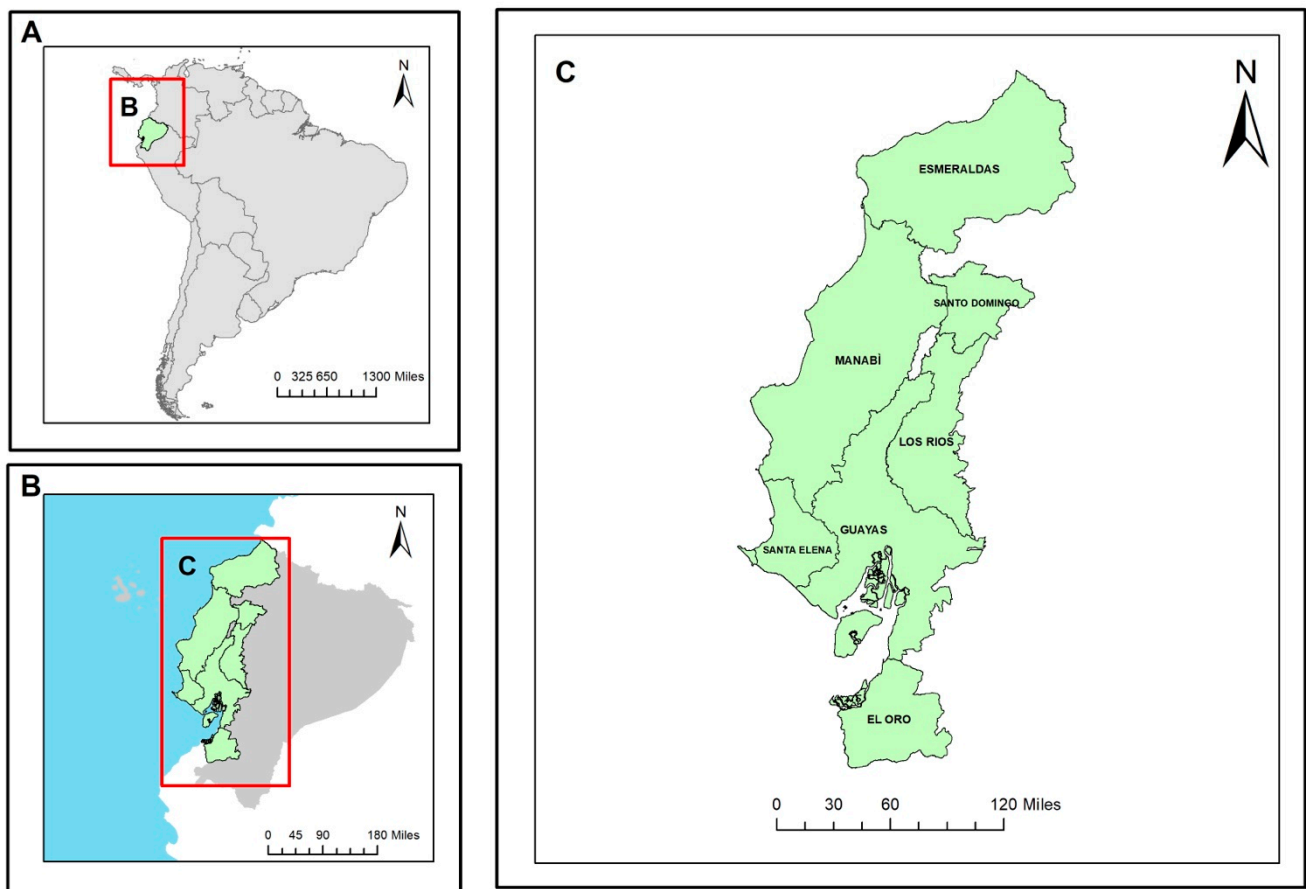


Figure 1. Study area. (A) Geographic location of Ecuador; (B) Litoral region of Ecuador; (C) provinces belonging to the Litoral region.

The Litoral or Coastal region is located between the coastal profile and the Andes mountain range [22]. The study area corresponds to a total of 70,647 km², covering the provinces of Guayas, Santa Elena, Manabí, El Oro, Los Ríos, Santo Domingo de los Tsáchilas and Esmeraldas (Figure 1) [23]. From a geomorphological point of view, the coastal region is characterized by a variety of reliefs, plains and large types of coasts (high cliffs with small bays; medium and low cliffs with small cliffs and large beaches; low, adeltaic type with an anastomosing network) [24]. On the other hand, it also has a privileged diversity in soil structure, which can vary depending on the province. The soils that can be observed are: vertisols, alfisols, entisols, aridisols, molisols, andisols, inceptisols and inceptisols [25].

There are currently a large number of gold mines spread along the coastal region, both legal and illegal. However, Table 1 only shows the gold mining concessions that are registered, according to the Mining Cadastre Web Geoportal of the Mining Regulation and Control Agency (ARCOM).

Table 1. Gold mining concessions in the Litoral region.

N°	Province	Canton	Concession Regime					Total Concessions by Canton	
			Artisanal Mining	Small Mining	Medium Mining	Large Mining	General Regime		
1	Esmeraldas	Esmeraldas	—	—	—	1	—	1	
		Atacames	1	—	—	—	—	1	
		Eloy Alfaro	2	1	—	—	—	3	
		Muisne	—	—	—	—	1	1	
		Quinindé	—	—	4	2	—	6	
		San Lorenzo	1	—	—	3	—	4	
Total concessions according to regime in Esmeraldas			4	1	4	6	1	—	
2	Santo Domingo de los Tsáchilas	Santo Domingo	4	—	—	—	—	—	4
		Total concessions according to regime in Santo Domingo			4	—	—	—	—
3	Manabí	Jama	1	—	—	—	—	—	1
		Pedernales	1	—	—	—	—	—	1
		Total concessions according to regime in Manabí			2	—	—	—	—
4	Los Ríos	Babahoyo	—	—	—	—	2	—	2
		Montalvo	—	—	—	—	1	—	1
		Urdaneta	—	—	—	2	—	—	2
		Total concessions according to regime in Los Ríos			—	—	—	2	3
5	Guayas	Guayaquil	15	—	—	—	—	—	15
		Balzar	—	1	—	—	—	—	1
		General Antonio Elizalde	—	—	—	—	2	—	2
		Naranjal	—	3	—	—	—	—	3
		Balao	3	—	—	—	—	—	3
		Total concessions according to regime in Guayas			18	4	—	—	2
6	Santa Elena	—	—	—	—	—	—	—	—
		Total concessions according to regime in Santa Elena			—	—	—	—	—
7	El Oro	Pasaje	29	3	—	—	3	—	35
		Chilla	3	—	—	—	3	—	6
		El Guabo	4	7	—	—	—	—	11
		Santa Rosa	62	16	—	—	2	—	80
		Atahualpa	36	2	—	—	4	—	42
		Zaruma	6	10	—	—	5	—	21
		Marcabeli	3	—	—	—	—	—	3
		Portovelo	8	2	—	—	2	—	12
		Piñas	—	2	—	—	1	—	3
Total concessions according to regime in El Oro			151	42	—	—	20	—	
Total mining concessions in the Litoral region								264	

2.2. Methods

For a better understanding of this study, the methodology was divided into three sections. The first was based on the analysis and interpretation of the historical situation of artisanal and industrial gold mining in the Litoral region of Ecuador. The second section consisted of analyzing and describing the current situation of artisanal and industrial gold

mining. Finally, the political, socioeconomic and environmental challenges of gold mining in the Ecuadorian Litoral territory were established.

The development of the first and second sections was carried out using two methods. On the one hand, a systematic literature review focused on the analysis of different documents published in high impact scientific databases such as Scopus and Web of Science. In the search process, filters were applied to establish the years of the publications (pre-Inca era–2018 for history and 2019–2021 for the current situation) and certain search parameters, also known as keywords, were also established (Table 2). Once the search results were obtained with their respective filters, the titles, related terms and abstracts of each publication were analyzed in order to carry out a selection process that would allow the extraction of the information necessary for the research. Twelve documents were obtained on the history of gold mining with respect to the political, socioeconomic and environmental situation, and five documents on the current situation in the area; see Table 2.

Table 2. Methodological process for the bibliographic review.

Subject	Keywords	Period	Scopus/Web of Science
History of gold mining in the Litoral Region	"Gold" and "mining" and "Ecuador".	Inca period–2018	12 [26–37]
Current situation of gold mining in the Litoral Region		2019–2021	5 [14,38–41]

The second method consisted of a review and analysis of grey literature (Table 3). Grey literature refers to a set of documents of various kinds, which have not undergone review or editing processes and which are not usually disseminated through publication but rather through limited (non-conventional) channels.

Table 3. Grey literature methodological process.

Grey Literature	Registration
Foreign investment and mining policy in Ecuador	June 2017
Ecuador's current mining legislation, including the Mining Code	1986
Mining Code Reform Law	1982
National Mining Sector Development Plan	July 2016
Organic Reformatory Law to the Mining Law, the Reformatory Law for Tax Equity in Ecuador and the Organic Law of the Internal Tax Regime.	Official Gazette 037, 16-VII-2013
Integrated environmental management in the Puyango river basin	2013

In relation to the second section, field visits were made to the different provinces, cantons and parishes belonging to the coastal region, where gold mining concessions were present. During the visits to the gold mines, interviews were conducted using semi-structured questions, that is, open-ended questions directed to local miners, environmental directors of the Ministry of Environment, Water and Ecological Transition of Ecuador (MAATE, for its acronym in Spanish), environmental directors of the Autonomous Decentralized Provincial Governments (GADP, for its acronym in Spanish), Autonomous Decentralized Municipal Governments (GADM, for its acronym in Spanish), presidents of the parish councils (PJP), and inhabitants where the mining concessions are located

(Table 4). The issues addressed in the interviews were: displacement of people, loss of livelihoods, changes in population dynamics, cost of living, water scarcity and health impacts.

Table 4. Questions established to analyze the current situation of gold mining.

Participant	Questions
Local miner (26 interviewees, mining concession owner)	<p>What type of mining is developed? Has a permit to carry out mining activities? What type of technique is used for gold extraction, amalgamation or cyanidation? Wastewater in the extraction process is subjected to some treatment process, prior to its environmental discharge? Do you as a miner use any procedures to mitigate the impacts of gold mining? State three elements/components of the environment that are most affected by pollution?</p>
Local authority (26 interviewees, political leaders in the mining area)	<p>In its jurisdiction, ordinances have been created to control and monitor mining activities? Do you know if there is illegal gold mining in your canton and/or parishes? Do you know if the inhabitants of your canton and/or parishes have had health problems associated with gold mining?</p>
MAAE (6 interviewees, government representatives per province)	<p>Do you know if gold mining is developed in your province? Do you know if illegal gold mining is taking place in your province? There have been reports of contamination from gold mining? How has the Environmental Authority developed audits of gold mining concessions (rights)? How has the Environmental Authority developed water monitoring in the water bodies in the mining influence zone? During the visits and/or audits, has the accumulation of mining waste been evidenced? Do you consider that leaching occurs in the residual accumulations?</p>
Mining town residents (26 interviewees, community representatives per canton)	<p>Do you consider that gold mining has improved the quality of life in the area? Your monthly income covers all monthly expenses? Has gold mining caused population displacement for any reason? Has gold mining resulted in the loss of livelihoods? Has the cost of living changed since the advent of gold mining? Do you consider that with gold mining activity there is a shortage of water for daily activities? Have any family members or acquaintances experienced health problems or death due to gold mining contamination?</p>

Finally, in the third section, we proceeded to establish the political, socioeconomic and environmental challenges present in gold mining in the Litoral region. For this, an

expert judgment validation method was used, which consists of a set of opinions provided by professional experts on a topic, in order to verify the reliability of a research. Likewise, a brainstorming session and a round table were carried out with the participation of researchers who gave different perspectives to integrate the challenges of gold mining in the coastal region.

3. Results

The results that respond to the objectives of this study are presented below. The first section describes the history of gold mining in the coastal region of Ecuador in relation to mining policy, the socioeconomic sector and the environmental aspect, based on an exhaustive bibliographic review. The second section analyzes the current situation of gold mining in the coastal region with respect to the displacement of people, loss of livelihoods, changes in population dynamics, cost of living, water scarcity and health impacts, based on interviews conducted during field visits to the mining areas. Finally, the challenges present in gold mining in the coastal region in terms of mining policy, the socioeconomic sector and the environmental aspect are presented.

3.1. History

Pre-Hispanic cultures were the ones that developed the most mining activities in the Republic of Ecuador. For example, the people belonging to the Tolita Culture worked with gold and platinum between 500 B.C. and 500 A.D.; while the Cañaris worked with gold and silver [26–31]. There is no certainty about the tools used in pre-Columbian times to exploit gold in shallow mines and in the arid material of the Pindo-Puyango rivers. However, it is known that tools such as the wedge, the combo, the pick, the barreta, the shovel and the wheelbarrow were used in colonial times, causing a low yield in the exploitation of gold quartz [32].

Later, in the mid-sixteenth century, the discovery of gold particles motivated prospectors to go through rivers and mountains until they finally found the “golden nuggets”, which belonged to the areas of Zaruma and Portovelo. The South American Development Company (SADCO) was in charge of exploiting the Portovelo mining area at the end of the 19th century until the middle of the 20th century. Once SADCO’s activities concluded, the Industrial Mining Associated Company (CIMA) was established and worked until the 1970s, giving way to exploitation by small miners and artisans [26].

3.1.1. Mining Policy

At the beginning, mining did not have regulations or legal bases to control the activities carried out, which caused repudiation and misinformation among the population due to the lack of mining policies [33–41]. Over the years, the mining industry expanded, and was contemporary with the processes of formation of the Ecuadorian State. Around the year 1830, a great interest was generated in the consecration of property rights and the attraction of foreign investment, which led to the development of the Mining Promotion Law. The purpose of this law was to reactivate the productive sector of the country with the help of the alternating mining activity in the southern zone of Ecuador [27]. In 1886, the Mining Code of Ecuador was enacted; this law was intended to awaken the interest of foreign investors in the discovery, prospecting and exploitation of mines, in addition to providing legal certainty for mining concessionaires. This legislation turned around the forms and conditions of appropriation and exploitation of the deposits; it also influenced the transformation of the norms that regulated the subsoil domain [27]. It is important to note that this legislation recognized precious stones (such as gold, silver, etc.) as the object of the same and, upon a reform in 1982 (Reformatory Law of the Mining Code), petroleum was added to the list. This reform also allowed the owners of the properties to dispose of the minerals as owners of the property [42,43].

In 1937, the Mining Law was enacted; this law was in charge of determining that the minerals found in the subsoil belonged to the State’s domain. One year later, the

Codification of the Mining Law was issued [41]. By 1991, a new Mining Law, also known as Law 126, was presented. This law incorporated the principles of State ownership of both mines and deposits and categorically involved the rights of miners. It also incorporated the perception that the Ecuadorian State should legalize mining activities that had complied with the requirements set forth in the law [34]. In 2001, some reforms were incorporated into the Mining Law, which were responsible for qualifying mining management as a national interest, a priority and fundamental for development, including regulations on environmental protection [41]. By 2008, the Constitution of the Republic established a range of environmental principles providing rights to native and indigenous peoples as new values of the State [10]. A year later, in January 2009, the Mining Law and its Regulations were approved in order to generate an effective model of economic progress focused on responsible and organized mining. This law was in charge of administering, regulating, controlling and managing the strategic mining sector, in accordance with the principles of sustainability, precaution, prevention and efficiency [9]. Finally, in 2013, an amendment to the Mining Law was made, called the Organic Reformatory Law to the Mining Law, the Reformatory Law for Equity in Ecuador and the Organic Law of the Internal Tax Regime [44].

It is essential to highlight that there are unique legislative measures that are applied in some areas of the country depending on the mining situation in order to avoid catastrophes. A clear example of this, applied in the province of Esmeraldas on 24 March 2011, is an injunction issued by a judge prohibiting mining exploitation, whether legal or illegal, in the San Lorenzo and Eloy Alfaro cantons. This injunction was ratified in 2018; however, in consecutive years the established measure was ignored. In the past, ancestral mining was carried out in the province (without consequences for the environment due to the use of nets and pans), but in recent years it has been practiced in the form of small- and medium-scale mining (with machinery and mercury in the open air), which is harmful to the ecosystem, which is why the precautionary measure was established—in order to minimize the contamination of rivers and the inhabitants of communities that consume the affected water [45,46]. A similar situation occurred in the city of Zaruma, where the Government of the Republic declared a state of emergency for sixty days on 14 September 2017 due to the fact that excavations were being carried out in soil declared to be the cultural heritage of the country. According to investigations carried out, there were areas exploited for gold mining that represented a risk for the inhabitants, which is why the State took the decision to intervene by taking preventive measures [14].

3.1.2. Socioeconomic Sector

At the end of the 1990s, Ecuador was going through a financial crisis. To remedy the situation, the government (during the period 2000–2006) developed processes to offer the country's mining resources to foreign investors interested in carrying out this activity. Thus, with the intention of achieving the country's development, and together with pro-extractivist reforms, the Ecuadorian territory moved towards an authoritarian political system known as "political domination". As a consequence, a social resentment of the people towards the political institutions originated, which has been increasing over the years due to several factors [30].

On several occasions, there have been social, political, economic and environmental confrontations in communities due to mining projects. In some cases, the inhabitants of the mining areas say that they are not convinced by the land negotiation agreements and that they are often pressured to sell. In addition, there have been reports of destruction of the inhabitants' buildings by the companies in charge of the megaprojects [31]. Likewise, there have been evictions of families without any relocation agreement to make way for the mining companies [47]. In addition, indigenous movements have been unleashed against mining companies, causing clashes with the military that have resulted in injuries and even the death of leaders [35,36].

Esmeraldas is one of the most conflictive areas, and is also considered one of the most excluded and poorest regions in Ecuador, due to the lack of opportunities in the area for 22 years. At that time, there was a shortage of labor, so gold mining emerged as a job option for people because timber and palm oil activities did not require more labor. Social conflicts caused by gold mining include lack of access to water, distrust between families, and broken social relations. Armed conflicts have also occurred in the province over the last 50 years, mainly due to the illegal appropriation of gold material, resulting in the death of people due to confrontations [37]. Economic consequences include chronic poverty, in addition to illicit activities such as tax evasion, smuggling of mining inputs, capital flight and money laundering, import of unregistered machinery, etc. [45].

3.1.3. Environmental Impacts

In general, the most significant impact caused by gold mining is the contamination of soil and water resources. This can occur due to improper dumping or infiltration of toxic substances used in mining [28]. Sometimes, no remediation measures are applied after the mineral extraction process, leaving the pools of contaminated water exposed to the open air (Figure 2a). As a result, there is evidence of enormous extensions of brick-colored soil, fish and macroinvertebrates affected by the accumulation of heavy metals such as mercury, cyanide and arsenic [46,47]. These contaminants can also cause respiratory, skin and carcinogenic diseases that affect people's wellbeing. The debris generated by mining waste (Figure 2b) is also a problem, because it can cause the death of aquatic species and even humans [29]. Another impact related to gold mining is the change in the geographic landscape, as it implies changes in land use such as degradation and erosion, modifications to the relief, and large-scale deforestation to make way for the machinery used in mining activities [28].



Figure 2. Gold mining impacts. (a) Pools of contaminated water exposed in the open pit; (b) debris generated by the extraction of material for gold.

The Puyango-Tumbes watershed serves as a border between northern Peru and the provinces of Loja and El Oro in southeastern Ecuador, covering a total area of 5494.57 km² [48]. According to studies carried out since the beginning of the 20th century in the upper part of the Puyango River, high concentrations of contaminants from mining have been found in Portovelo-Zaruma, which has had an impact on the Peruvian territory. In 2001, a study was carried out in the area; the results showed that gold mining activities were affecting the ecosystem because of the tailings in the rivers, which subsequently released cyanide, mercury and other metals that exceeded the established quality criteria. The effects consisted of: reduced aquatic diversity, elevated levels of metals in larvae, large amounts of metals bound to suspended sediments at ambient pH conditions, and the levels of metals in carnivorous fish were low, with the exception of mercury [33]. In

2010, another was carried out, which showed the presence of about 1.5 tons of mercury being released per year in the city, of which 70% evaporated and 30% was released with tailings [49]. Later, in 2017, another investigation was conducted to analyze heavy metal contamination; the results indicated that the concentrations of Pb and As exceeded the permissible limits for metals in soils. In addition, biological samples (blood, urine and hair) were collected and, the results determined that inhabitants residing near the Puyango River contained small amounts of Hg and Pb inside their organism [32]. As a consequence of all the contamination that the river receives, no aquatic life forms develop; in addition, water consumption, and the use of water for agriculture and livestock were disabled. Due to all of these effects, in 2018, the Federation of Farmers of Tumbes filed a petition for a lawsuit against the government of Ecuador for the alleged contamination of the Tumbes River.

In 2010, an analysis was conducted in water bodies in Esmeraldas, in the Mario Unión and Sabaleta estuaries, and in the Santiago and Sabaleta rivers. Abnormalities were identified in the fish, such as deformities, as well as the presence of heavy metals inside the fish due to illegal gold mining. Later, in 2013, the Catholic University of Ecuador conducted a study that showed that the Maria estuary contained exaggerated amounts of aluminum, which exceeded the limits established in the regulations by 580 times, as well as exceeding the standard of copper by 2.4 times, the standard of iron by 33 times, and the standard of manganese by 1.3 times. It was determined that all these substances were the result of illegal mining carried out in these zones [45].

3.2. Current Situation

There is currently a total of 264 legally registered gold mines in the Litoral region, including artisanal mining, small-scale mining, medium-scale mining, large-scale mining and general regime (Table 1). The province with the highest number of concessions is El Oro, with a total of 213 gold mines, followed by Guayas, with 24 mines, Esmeraldas, with 16 mines, Los Ríos, with 5 mines, Santo Domingo de los Tsáchilas, with 4 mines, and Manabí, with 2 mines. Unlike the other provinces mentioned, Santa Elena does not have any registered gold mines, so there are no problems related to gold mining in the area.

3.2.1. Mining Policy

In recent months, the Ministry of Energy and the National Police have registered an alarming increase in illegal mining throughout Ecuadorian territory due to the lack of regularization of the extractive activity of gold mining during the COVID-19 pandemic. Among the provinces with clear evidence of illegal mining is El Oro, specifically in the San Lorenzo canton; this indicates that measures established in the canton in 2011, which prohibit any type of extraction in the area, are being disregarded. As a consequence of the activities carried out in the sector, on 18 November 2020 there was a landslide in an illegal mine that resulted in the death of several people [46].

With respect to political issues, the Organization of American States (OAS) in 2020 admitted the petition filed by the Federation of Farmers of Tumbes (Peru) against the government of the Republic of Ecuador for the alleged contamination of the Tumbes River from mining activity in the Portovelo-Zaruma district. Likewise, farmers and environmentalists from the neighboring country carried out a peaceful protest on 25 January 2021 in order to demand a pronouncement from the Inter-American Court of Human Rights, since the presence of heavy metals in the river continues despite the lawsuit filed, and there is a risk to the flora, fauna and health of approximately 200,000 people [50].

3.2.2. Socio-Economic Sector

In Ecuador, cantons such as Zaruma, Portovelo, and Camilo Ponce Enríquez extract 86% of the gold exported in the country through small-scale mining; however, only 0.38% of the territory's population resides in these areas. Despite the large exports generated by the cantons, they have average poverty rates for unsatisfied basic needs, 62% in Zaruma and

58% in Portovelo, according to data from the 2010 Population and Housing Census [51]. On the other hand, 84.6% of the inhabitants of San Lorenzo canton live in poverty, a percentage that exceeds 60% nationally and 51% in the province of Esmeraldas; only 23% of households have basic services in the canton [38,52].

In the interviews conducted, some miners stated that, due to the Mining Agreement decreed in 2009, many people were displaced to make way for large mining concessions. For this reason, many opted to engage in illegal mining (inside and outside the canton), and with all this came violence and poverty in the exclusion zones. Faced with the various problems and conflicts caused by illegal activity, they preferred to sell their land and move away from the concentration zones in search of a better way of life, leaving behind the place that had been their home for a long time. On the other hand, interviewees also stated that there are people constantly joining the mining areas from other regions of Ecuador and Peru who are willing to work for lower wages due to the lack of job opportunities and offers.

In the country, informal miners are known as “sableros”. They are generally trapped between poverty and violence, which is why they risk their lives performing dangerous activities to obtain gold and thus earn an income to sustain themselves. In Zaruma and Portovelo, the sableros often enter subway mines that do not have oxygen, so they use long hoses to breathe while searching for gold veins. Some say that they only know how to “sabre” because they have worked in the mines since they were teenagers and that they have often broken into legal and illegal concessions to steal gold material. They also comment that sometimes they apply for jobs in formal companies, and once inside, they ingest small pieces of gold to later process them in their bodies and keep the material to make a profit by selling it.

Regarding the cost of living, some residents living near the mining concessions said that they have benefited from the job opportunities in the gold mines, but that salaries are minimal. While residents who own commercial establishments (stores) stated that mining activities do not influence their economy, because sales have not increased in their establishments and, in addition, government agencies are very strict in the regulation of prices implemented in sales.

One of the main reasons why people resort to informal and illegal gold mining activities is related to poverty and lack of job opportunities. According to a report by the National Institute of Statistics and Census of Ecuador (INEC), the province of Esmeraldas is one of the poorest and most excluded provinces in the country. Thus, three of its cantons have the highest poverty rate, Rio Verde (63%), Eloy Alfaro (64%) and Muisne (65%) of the coastal region. Meanwhile, in the province of Manabí, two cantons, Pichincha and Olmedo have a 63 and 61 percent poverty rate. It is important to note that these two provinces have the highest poverty rates in terms of multidimensional aspects, unsatisfied basic needs and access to basic services. These are incentives for the population of these cantons to migrate and go to develop gold mining activities in a precarious and unsafe way in areas with a high gold content, such as Alto Tambo in the province of Esmeraldas, and in the neighboring province of Imbabura in the area of Buenos Aires. Thus, after the province of El Oro in terms of mining history, the province of Esmeraldas in the last 10 years has shown an exponential increase in gold mining activities in the coastal region.

3.2.3. Environmental Impacts

In Ecuador, the use of mercury for gold amalgamation is prohibited; however, its use is still very frequent in the country, such that the substance is spread by rivers and ravines [17]. In this regard, activist Nathalia Bonilla stated in 2020 that due to the increase in illegal mining activities during the pandemic, the water sources of San Lorenzo and Eloy Alfaro have become contaminated. She also added that 80% of the rivers are polluted, but people do not have good water, so they have to continue using water resources with toxic substances [53]. On the other hand, 19.45% of the water in the province of El Oro is contaminated due to the activities carried out in Zaruma and Portovelo [14]. All these data

are of great concern, since they show that most of the populations settled on the banks of the rivers in the gold ore mining areas do not have adequate drinking water systems, which represents a serious risk to the health of the people.

Exposure of people to water contaminated with toxic substances such as mercury can cause illnesses, as reported by gold mining workers in the province of Esmeraldas. Some of the diseases they reported contracting included: skin diseases, intestinal disorders, infections, vaginal problems (in the case of women), stomach diseases, and respiratory problems, among others. In addition, they mentioned knowing people who acquired long-term diseases such as Alzheimer's and cancer.

In 2020, a study was conducted in the Portovelo-Zaruma area, specifically in the Puyango-Tumbes river. The results showed that there was cyanide contamination at concentrations 9088 times higher than the established CCME standard of 5 g/L, and 1136 times higher than the 24-h LC 50 concentration of 40 g/L free of CN⁻ for some species. The levels of affectation arose due to mining malpractice and environmental management in 87 gold processing centers, which used mercury tailings to obtain the ore in the river [39]. Another effect that could be seen in the city of Zaruma was large deformations due to land subsidence generated mainly by illegal subway gold mines [40]. The impact of these mining activities was so great that on 2 July 2021, a sinkhole was created (Figure 3a), which reached a diameter of 20 m and a depth of 30 m, putting at risk 50 homes located near the affected area (Figure 3b).

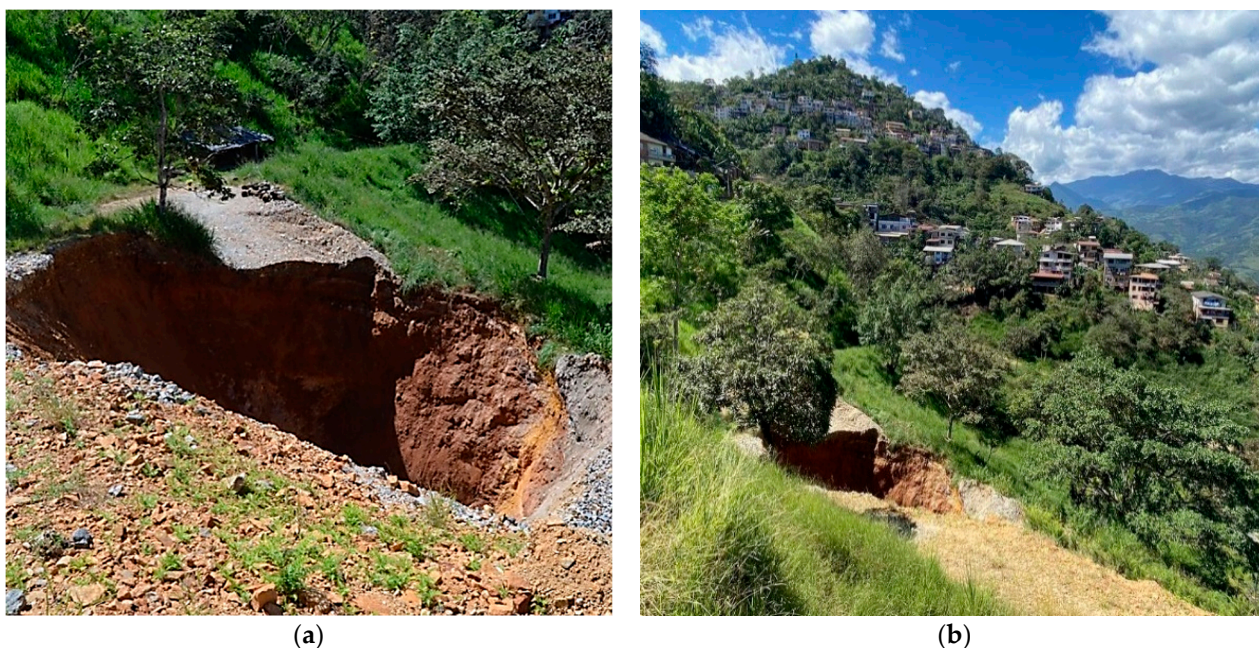


Figure 3. Sinkhole in the province of El Oro, city of Zaruma. (a) Sinkhole formation; (b) houses at risk due to sinkhole formation.

In the Los Ajos sector of the San Lorenzo canton, illegal mining activities were registered in January 2021, despite the fact that the measures imposed prohibit it. As a result, the Ecuadorian Chocó (one of the areas with the highest endemism of species in the country) is being affected by indiscriminate deforestation to make way for roads for illegal mining machinery [54–56]. Inhabitants of the area state that not even the COVID-19 situation has stopped the “sableros”, because there are 52 active mining camps in the area that are causing great damage to the area, while also creating insecurity, so they demand that the authorities control the permits granted for these activities. The Alto Tambo sector was also affected, because after inspections carried out by the authorities in May, illegal miners invaded the area and destroyed a large part of the zone, putting the Awá Nationality that resides in the surrounding area at high risk (Figure 4a,b).



Figure 4. Invasion by illegal miners. (a) Machinery used for gold extraction; (b) deforestation of the affected area.

3.3. Challenges

The findings suggest that Ecuador faces many challenges, both in the political sphere and in socioeconomic and environmental respects. On the one hand, it is evident that the country lacks policies that direct the mining sector towards more responsible and environmentally friendly activities. There is also a need for greater control of illegal mining due to its exponential increase as a result of the COVID-19 pandemic and the lack of job offers, causing various forms of damage to the ecosystem. The provinces belonging to the Litoral region with the most conflict are Esmeraldas and El Oro, which, according to a systematization developed by the Ombudsman's Office and the Colectivo de Geografía Crítica, occupy the first place with respect to the violation of human rights and nature at the national level [38]. Considering the problems that have arisen in the two provinces, it should be considered a priority to establish laws in order to improve the situation in the two zones and avoid conflicts with neighboring countries due to the contamination generated by the zones.

Since the exploration and extraction of gold ore in the country began, there have been socioeconomic conflicts that have harmed workers and residents in the gold mining areas. The Ecuadorian State should give priority to the people involved in gold mining activities in the country, implementing controls on the remuneration of mining workers, because, as has been stated, they do not receive a fair salary despite the risk they run when carrying out extraction activities. Strict plans should also be implemented to prevent mining concessions from using mercury to extract gold, as the contamination of water sources means that the local population has no water for drinking or other activities. It would also be advisable to offer jobs and invest in education, given the lack of opportunities in conflict zones such as Esmeraldas and El Oro.

Mining sector regulators should socialize with all the social actors involved in the mining processes about the lack of knowledge of the mining formalization and regulation processes. This will help to ensure that these processes are carried out in accordance with the law and comply with environmental regularization processes. In addition, the Ecuadorian government should promote specialized technical assistance programs on issues related to environmental management, mining safety and professional training for ASM; to achieve this, academia should provide support in the education and training of miners, making them aware of the risk of using prohibited substances such as Hg, as well as providing instruction on the implementation of more environmentally friendly extraction strategies. On the other hand, it is essential to establish incentives focused on environmental protection and entrepreneurship generation. These alternatives could be an option that would allow the adoption of better environmental practices in the gold extraction process and improve the local economy of the miners.

Perhaps the most serious challenge faced in gold mining concentration zones is the lack of awareness and knowledge regarding exposure to heavy metals such as mercury, as

people are often unaware of the effects they can cause to the environment. This process, together with the lack of control and monitoring in mining areas, as well as the lack of management of mining waste generated in the extraction areas and the lack of legal regulations for the management of mercury, have a significant influence on the environmental aspect. An effective measure for minimizing environmental impacts could be to carry out government supervision to ensure that gold mining concessions mitigate the damage caused by their extractions, thus ensuring that they remediate (or at least minimize) the damage caused to the ecosystem.

4. Discussion

In recent decades, Ecuador has made great efforts to implement legislation to regulate the activities developed by the mining sector. However, it is evident that in recent years, there has been a loss of interest in the political aspect of mining, since the same law has been in force in the country since 2009, without taking into account the effects that have been generated over the years. It is also clear that there is a lack of rigorous control in the application of the laws; this was evidenced by informal talks with the gold mine workers (outside the interview questions), since on several occasions they mentioned that the visits by the authorities were scarce, which indicates the lack of monitoring to verify whether the mines comply or not with the established regulations and, most importantly, to verify that they do not use mercury to extract the mineral. According to [54], Ecuadorian legislation has its own dynamics in situ, and it is naïve to believe that the laws of the country can control the sector [54]. Other authors, such as [55], mention that legislation often involves two factors that generate negotiations in the legal framework of the mining sector: national laws and socio-normative agreements, which in this case are those that are applied in the country, although not in a recognized manner [56].

At this point, it is important to note that legislation should require the implementation of mitigation measures. However, this could mean a loss, since there is a great controversy in controlling and regulating gold mining practices, because if mitigation measures are applied, the potential to placate marginalized groups will be reduced, while if restoration measures are not used, environmental contamination impacts will also be present, as mentioned in [57]. To maintain greater control over gold mining in Ecuador, mining activities should be formalized. However, ref. [58] state that attempts to formalize the mining sector are generally unsuccessful, and as a consequence, pollution levels increase. According to the authors, in order to carry out an effective formalization process, education must first be implemented to prevent the continuation of incorrect extraction methods, and thus reduce environmental damage [58].

The perspective has not changed much in the historical and current situation regarding environmental impacts in gold mining areas in the coastal region of Ecuador, since the same aspects are present: contamination of rivers, water scarcity for people, reduction or lack of aquatic diversity and people with the presence of mercury in their bodies. The most worrisome aspect is that, according to the analyses carried out, all of these impacts have been occurring in the Puyango River since 2000, which is indicative of the lack of control in the Portovelo-Zaruma areas and the lack of awareness on the part of the illegal miners. However, ref. [15] mentions that studies conducted on ASM show that mining has not caused water contamination. Furthermore, he adds that in cities such as Portovelo, Zaruma, Nabija, Ponce Enriquez and Santa Rosa, metallic substances and metalloids have been detected at well below the limits established in the regulations [15]. Although the studies carried out show low levels of mercury, it must be taken into account that in general, the laboratories responsible for the analyses only have the capacity to measure 0.005 ppm, while the maximum permissible parameters in the country are established at 0.0002 ppm. There is a great difference between these two levels, so the probability of detecting high levels of mercury is very low, not because it is not present, but because of the lack of specialized equipment able to provide concrete results.

Although Ecuador has major shortcomings in the mining sector due to poor extraction practices or illegality, it is not the only country of which this is the case. In other countries around the world, these situations are also present. Such is the case in Colombia, where there have also been cases of mercury contamination of rivers due to the amalgamation processes used to extract gold, the introduction of solid loads, metals and waste used in mining, and the use of mercury in the mining industry [58]. On the other hand, in Ghana, there are cases of soil contamination with averages of 0.024 mg kg^{-1} , which is a very low concentration, well below the established criteria for human health [59–62].

5. Conclusions

Ecuador has had the same law regulating the mining sector since 2009, which indicates that new legislation is needed to adapt to the current situation with COVID-19. There is a major conflict regarding the preventive norms applied to the San Lorenzo canton in the province of El Oro, since, despite the fact that gold mining (legal or illegal) is prohibited in the area, there are still cases of environmental impacts caused by the influence of mining activities. Therefore, the authorities should carry out more frequent inspections to detect illegal gold mines in order to dismantle them and reduce pollution, especially of water resources, especially in the provinces of El Oro and Esmeraldas, which have proven to be the areas with the most conflict in the Litoral region.

Due to the decrease in employment in the provinces of El Oro and Esmeraldas, illegal mining activities have emerged as an option for survival and daily sustenance. However, these activities cause major conflicts that lead to the insecurity of the people living in the extraction zones. In the first instance, there is the violation of people's rights due to their eviction from their homes in order to make way for the megaprojects; there are also reports of armed conflicts, labor exploitation associated with minimum wages, lack of access to water, and high risk of diseases related to direct contact with heavy metals.

The analysis of the environmental aspect suggests that mercury is present in some areas of the Litoral region, specifically in El Oro and Esmeraldas. These contamination problems are not a recent issue, as illegal mining has been evident in these areas for several years. As a consequence, water resources, aquatic and terrestrial ecosystems are affected due to gold mining activities which, although they are small-scale in most cases, the contamination is due to the malpractice of the activities at the time of processing the mineral through the tailings in which mercury is used.

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