

Analysis of mine closure practices and the regulatory mining framework in the Córdoba province – Colombia

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Abstract

Mining has been a traditional economic activity in the province of Córdoba, in the north of Colombia, representing in average 1.83% GDP of the region and producing over US\$4.920 million in annual royalties for the country. Nickel, coal, gold, limestone, clays and building materials are resourced, and there are great expectations to produce copper. It faces, however, critical environmental challenges, particularly in water management, due to inadequate regulatory frameworks and the rise of informal mining activities. This study analyzes environmental licenses issued in Córdoba over the past two years by the regional environmental bodies, focusing on coal and building materials extraction, to assess compliance with national and international standards. The findings reveal significant gaps in Colombia's regulatory framework, especially in water management, compared to global best practices outlined by organizations such as the International Council on Mining and Metals (ICMM) and the Asia-Pacific Economic Cooperation (APEC).

Key deficiencies include the lack of detailed strategies for water resource monitoring, prevention of acid mine drainage (AMD), and long-term water quality protection. Current closure plans often fail to incorporate site-specific water monitoring, such as tracking pH levels, potentially toxic metals concentrations, and total dissolved solids, which are crucial for early contamination detection. Additionally, the absence of robust financial assurances and climate change adaptation measures further exacerbate the risks of long-term environmental liabilities.

The study highlights the need for Colombia to align its regulatory framework with international standards, emphasizing integrated water management, stakeholder engagement, and post-closure monitoring. Addressing these gaps is essential for ensuring sustainable mining practices, mitigating environmental and social risks, and safeguarding water resources in mining regions like Córdoba. The findings underscore the importance of adopting global best practices to enhance environmental stewardship and achieve long-term ecological rehabilitation in Colombia's mining sector.

Keywords: Water management, Mine closure practices, legacy issues, community engagement, socioeconomic effects, Colombia

Introduction

The province of Córdoba, located in northern Colombia between the Andes Mountains and the Caribbean Sea, is a region where mining plays a significant economic role, contributing 1.83% to the regional GDP. Key

minerals extracted include coal, gold, nickel, limestone, and building materials, with emerging interest in copper production. As of 2017, there were 146 active mining contracts, predominantly for building materials (42%) and coal (15%), alongside gold (26%) and

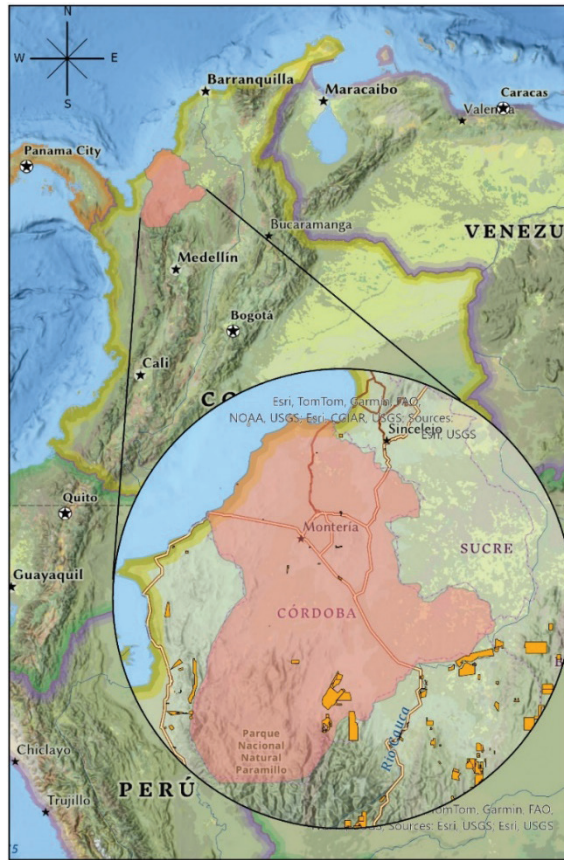


Figure 1 Geographic location of the Córdoba province - Colombia. Source: National Mining Agency (ANM), Colombia.

nickel (4%). However, the sector faces growing challenges, including environmental degradation, particularly in water resources, exacerbated by informal mining activities and outdated regulatory frameworks. Water management in mining has become a critical issue in Córdoba, with documented cases of uncontrolled discharge of contaminated wastewater from coal mines into local water bodies. This has led to negative effects on ecosystems and communities, as mine waters often mix with surface runoff, accumulating in ponds and posing significant environmental and health risks. The lack of robust regulatory mechanisms to address these issues, combined with the rise of illegal mining, has further complicated water resource management in the region.

Colombia's mining sector is governed by the Mining Code (2001) and the Political

Constitution (1991), with environmental oversight provided by the Ministry of Environment and Sustainable Development (MADS) through instruments such as Decree 1076 (2015) and guidelines for Environmental Impact Assessments (EIA). Despite recent efforts to modernize regulations, including the 2022 ANLA guide for mine closure, significant gaps remain, particularly in water management, climate change adaptation, and stakeholder engagement. These shortcomings contrast sharply with international standards, such as those from the International Council on Mining and Metals (ICMM) and the Asia-Pacific Economic Cooperation (APEC), which emphasize integrated water management, acid drainage prevention, and post-closure monitoring.

This study examines environmental licenses issued in Córdoba over the past two

years, focusing on coal and building materials extraction, to assess compliance with national and international standards. Key areas of analysis include water management, ecological rehabilitation, socioeconomic effects, and air quality, with a particular emphasis on mine closure practices. By identifying gaps and proposing alignment with global best practices, this research aims to contribute to the development of more sustainable and environmentally responsible mining practices in Colombia.

Methods

The study was conducted through an analysis of environmental licenses granted within the last two years in this province by environmental regional authorities. The licenses correspond to medium scale mining projects, as defined in the respective Colombian law: coal up to 850,000 t per year (open pit) or 650,000 t per year (underground) and building materials up to 350,000 m³ per year (MME 2016). The licenses were analyzed in terms of the current regulation framework in Colombia, including the recently issued guide for the formulation of the closure and abandonment plan that mining users must present in the EIA (ANLA 2022). Due to the evident weakness of the current regulation, closure activities were also compared with guidelines provided by international organizations such as APEC (Asia-Pacific Economic Cooperation) (APEC 2018) and ICMC (International Council on Mining and Metals) (ICMM 2019). This analysis aimed to identify areas of convergence and divergence between local environmental licenses and international mine closure standards in key aspects, including water management, socioeconomic monitoring, ecological rehabilitation, air quality, and terrain stability. The results, also applicable to other regions, highlight a list of aspects that are persistently absent in mine closure plans and could serve as a global reference framework to evaluate the effectiveness and sustainability of mine closure plans in the Córdoba province. This methodological approach facilitated a comprehensive and rigorous assessment, highlighting areas that could benefit from increased alignment with international best practices in mine closure.

The mining regulation framework in Colombia

Colombia's mining sector is regulated primarily by the Mining Code (2001), which governs mineral exploration and exploitation. The National Mining Agency (ANM), under the Ministry of Mines and Energy, oversees mineral resources and grants permits through the approval of a Work and Infrastructure Program (PTO) and the signing of Mining Concession Contracts. Environmental regulation falls under the Ministry of Environment and Sustainable Development (MADS), guided by Decree 1076 (2015), Mining and Environmental Guides (2005), and Terms of Reference for EIA (ANLA, 2016). Both the National Authority of Environmental Licenses (ANLA) and Regional Autonomous Corporations (CARs) issue environmental licenses, but CARs deal with smaller-scale projects.

Mining projects require both a Mining Concession Contract and an Environmental License. The Closure and Abandonment Plan is integrated into the EIA but is not independently requested. While consultation with Indigenous and local communities is mandatory for projects with significant environmental or social repercussions, general community engagement is limited and cannot block project development. Financial assurances are required but are insufficient, with miners obliged to provide environmental policies equivalent to 5% of exploration and construction investments and 10% of production value. These provisions do not adequately cover closure and post-closure costs, highlighting a critical gap in ensuring long-term environmental and financial accountability.

Results

Analysis of mine closure practices

Mine closure practices in Córdoba, Colombia, are guided by comprehensive Final Closure Plans that address physical stabilization, ecological rehabilitation, waste disposal, and facility dismantling, in line with national regulations. However, environmental licenses often lack specificity in critical areas, particularly water management, air quality, socioeconomic monitoring, and



stakeholder engagement. The application of the APEC (2018) mine closure checklist reveals significant gaps in current practices. These include the absence of mechanisms to prevent or mitigate acid and mine drainage, insufficient monitoring of water resources during and after closure, and inadequate financial assurances to cover long-term liabilities, such as water treatment and site maintenance. A key deficiency is the lack of detailed strategies for water management, particularly in preventing acid mine drainage (AMD), which can persist for decades if not properly addressed. International guidelines, such as those from the ICMM (2019), emphasize the need for integrated water management from the early stages of mining operations, including measures to protect water resources and monitor water quality post-closure. In contrast, current practices in Córdoba often fail to include site-specific water monitoring plans, such as tracking pH levels, potentially toxic metals concentrations, and total dissolved solids, which are critical for early detection of contamination.

Another area for improvement is the incorporation of climate change considerations into closure plans. Internationally, frameworks like those from ICMM and APEC recommend using climate change models to assess site-specific risks, such as increased rainfall or drought, which could have a great influence on water management and long-term site stability. Colombia's regulatory framework does not yet mandate such assessments, leaving closure plans vulnerable to future climate-related challenges.

Stakeholder engagement is another critical gap. While Colombian regulations require community consultation during the licensing phase, there is no formal mechanism to involve local communities in the verification of closure activities. International best practices, such as those outlined by ICMM, stress the importance of ongoing engagement with stakeholders, including minority groups, to ensure that closure plans align with community expectations and needs. This is particularly important in Córdoba, where mining activities often intersect with vulnerable ecosystems and marginalized communities.

Financial assurances for closure and post-closure activities also fall short. Current regulations require miners to provide environmental policies equivalent to a percentage of project investment, but these amounts are often insufficient to cover long-term liabilities, such as water treatment or ecosystem restoration as they are not directly related to the real nature and extension of the affected area. International standards, such as those from APEC, recommend more robust financial mechanisms, including bonds or trusts, to ensure that funds are available for unforeseen post-closure costs.

The 2022 ANLA guide introduces improvements by recommending the inclusion of climate change, circular economy, and risk analysis in closure plans. However, its non-binding nature limits its influence on licensing decisions. To address these gaps, Colombia must strengthen its regulatory framework by aligning it with international best practices, particularly in water management, climate change adaptation, stakeholder engagement, and financial assurances. These measures are essential for ensuring sustainable mine closure and minimizing long-term environmental and social risks in Córdoba and other mining regions.

Water use monitoring and management

Despite the frequent reference to water quality and quality control, the closure plans show a weakness in the implementation of an appropriate set of indicators, especially in the case of groundwater. The effective monitoring of water and terrain during closure and post-closure phases is imperative to ensure environmental integrity and site stability. However, the closure activities described in the mining license fail to include strategies for water resourcing, management, and monitoring. This represents a significant gap when compared to international standards. The “Integrated Mine Closure: Good Practice Guide” of the International Council on Mining and Metals (ICMM, 2019) emphasizes that closure planning must incorporate water management from the early stages, including measures for acid drainage prevention and water resource protection. However, current closure practices in Córdoba do not include

any detailed and clear strategies to address these critical aspects.

In addition to these deficiencies, current mine closure plans do not specify any methodologies for addressing potential effects on the hydrological balance and aquifer connectivity, which are essential for long-term water resource sustainability. International standards, such as those outlined by ICMM, emphasize the need for hydrogeological modeling to predict changes in groundwater flow post-closure and to mitigate potential contamination risks. Additionally, the absence of predictive models for water contamination and advanced risk assessment methodologies, as recommended by APEC, limits the ability to anticipate and proactively manage long-term water quality challenges. Furthermore, closure plans fail to require the implementation of passive water treatment systems, such as artificial wetlands and metal retention systems, which are widely recognized by ICMM and APEC as cost-effective, sustainable solutions for managing contaminated mine water over extended periods. Strengthening these aspects within the regulatory framework would significantly enhance the effectiveness of water management strategies in post-mining landscapes.

A deficient water management strategy in mine closure can lead to contamination of surface and groundwater sources, with long-term consequences for local communities and dependent ecosystems. Acid mine drainage, for instance, can persist for decades if preventive measures are not adequately implemented. The “Mine Closure Checklist for Governments” from APEC (2018) underlines the necessity of evaluating and mitigating these risks to safeguard water quality after mine closure. Without robust control mechanisms, mining sites may become sources of perpetual environmental liabilities, requiring expensive remediation efforts and posing significant socio-environmental risks.

A robust post-closure monitoring program is essential to ensure long-term site stability and environmental sustainability. According to ICMM (2019), an effective monitoring framework should include

parameters such as pH, potentially toxic metals concentrations, and total dissolved solids, with site-specific sampling frequencies tailored to local hydrological conditions. However, current closure plans in Córdoba lack explicit guidelines on these critical aspects. The absence of a comprehensive monitoring approach jeopardizes the ability to detect early warning signs of contamination and implement corrective actions in a timely manner. Addressing these deficiencies by incorporating international best practices will significantly strengthen water management in mine closure plans in Córdoba. Aligning regulatory frameworks with global guidelines will enhance environmental stewardship, mitigate long-term liabilities, and ensure the sustainable rehabilitation of former mining sites.

Conclusions

The analysis of mine closure practices in Córdoba, Colombia, reveals significant gaps in water management, particularly in monitoring, prevention of acid drainage, and long-term water resource protection. Current closure plans lack detailed strategies for groundwater and surface water monitoring, as well as measures to mitigate contamination risks, such as acid mine drainage. This contrasts sharply with international standards, such as those outlined by ICMM and APEC, which emphasize integrated water management from the early stages of mining operations. Without robust water management strategies, mining sites risk becoming sources of perpetual environmental liabilities, threatening local ecosystems and communities.

The study also highlights the broader regulatory weaknesses in Colombia's mine closure framework, including insufficient stakeholder engagement, inadequate financial assurances, and a lack of binding guidelines for post-closure land use. While the 2022 ANLA guide introduces some improvements, its non-binding nature limits its effectiveness. Furthermore, the guide lacks explicit methodologies and technical specifications necessary to ensure effective hydrological rehabilitation and long-term water quality protection. The



absence of clear, enforceable measures leaves room for inconsistent implementation, undermining the sustainability of closure practices. To ensure sustainable mining practices, Colombia must align its regulatory framework with international best practices, particularly in water management, and enforce stricter compliance to mitigate long-term environmental and social risks. Addressing these gaps is crucial for achieving environmental integrity and safeguarding water resources in mining regions like Córdoba.

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