Towards Responsible Mining: The Imperative Integration of Geoethics into Cuban Mining Engineering

Hacia una minería responsable: La imperativa integración de la Geoética en la Ingeniería de Minas en Cuba

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Abstract

Mining activity in Cuba, a fundamental pillar of its economy, faces the critical challenge of harmonizing resource extraction with environmental protection and social development. This article argues for the imperative need to systematically integrate geoethics into the education of Cuban mining engineers, positing that traditional, robust technical training is insufficient to address contemporary complex socio-environmental dilemmas. Through conceptual analysis and a critical review of the mining engineering curriculum, existing educational gaps are identified. A dual curricular model is proposed, one that mainstreams geoethical principles across technical subjects and establishes a specific, mandatory core course. The study concludes that this integration is essential for cultivating responsible professional praxis, ensuring the social license to operate, and transitioning towards a sustainable and ethically responsible mining model in Cuba, one that guarantees both profitability and ecological integrity, as well as community well-being.

Keywords: geoethics, mining sustainability, professional training, curriculum development

Resumen

La actividad minera en Cuba, pilar fundamental de su economía, enfrenta el desafío crítico de armonizar la extracción de recursos con la protección del medio ambiente y el desarrollo social. Este artículo sustenta la imperativa necesidad de integrar disciplinariamente la geoética en la formación del ingeniero de minas cubano, argumentando que la sólida instrucción técnica

tradicional resulta insuficiente para abordar los complejos dilemas socioambientales contemporáneos. Mediante un análisis conceptual y una revisión crítica del plan de formación del ingeniero de minas, se identificaron las brechas formativas existentes y se propuso un modelo curricular dual que transversaliza los principios geoéticos en las asignaturas técnicas e instituye una asignatura específica obligatoria. El estudio concluye que esta integración es fundamental para cultivar una praxis profesional responsable, asegurar la aceptación social para operar y transitar hacia un modelo de minería sostenible y éticamente responsable en Cuba, que garantice tanto la rentabilidad como la integridad ecológica y el bienestar comunitario.

Palabras clave: geoética, sostenibilidad minera, formación profesional

1. INTRODUCTION

Mining represents a strategic economic activity for Cuba's development, with mineral resources such as nickel and cobalt positioned as key elements in its export portfolio and within the global energy transition context (Quintana, 2017). However, this activity inherently entails significant territorial transformation, generating potentially irreversible environmental impacts and complex social dynamics in neighboring communities (Lafita, 2021). This scenario presents a fundamental dilemma for the Cuban mining sector: how to reconcile the economic utilization of subsurface resources with the preservation of ecosystem integrity and intergenerational well-being.

In the educational sphere, the traditional training of mining engineers in Cuba has predominantly focused on mastering basic sciences and applied engineering, developing professionals competent in technical, economic, and operational safety aspects. Nevertheless, contemporary challenges demand a more comprehensive professional profile that transcends technical optimization to reframe ethical behaviors in natural resource management, environmental liability rehabilitation, community dialogue, and the implementation of international sustainability standards. This paradigmatic evolution urgently requires a robust ethical framework to guide technical decision-making in the face of growing socio-environmental complexities.

It is precisely within this critical context that geoethics emerges as an indispensable conceptual and practical pillar. Defined as the systematic reflection on the values and principles that should guide human interaction with the Earth system (Peppoloni and Di Capua, 2017), geoethics provides conceptual and methodological tools for navigating the dilemmas between economic profitability, environmental responsibility, and social commitment. Its relevance acquires particular urgency in Latin America, where mining

activity generates significant environmental impacts and recurrent social tensions, as evidenced by documented cases of soil degradation and community impact in mining regions like Moa, Cuba (Suárez *et al.*, 2011; Villacorta *et al.*, 2024).

It is important to emphasize that the mere existence of legal frameworks does not per se guarantee responsible mining practices, as warned by Santos-Rodríguez (2022), who underscores the imperative need to develop a deontological code that internalizes ethical principles within mining professional culture. This perspective is reinforced by observations from the "Mining and the SDGs – A 2020 Update" report (Responsible Mining Foundation and Columbia Center on Sustainable Investment, 2020), which reveals fragmented and superficial progress in integrating the Sustainable Development Goals within the global mining industry, with particularly notable deficiencies in critical areas such as water management, public health, and gender equity.

Consequently, the formal incorporation of geoethics into the training of mining engineers transcends its status as an optional supplement to become a necessary condition for transitioning towards a sustainable mining model.

Therefore, the fundamental objective of this article is to holistically argue the necessity of integrating geoethics into the curriculum of the Mining Engineering program in Cuba. To achieve this purpose, its conceptual foundations will be analyzed, the specific challenges of the Cuban mining sector will be examined, and finally, a concrete model for curricular integration with a transversal and specific focus will be proposed.

The present article derived from a research associated with the project *Environmental Ethics in Community-Mining Management*, funded by the Ministry of Higher Education of Cuba.

2. MATERIALS AND METHODS

2.1. Methodological approach, data sources, and collection strategy

This research employs a mixed-methods design, combining qualitative content analysis with strategic foresight elements. The approach is primarily descriptive-analytical, examining the current state of mining engineering education in Cuba and its relationship to geoethical principles. This diagnostic phase is coupled with a propositional dimension focused on developing a model for curricular integration.

To ensure robustness, the study draws on a triangulation of data sources:

1. **Comprehensive document analysis:** This involved a critical review of the prevailing mining engineering curriculum in Cuba ("Plan E") (2018), the sector's legal and regulatory framework, and the international body of scientific literature on geoethics and sustainable mining.

2. **Faculty surveys:** A custom-designed questionnaire was administered to faculty members at Moa University ("Dr. Antonio Núñez Jiménez"). As the principal institution for mining education in Cuba strategically located in a major mining region since its founding in 1976 the university provides a critical vantage point. The survey assessed the faculty's familiarity with, attitudes toward, and practical experience in teaching geoethics.

3. **In-depth curriculum scrutiny:** The "Plan E" curriculum underwent a detailed examination to identify both explicit and cross-curricular inclusions of geoethical content, thereby pinpointing specific educational gaps.

2.2. Analysis techniques

The processing and analysis of collected information were conducted using the following techniques:

- Qualitative content analysis of curricular and regulatory documents.
- Systematization and interpretive analysis of the faculty survey results.
- Comparative study of international experiences in teaching geoethics, contrasting them with the Cuban reality.
- Identification of gaps between current training and the demands of a sustainable mining sector, derived from contrasting documentary analysis and survey data.

For the prospective analysis, scenario methodology was applied, considering:

- Identification of key variables in the Cuban mining-educational system based on previous findings.
- Analysis of relevant stakeholders (educational sector, mining companies, communities, regulatory entities).
- Construction of trend, normative, and alternative scenarios.

- Definition of critical factors for transitioning towards the optimal scenario.

2.3. Methodological limitations

The main limitation of this study lies in the scarce availability of updated, publicly accessible quantitative data on specific socio-environmental indicators related to mining in Cuba. This limitation was mitigated through the triangulation of available sources and the utilization of primary data generated from the faculty survey.

2.4. Ethical considerations

The research was conducted adhering to the principles of scientific rigor, academic integrity, and methodological transparency. The anonymous and confidential use of data obtained from the survey was guaranteed, and a critical-constructive approach was maintained throughout the analysis and proposal formulation.

3. RESULTS

3.1. Diagnosis of mining education in Cuba: Identification of curricular gaps

Analysis of the "E" curriculum for the Mining Engineering degree reveals a curricular structure with significant limitations in addressing contemporary challenges of sustainable mining. The documentary review demonstrated that fundamental principles of geoethics—such as responsibility, sustainability, precaution, transparency, and participation—are not explicitly integrated into the learning objectives or content of core technical courses.

This deficiency is reflected in the results of the survey administered to professors at the University of Moa (Universidad de Moa, 2024), where 91,7 % of respondents confirmed the absence of specific courses dedicated to geoethics. It is particularly noteworthy that 66,7 % of the faculty acknowledged having received no formal training in this discipline, while 75 % of respondents considered its integration into the curriculum to be fundamental or very important for the education of well-rounded professionals

3.2. Analysis of the national mining reality and its alignment with development policies

The assessment of the Cuban mining context demonstrates the necessity of incorporating geoethics into professional training. Cuba possesses significant mineral resources, with nickel and cobalt being strategic elements that have

substantially contributed to the national economy, accounting for up to 23 % of the country's exports in recent periods (ONEI, 2022).

According to Quintana (2017), in addition to nickel and cobalt, Cuba also exports chromium, zeolite, metallic lead, lead and zinc concentrates, and doré gold (a gold and silver alloy). This author suggests that the island has potential to increase exports of minerals and products such as micronized calcium carbonate, bentonite, and salt.

However, after decades of intensive exploitation in regions like Moa, cumulative impacts are evident, demanding a new approach in professional practice. Specialized studies have documented significant environmental damage, including atmospheric pollution with particulate matter and gases such as sulfur dioxide, which have affected the quality of life in neighboring communities (Suárez *et al.*, 2011).

The analysis of the public policy framework reveals that, although the National Economic and Social Development Plan until 2030 (2019) establishes guidelines towards sustainability, unresolved tensions persist between the productive objectives of the mining sector and effective environmental protection. This duality manifests in the coexistence of ambitious production targets with limited technological capacities to implement environmentally responsible mining practices.

3.3. Foundations for the curricular integration of geoethics

Geoethics constitutes the appropriate conceptual framework for addressing the identified problems in the Cuban mining sector. Its guiding principles establish the epistemological foundations for a professional practice that harmonizes technical efficiency with social legitimacy (Peppoloni and Di Capua, 2017). In the specific context of Cuba, this perspective implies a critical re-evaluation of traditional technical paradigms, where fundamental notions must transcend conventional economic analysis to incorporate a comprehensive assessment of their socio-environmental externalities and long-term ecological footprint.

The systematic application of these principles would transform technical decision-making. For example, the concept of Cut-off Grade could be addressed by considering not only its economic formulation but also its impact on the mine's lifespan and waste generation. Similarly, slope stability analysis should incorporate long-term safety criteria and risk assessment for neighboring communities, going beyond mere regulatory compliance.

3.4. Curricular integration proposal and its viability

To address the identified gaps, a dual curricular integration model is proposed, combining mainstreaming into existing courses with the creation of a specific subject. Mainstreaming involves incorporating geoethical principles into fundamental technical disciplines through:

In *Mining processes*, the inclusion of socio-environmental impact analysis in the selection of exploitation methods.

In *Geomechanics*, the incorporation of the precautionary principle in slope design.

In *Environmental management*, the focus on intergenerational responsibility in closure plans.

Due to its importance in the current context, the course Geoethics and Mining Social Responsibility is proposed, with content including geoethics fundamentals, regulatory frameworks, analysis of national case studies, and community dialogue techniques.

The feasibility analysis indicates that implementing this model represents a strategic investment for the development of the national mining sector, aligning with the guidelines of the National Development Plan and responding to the sustainability demands identified in the diagnosis.

4. DISCUSSION

4.1. Rationale for curricular integration proposal

The obtained results consistently demonstrate the necessity of implementing a dual curricular integration model for geoethics in the training of mining engineers in Cuba. This proposal is grounded in the diagnosis revealing significant gaps between the competencies developed in the current curriculum and the challenges presented by contemporary professional practice (Villacorta *et al.*, 2024). Evidence gathered through surveys of the faculty at the University of Moa corroborates this need, where although 75 % of the teaching staff recognizes the fundamental importance of geoethics, 91,7 % confirms its absence in the current study plans.

The proposal to mainstream geoethical content into existing technical courses addresses the need to contextualize ethical principles within specific professional practice. As noted by Peppoloni and Di Capua (2017), geoethics should not constitute abstract knowledge but rather a tool for concrete application in decision making. The incorporation of socio-environmental impact analysis in the selection of mining methods, or the integration of the

precautionary principle in slope design, represent practical applications that enable moving beyond the purely technical approach that has traditionally characterized mining education.

4.2. Viability and implementation strategy

The feasibility analysis of the proposal indicates that its implementation is viable and aligns with the guidelines established in the National Economic and Social Development Plan until 2030. The existence of the Ergo-environmental discipline in the current curriculum provides a suitable platform to initiate the mainstreaming process, particularly regarding environmental management and protection.

Successful implementation will require a gradual strategy that considers:

Faculty training: Given that 66,7 % of the teaching staff acknowledges not having received training in geoethics, it is necessary to develop professional development programs to expand the teachers' cognitive spectrum and equip them with the required competencies for delivering this content.

Development of teaching materials: The creation of case studies based on the Cuban mining reality, particularly from regions like Moa, will enable the contextualization of geoethical principles within real situations that future engineers will face.

Articulation with the productive sector: Collaboration with mining companies such as Cubaniquel will help align the training with the sector's real needs, while also facilitating access to real-world scenarios for the practical application of knowledge.

The establishment of the specific course "Geoethics and Mining Social Responsibility" would complement this process by providing the necessary conceptual and methodological framework to integrate the various aspects addressed in a transversal manner.

4.3. Expected benefits and contribution to national development

The implementation of this curricular proposal would generate significant benefits across multiple dimensions. For the national mining sector, it would contribute to transitioning towards a sustainable mining model, enhancing international competitiveness through the adoption of globally recognized standards (Responsible Mining Foundation and Columbia Center on Sustainable Investment, 2020). Training engineers with geoethical competencies would facilitate access to international markets requiring

sustainability certifications, representing a comparative advantage for the Cuban mining industry.

For communities in mining regions, this training would establish new foundations for the relationship between industry and society, promoting more transparent dialogue processes and a more equitable distribution of benefits (Santos-Rodríguez, 2022). The incorporation of community participation in technical decision-making represents a significant advancement toward building stronger social legitimacy for mining operations.

In the environmental sphere, the systematic application of precautionary and intergenerational responsibility principles will help minimize historical environmental liabilities and prevent new impacts, contributing to the protection of Cuba's natural heritage, including areas of high ecological sensitivity such as the Alejandro de Humboldt National Park.

The integration of geoethical competencies into the training of future mining engineers constitutes fundamental added value, preparing them to lead the sector's transition towards more sustainable and socially responsible practices. This comprehensive preparation will enable them to address the complex ethical dilemmas inherent in contemporary professional practice, facilitating decision-making that is not only technically sound but also ethically grounded in criteria of socio-environmental justice and responsibility towards the territory and communities.

5. CONCLUSIONS

- The analysis of the "E" curriculum for Mining Engineering in Cuba reveals the absence of explicit integration of geoethical principles, constituting an educational gap in addressing contemporary mining sector challenges.
- The survey of professors at the University of Moa demonstrates that while 75 % of the faculty recognizes the fundamental importance of geoethics, 91,7 % confirms its absence in the curriculum and 66,7 % lacks specific training in this discipline.
- The diagnosis of the Cuban mining context evidences the urgent need for professionals with geoethical competencies, particularly in regions like Moa where documented cumulative environmental impacts and social tensions require new management approaches.
- The viability of a dual curricular integration model is demonstrated, combining the mainstreaming of geoethical content in technical

courses with a specific subject, leveraging existing capacities within the Cuban higher education system.

- The implementation of the proposed new course would significantly contribute to the national mining sector's competitiveness through the adoption of international sustainability standards, improve community relations, and strengthen environmental protection.

- This study establishes that integrating geoethics into mining engineering education is a necessary condition for the sustainable development of Cuba's mining sector, aligning with national development objectives and global trends toward responsible mining.

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Información adicional

Conflicto de intereses

Los autores declaran que no existen conflictos de intereses.

Contribución de los autores

YCG: conceptualización, redacción del original. ACP: diseño de la investigación, supervisión, y aprobación de la versión final. KCB: supervisión y corrección del original. Aprobación de la versión final.

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