

An Environmental Audit of a Rock Aggregate Mining Company

Auditoría ambiental de una empresa minera que explota agregados pétreos

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OPEN ACCESS

Recibido: 29/01/2021

Aceptado: 30/04/2021

Publicado: 25/06/2021

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Abstract

Objective: To conduct an environmental audit in mining company dedicated to the exploitation of stone aggregates in La Guajira, Colombia. **Methodology:** The research is descriptive, of documentary review and direct observation, with a field design, non-experimental and of a correlational-causal cross-sectional cut. To collect the information, a checklist and a 57-item structured questionnaire were applied, applying validity and reliability by means of expert criteria. **Results:** The main findings indicate that the work by the environmental management of the mining company is not adequate with respect to the environmental obligations determined by environmental regulations, among them are the problems of environmental degradation, deforestation, and emissions of particulate matter. **Conclusions:** A better environmental organization and a rigorous application of environmental management measures that mitigate, compensate, prevent, or correct the negative effects are required, considering that those applied in the medium term are strengthened and new strategies and environmental management measures are established to comply with current environmental regulations.

Keywords: Environmental audit, environmental management measures, environmental regulations, environmental problems.

Resumen

Objetivo: Realizar una auditoría ambiental en empresa minera dedicada a la explotación de agregados pétreos en La Guajira, Colombia. **Metodología:** La investigación es de carácter descriptiva, de revisión documental y observación directa, con diseño de campo, no experimental y de corte transeccional correlacional-causal. Para recolectar la información, se aplicó una lista de chequeo y un cuestionario estructurado por 57 ítems, aplicando la validez y confiabilidad mediante el criterio de expertos. **Resultados:** Los principales hallazgos indican que el trabajo por la gestión ambiental de la empresa minera no es el adecuado respecto a las obligaciones ambientales que determina la normatividad ambiental, entre ellos se encuentran los problemas de degradación ambiental, deforestación y emisiones de material particulado. **Conclusiones:** Se requiere de una mejor organización ambiental y una aplicación rigurosa de medidas de manejo ambiental que mitiguen, compensen, prevengan o corrijan los efectos negativos, teniendo en cuenta que las aplicadas a término medio se fortalezcan y además se establezcan nuevas estrategias y medidas de manejo ambiental para cumplir con la normatividad ambiental vigente.

Palabras clave: Auditoría ambiental, medidas de manejo ambiental, normatividad ambiental, problemas ambientales.

Introduction

Given the advancements in natural resource consumption and its negative effects, environmental audits have helped ensure regulatory compliance to protect the environment. In this regard, the mining industry does not usually establish environmental management systems for consuming natural resources. In fact, these measures, along with environmental audits, are commonly only implemented in developed countries with sufficient economic means and awareness to enforce effective environmental management systems [1].

According to the global environmental landscape, the environmental problems generated by mining companies arise as a result of exploitation processes and the irrational use of natural resources [2]. Hence, an important tool for reducing the environmental impacts of mining and mineral ore processing operations is the environmental audit, which is an essential component of the “Plan-Do-Check-Act” cycle of an environmental management system to verify performance and compliance with environmental regulations. One of the most widely acknowledged audit standards in this regard is ISO 19011, which describes environmental auditing processes and the systematic and documented processes through which evidence is obtained, and mining company activities are objectively evaluated [3].

In this context, the exploitation of rock aggregates has caused several issues, affecting nearly all river networks in Colombia. For example, the extraction of rock, sand, clay, and other elements from riverbeds has drastically altered the riverbeds, thus causing fish deaths, the extinction of some species, and a high-risk index due to floods and avalanches [4, 5, 6]. According to [5], some environmental impacts from the exploitation and extraction of material ore and the construction of access roads affect the flora by reducing the number of forest species. This is in addition to the high levels of fauna migration caused by the alteration of exosystemic balances and natural habitats.

Despite being one of the richest regions in mineral ore such as coal, gypsum, clay, lime rock, salt, marble, and barite, the Colombian region of La Guajira has low compliance rates with environmental protection laws. Environmental management is improperly handled by the mineral ore companies operating in this region [7, 8, 9]. For example, mining companies exploiting rock aggregates throughout this region can be cited. The mining activities, processes, and stages of these companies generate negative environmental impacts. These companies first intervene in the area by removing vegetation, trees, shrubs, and herbaceous species. They then begin blasting activities to facilitate exploitation. The following stage is the mineral ore extraction using heavy machinery. Extracted rocks are then taken to a crushing plant, where they are classified according to their diameter for their subsequent crushing. Next, crushed rocks are piled up, loaded, and transported to deposits. These processes or stages generate several negative environmental impacts [8, 9, 10].

Consequently, this study conducts an environmental audit at a mining company in La Guajira, Colombia, dedicated to exploiting rock aggregates. This study will identify certain aspects that are often not considered: environmental issues, management measures, regulatory compliance rates, and environmental strategies currently in place or that require reinforcement. Finally, the study proposes new environmental protection optimization strategies.

Therefore, this research is relevant within the theoretical framework because it provides a remedy for the various harms caused daily by the mining of rock aggregate, thus evidencing, in the first place, the advantages of implementing different strategies, as well as the application of assessment and inspection tools, such as environmental audits.

From a practical viewpoint, this study is important because it fosters the use of good environmental practices. By implementing these good practices, mining companies dedicated to exploiting rock aggregates could avoid issues with the environmental authorities, thus enhancing their reputation and goodwill as well as attracting investors. This way, the rock aggregate exploitation industry in La Guajira, Colombia, would become known at both the national and international levels.

This study is significant from a methodological viewpoint because it transcends environmental protection through the application of extremely rigorous environmental evaluation tools, such as environmental auditing processes. These processes can yield excellent results, such as stronger compliance with environmental regulations, fewer fines and penalties, and avoiding legal actions that may hinder these mining activities.

Metodología

This study was correlational and descriptive. Furthermore, the field study design was nonexperimental, causal-correctional, and cross-sectional [11, 12], and its sources were documentary review and direct observation [13]. Moreover, this study did not work with samples, but with the total population. For the study, the sample population was finite and corresponded to a mining company dedicated to the exploitation of rock aggregates in La Guajira, Colombia [8, 9, 10]. For data collection, a checklist based on an iterative cycle with a qualitative research design [14, 15, 16] and an open-answer survey [11, 12] were used, allowing us to find the required information.

The checklist used in this study included the impacted environmental factors and their affectation from rock aggregate exploitation. For these purposes, formal statistical procedures were not used; only compliance rates with Colombian environmental regulations were determined. This information was used to develop the first draft of the checklist used. Then, this checklist was validated and retrofitted according to findings from interviews with subject-matter experts and researchers, as well as additional findings from existing literature. Additionally, the survey examined 57 items contained in three (3) open questions that assessed this study's research variables: environmental problems, environmental management measures, and environmental regulations and strategies applied to a mining site dedicated to the exploitation of rock aggregates.

Regarding the validity and reliability of the research instruments used, their relevance was evaluated in terms of their scope, content, effectiveness, coherence, and writing, among others. These instruments were also validated by subject-matter experts in the areas of research methodology, environmental sciences, and mining at La Guajira, Colombia. Nevertheless, reliability was not measured because this study is subject to individual researcher criteria both in terms of field observation and the selection of documentary materials.

Results and Discussion

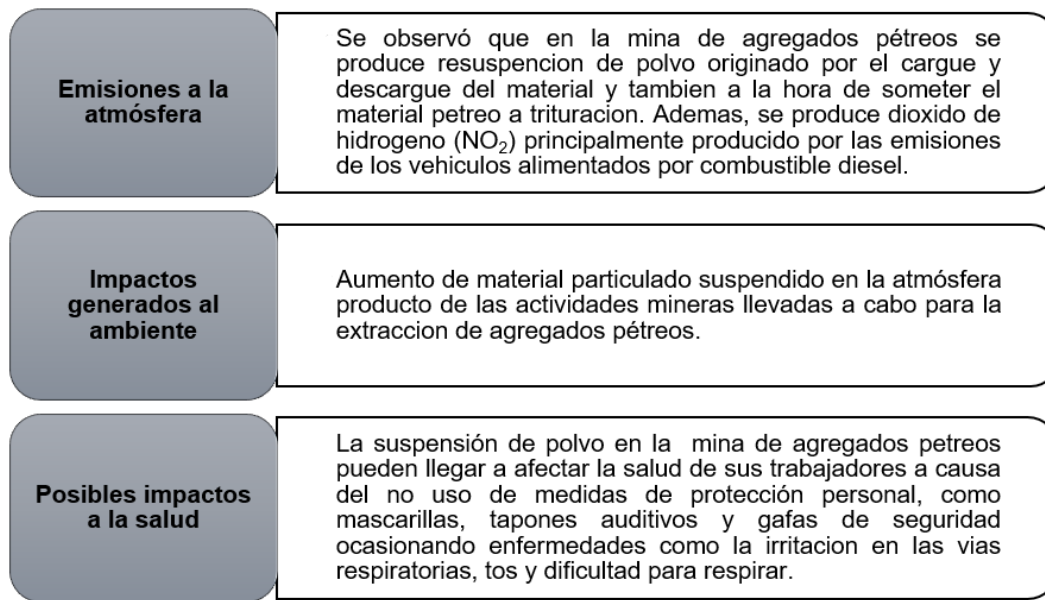
Environmental Issues

Environmental issues arise from the unbridled destruction of natural resources and the environment. Mining activities usually contaminate aquatic ecosystems and soils, modify the landscape, cause subsidence, and generate changes in vegetation. Their consequences are also commonly manifested in soil losses or degradation, surface water contamination, air pollution by particulate matter or greenhouse gases, farming

land losses, biological diversity losses, landscape disturbance, and negative impacts on human health [17, 18]. The mining site of interest in this study exploits rock aggregates in La Guajira, Colombia. This site denotes environmental problems in terms of soil degradation, atmospheric pollution, ambient noise, endemic fauna migration, and biodiversity loss.

The mining company uses blasting as part of their exploitation processes, which involves detonating explosives directly into the soil. This drastically alters the soil's natural dynamics and decreases landscape and fauna diversity by changing their natural structure and conditions. Additionally, the heavy-duty vehicles used for extracting alluvial material must be contemplated, as they compact soils, thus causing them to lose porosity and permeability. Moreover, several issues were also found regarding the air quality due to rock aggregate exploitation in La Guajira, Colombia, as shown in Figure 1.

Figure 1. Atmospheric Emissions and Other Impacts from a Mine Site dedicated to the Exploitation of Rock Aggregates.



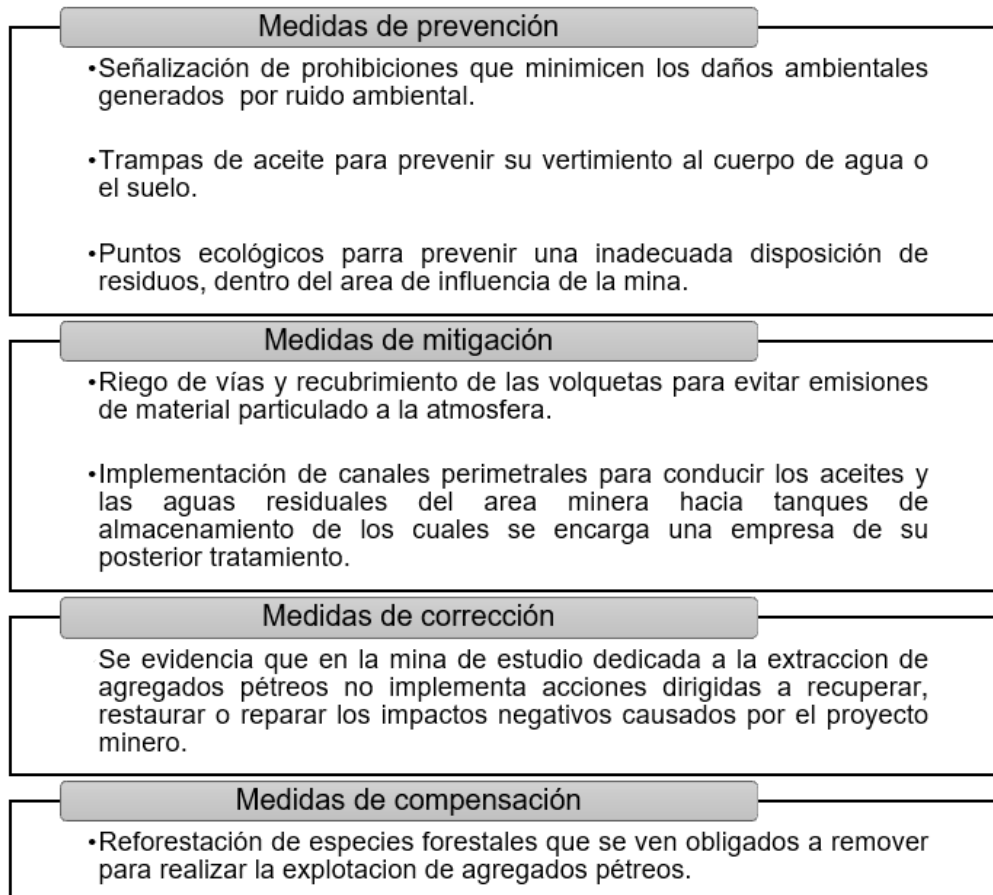
Source: Prepared by the Authors

Similarly, mining operations produce significant ambient noise due to the heavy machinery used. For example, in this study's rock aggregate extraction mine, 3 backhoes, 2 crushers, and 27 dump trucks worked continuously for 12 h, emitting noise levels within the 70–80, 65–75, and 55–65 dB ranges, respectively. For this reason, machinery is considered the main source of ambient noise generation due to vehicle movements and extensive horn use. At the same time, the migration of the endemic fauna is attributed to the many hours of ambient noise produced by the machinery when stripping and extracting rock aggregates. In fact, these species losses are attributed to the blasting activities performed to remove the vegetation cover from the open pit mine. Although blasting does not occur every day, it changes the landscape significantly and contributes to fauna and flora losses whenever it occurs. Additionally, several factors that cause biodiversity loss were identified. For example, deforestation and pit creation related to rock aggregate extraction have caused several species to lose their habitats. This has generated negative effects on the local biodiversity due to the fragmentation of natural habitats, thus exerting negative edge effects. This phenomenon occurs in areas where two different natural habitats or two adjoining structurally different communities come into contact [19].

Environmental Management Measures

In an attempt to reduce the negative impacts on the social and environmental component [20], governments, companies, and nongovernmental organizations are increasingly adopting environmental management measures to ensure that whoever causes environmental damage bears the corresponding repair costs. Therefore, the mining company that exploits rock aggregates in La Guajira must budget expenses to remedy the impacts caused by its activities. Colombian environmental regulations provide that the scope of the mining industry must focus on environmental impacts and management measures, whereby these measures and strategies must be aimed at preventing, mitigating, correcting, and compensating for the negative impacts or effects generated. Mining companies must also obtain environmental permits, which condition the implementation of these measures on the protection of human health and the environment [21]. Hence, this rock aggregate exploitation mine must identify the environmental effects generated by its activities and implement effective follow-up and monitoring plans during the mining stage, as well as an adequate abandonment plan in its post-mining stage, to obtain the corresponding environmental and mining permits. Based on the foregoing and considering the environmental issues evidenced at the rock aggregate exploitation mine in La Guajira, Colombia, Figure 2 shows the measures that must be implemented to prevent, mitigate, correct, and compensate for the impacts caused by its mining activities.

Figure 2. Prevention, Mitigation, Correction, and Compensation Measures for Unwanted Environmental Impacts from a Mining Company dedicated to the Exploitation of Rock Aggregates in La Guajira, Colombia.



Source: Prepared by the Authors

Environmental Regulations

In Colombia, all mineral ore resources legally belong to the government and are managed by the Ministry of Mines and Energy (MME). Additionally, they are overseen by the National Mining Agency (ANM), which grants concessions through a single 30-year contract covering exploration, mine site construction, and mining exploitation. At the end of its original 30-year term, this contract can be renewed for another 30 years. For this, an environmental impact assessment must obtain an environmental permit [22]. This environmental permit is a policy instrument that integrates environmental protection into the development process, thereby achieving a balance between economic development and the protection and preservation of the environment [23]. The environmental permits for the mining industry in Colombia are a cause of concern. Both MME and ANM have the challenge of facing the formalization of approximately 300,000 artisanal miners dedicated to the extraction of gold, diamonds, emeralds, coal, construction minerals, etc. However, currently, they have only reached about 7% of the total number of known mining units operating in the country [24].

The rock aggregate exploitation mine under study in La Guajira, Colombia, complies with Executive Order 2041 of 2014 (which regulates matters related to environmental permits) through an environmental permit resolution issued by the Regional Autonomous Corporation of La Guajira (Corpoguajira). Nevertheless, since the mining company still needs to implement an environmental management plan that mitigates, compensates, prevents, corrects, or rehabilitates, in addition to several plans aimed at reducing the damage caused by its mining activities, this mining company only moderately complies with these requirements. As a result of field observations using a checklist, it was determined that the rock aggregate exploitation mine under study possesses some authorization granted by Corpoguajira. Table 1 presents the environmental authorization issued by Corpoguajira and shows whether the rock aggregate exploitation mine in La Guajira complies with the corresponding requirements.

Table 1. Environmental Authorization of a Mining Company that Exploits Rock Aggregates in La Guajira

Factor	License, Permit, or Concession	Compliant		What is missing?
		Yes	No	
Air	Atmospheric Emission Permit	x		Must establish greater control in road irrigation to ensure compliance.
Flora	Forest Exploitation Permit		x	Reforestation of endemic or endangered species. Re-purposing of plant species felled for the formation of microhabitats.
Prospecting and Exploration	Mining Title	x		
	Environmental Permit	x		Exercise greater monitoring, control, and compliance with Environmental Management Plan.
Water	Surface Water Concession	x		
	Wastewater	No dumping permit is required because wastewater does not contain high pollutant loads. Additionally, the mining company has a primary wastewater treatment system that reduces pollutant loads through grease traps and delivers treated water to a company for subsequent further treatment.		

Source: Prepared by the Authors

Environmental Strategies

Environmental strategies are a comprehensive and coordinated set of commitments and actions designed to exploit core competencies and enable a company to become competitive in the market and respond to environmental concerns through actions [26]. According to [27], strategies aimed at reducing mining impacts from hydrological viewpoint evidence that reforestation and river restoration leads to a strong reduction in sediment and water yields.

Partial reforestation in bare areas and a road irrigation system to reduce particulate matter emissions are two environmental strategies implemented using the rock aggregate exploitation mine under study. However, the environmental audit generated some important findings (see Table 2) that warrant the implementation of new environmental strategies within their mining processes.

Table 2. Environmental Findings at a Mining Company that Exploits Rock Aggregates in La Guajira, Columbia

Condition	Criterion	Cause	Effect
The auditing team was not provided with tests evidencing environmental monitoring measures.	Employ environmental monitoring for all its impacts and correcting measures, as per Executive Order 2254 of 2017 and Executive Law 2811 of 1974, which establish an emission management system.	The company does not have an Environmental Monitoring Plan in place to correct negative environmental impacts through Environmental Management Measures.	The company cannot conduct the corresponding management measures due to the absence of an Environmental Monitoring Plan, which means that the company does not comply with Executive Order 2254 of 2017.
During onsite visits, we observed that mining company workers were not wearing hearing protection devices against ambient noise.	Implement hearing protection devices to protect workers against ambient noise as per Executive Order 2254 of 2017 and Executive Law 2811 of 1974.	The company does not require its workers to wear hearing protection devices because it does not measure noise decibels during its operations.	The company cannot conduct the corresponding environmental noise controls for their workers, which means that the company does not comply with Executive Order 2254 of 2017.
During onsite visits, the auditing team did not observe a green wall around the rock-crushing plant.	Build a green wall around the rock-crushing plant as indicated by Executive Order 2254 of 2017.	The company does not have a green wall to prevent the dissemination of particulate matter.	The company does not conduct this mitigation measure, which means that the company does not comply with Executive Order 2254 of 2017.

Source: Prepared by the Authors

Conclusions

The environmental audits conducted at the rock aggregate exploitation mine in La Guajira identified several environmental issues generated in the exploration, exploitation, and loading and unloading stages. Some of these issues include biodiversity loss, endemic fauna migration, atmospheric emissions, and ambient noise. During this environmental audit, it was discovered that, although not very successful, the company has implemented some environmental management measures to control ambient noise and atmospheric pollutants. Therefore, environmental issues are not treated with the same level of importance, which is alarming because all issues, no matter how minor, have some degree of affectation.

Similarly, the environmental management measures required by the mining company that exploits rock aggregates aim to correct and compensate for unwanted environmental impacts on the soil, flora, and fauna. Additionally, the company must improve its environmental management by preparing and applying environmental monitoring and follow-up plans for mining activities to guarantee compliance with Colombian environmental regulations applicable to the mining industry.

Finally, as mentioned in its legal filings, this company exhibits clear environmental issues. However, their reality is very different since proper environmental management measures do not abide by government regulations. Therefore, this study proposes several recommendations to improve the company's environmental compliance rates..

References

1. P. Castka, C. Searcy, and J. Mohr, "Technology-enhanced auditing: Improving veracity and timeliness in social and environmental audits of supply chains," *J. Clean. Prod.*, vol. 258, no. April 2013, p. 120773, 2020. DOI: <https://doi.org/10.1016/j.jclepro.2020.120773>.
2. S. H. Farjana, N. Huda, M. A. Parvez Mahmud, and R. Saidur, "A review on the impact of mining and mineral processing industries through life cycle assessment," *J. Clean. Prod.*, vol. 231, pp. 1200–1217, 2019. DOI: <https://doi.org/10.1016/j.jclepro.2019.05.264>.
3. R. K. Jain, Z. "Cindy" Cui, J. K. Domen, R. K. Jain, Z. "Cindy" Cui, and J. K. Domen, "Environmental Auditing. Environmental Impact of Mining and Mineral Processing," in *Management, Monitoring, and Auditing Strategies*, 2016, pp. 201–227.
4. J. A. Jiménez-Arrieta, "Diagnóstico Socio-Ambiental de la explotación de material de arrastre en el municipio de San Carlos - Córdoba, Colombia.," Universidad De Córdoba, 2019.
5. J. A. Martínez-Ortiz, "Análisis de los Impactos Ambientales Generados por la Extracción de Material de Arrastre en Cuerpos de Agua – Caso de Estudio: Río Purnio.," Universidad Católica de Manizales, 2017.
6. R. Pineda-Murillo, "La cuestión territorial, la planificación y las políticas públicas en el análisis de la vulnerabilidad y la resiliencia socio-ambiental. El caso de la extracción de ma," Universidad de Buenos Aires, Argentina., 2018.
7. D. López-Juvinao, L. Torres-Ustate, and F. Moya-Camacho, "Tecnologías, procesos y problemática ambiental en la Minería de arcilla," *Investig. e Innovación en Ing.*, vol. 8, no. 2, pp. 20–43, 2020. DOI: <https://doi.org/10.17081/invinno.8.2.3857>.
8. K. Polo Bornachera, D. D. López Juvinao, and A. Henríquez Jaramillo, "Transferencia tecnológica para la producción limpia en la minería de materiales aluviales en La Guajira, Colombia," *Investig. e Innovación en Ing.*, vol. 8, no. 1, pp. 6–20, 2020. DOI: <https://doi.org/10.17081/invinno.8.1.3535>.
9. Y. E. Sánchez-Londoño and D. D. López-Juvinao, "Tecnologías limpias para la mejora de la gestión ambiental de la minería de sal en La Guajira, Colombia," *Prospectiva*, vol. 18, no. 2, pp. 1–15, 2020. DOI: <http://doi.org/10.15665/rp.v18i2.2374>.
10. D. D. López-Juvinao, *Mucho más que carbón, el escenario minero de La Guajira*, 1st ed. Riohacha, La Guajira, Colombia., 2010.
11. R. Hernández, C. Fernández, and M. del P. Baptista, *Metodología de la investigación*, 6th ed. Mexico, 2014.

12. R. Hernández Sampieri and C. P. Mendoza Torres, *Metodología de la investigación: Las rutas cuantitativa, cualitativa y mixta*, 2018th ed. Mexico, 2018.
13. F. G. Arias, *El Proyecto de Investigación Introducción a la metodología científica*, 6th ed. Caracas - República Bolivariana de Venezuela, 2012.
14. J. Arboleda, *Manual de evaluación de impacto ambiental de proyectos, obras o actividades*. Medellín, Colombia, 2008.
15. J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 3rd ed. Londres / Nueva Delhi: SAGE Publications Ltd., 2003.
16. J. S. Molléri, K. Petersen, and E. Mendes, "An empirically evaluated checklist for surveys in software engineering," *Inf. Softw. Technol.*, vol. 119, pp. 1–21, 2020. DOI: <https://doi.org/10.1016/j.infsof.2019.106240>.
17. G. Ofosu, A. Dittmann, D. Sarpong, and D. Botchie, "Socio-economic and environmental implications of Artisanal and Small-scale Mining (ASM) on agriculture and livelihoods," *Environ. Sci. Policy*, vol. 106, no. February, pp. 210–220. 2020. DOI: <https://doi.org/10.1016/j.envsci.2020.02.005>.
18. C. Candeias, P. Ávila, P. Coelho, and J. P. Teixeira, *Mining activities: Health impacts*, 2nd ed. Elsevier Inc., 2019.
19. N. Henao, A. M. Torres, J. C. Tafur, and L. Guevara, "¿Existe un efecto de borde sobre la estructura vegetal y el potencial de regeneración en fragmentos de bosque seco tropical?," *Biota Colomb.*, vol. 19, no. 1, pp. 3–20, 2018. DOI: <http://dx.doi.org/10.21068/c2018.v19n01a01>.
20. C. J. Barrow, *Environment and Development*, Second Edi., vol. 7. Elsevier, 2015.
21. A. Gómez Rey, C. A. Rincón, and G. A. Rodríguez, "Los regímenes de transición del licenciamiento ambiental en Colombia vistos desde la actividad minera," *Prolegómenos*, vol. 19, no. 38, pp. 161–181, 2016. DOI: <http://dx.doi.org/10.18359/prole.1976> Forma.
22. E. A. Holley, N. M. Smith, J. A. Delgado Jimenez, I. C. Cabezas, and O. J. Restrepo-Baena, "Socio-technical context of the interactions between large-scale and small-scale mining in Marmato, Colombia," *Resour. Policy*, vol. 67, no. April, p. 101696, 2020. DOI: <https://doi.org/10.1016/j.resourpol.2020.101696>.
23. A. Vargas, J. P. Sarmiento Erazo, and D. Diaz, "Has Cost Benefit Analysis Improved Decisions in Colombia? Evidence from the Environmental Licensing Process," *Ecol. Econ.*, vol. 178, no. October 2019, p. 106807, 2020. DOI: <https://doi.org/10.1016/j.ecolecon.2020.106807>.
24. M. M. Veiga and B. G. Marshall, "The Colombian artisanal mining sector: Formalization is a heavy burden," *Extr. Ind. Soc.*, vol. 6, no. 1, pp. 223–228, 2019. DOI: <https://doi.org/10.1016/j.exis.2018.11.001>.
25. E. Ruokonen and A. Temmes, "The approaches of strategic environmental management used by mining companies in Finland," *J. Clean. Prod.*, vol. 210, pp. 466–476, 2019. DOI: <https://doi.org/10.1016/j.jclepro.2018.10.273>.
26. T. K. Betts, F. Wiengarten, and S. K. Tadisina, "Exploring the impact of stakeholder pressure on environmental management strategies at the plant level: What does industry have to do with it?," *J. Clean. Prod.*, vol. 92, pp. 282–294, 2015. DOI: <http://dx.doi.org/10.1016/j.jclepro.2015.01.002>.
27. T. Pacetti, M. Lompi, C. Petri, and E. Caporali, "Mining activity impacts on soil erodibility and reservoirs silting: Evaluation of mining decommissioning strategies," *J. Hydrol.*, vol. 589, no. March, p. 125107, 2020. DOI: <https://doi.org/10.1016/j.jhydrol.2020.125107>.