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Sustainable Management Model in a mining unit in the process of closing in Mexico. Case Study

Modelo de Gestión Sustentable en una unidad minera en proceso de cierre en México. Caso de Estudio

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Abstract

As part of an Integrated Multiple Case Study (Yin, 2013), a method applied for the implementation of a Sustainable Management Model for the Mining-Metallurgical Industry of Mexico, the individual study of the mining analysis unit is presented, which is in the closing stage and belongs to the Au-Ag-Pb-Cu-Zn Mineralization Trend of the national territory. In addition to collaborating with the validation of the Model in field, this study aims to evaluate whether environmental, practices comply with legislative requirements and align with the international suggestions of the UN (2016) through Sustainable Development Goals selected from the agenda 2030. The contribution of this study lies in the importance that is generated from the closure strategy they have followed and how it impacts on the environment, involving ecological and social aspects primarily; the mining unit in the closing stage has been involved in clashes led by radical groups, arguing excessive devastation of important areas, forcing the corporation to execute plans for total closure.

Open pit mine, Closure plans, Mining environmental liabilities

Resumen

Como parte de un Caso de Estudio Múltiple Integrado (Yin, 2013), método aplicado para la implementación de un Modelo de Gestión Sustentable para la Industria Minero-metalúrgica de México, se presenta el estudio individual de la unidad minera de análisis, que se encuentra en etapa de cierre y pertenece al Trend de mineralización Au-Ag-Pb-Cu-Zn del territorio nacional. Además de colaborar con la validación en campo del Modelo, este estudio tiene por objetivo, evaluar si las prácticas medioambientales cumplen con los requimientos legislativos y se alinean a las sugerencias internacionales de la ONU (2016) a través de Objetivos de Desarrollo Sostenible seleccionados de la Agenda 2030. La contribución de este estudio radica en la trascendencia que se genera a partir de la estrategia de cierre que han seguido y cómo impacta en el ambiente, involucrando aspectos ecológicos y sociales primordialmente; la unidad minera en etapa de cierre se ha visto involucrada en enfrentamientos encabezados por grupos radicales, argumentando devastación desmedida de zonas importantes, obligando al corporativo a ejecutar planes de cierre total.

Modelo de gestión sustentable, Mina a cielo abierto, Planes de cierre, Pasivos ambientales mineros

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Introduction

The implementation of a Sustainable Management Model in the Mining-Metallurgical Industry of Mexico, provides the opportunity to present a transdisciplinary study, since it obeys the observations about the monitoring and evaluation that the Public Administration Agencies carry out to the units of the sector, in which they verify the fulfillment of the regulations and denote official and administrative stability, but contrary to this, the perception of society and non-governmental organizations (NGO´s) in terms of the environment, do not coincide and they set in motion, events that complicate the operability and continuity of various units involving political and economic interests.

There are registered in the industrial sector of mining, as a consequence of the activity of these groups known as radicals or NGO´s, rethinking of strategies, change of corporations, investors, corporate name and, in extreme cases, the closure of units. Such is the case of a mining unit located in the state of San Luis Potosí, dedicated since colonial times, to the extraction of *Dore* and other by-products, with an open pit exploitation system, and which in 2014 presented as official the execution of its Total Closure Plan.

For its part, the validation of the Sustainable Management Model, contemplates in its selection for convenience (Hernández, 2014), various mining-metallurgical units that cover types of mining system, metallurgical process, regions in the national territory and type of ore (metallic, non-metallic), being a unit in the closing stage, a representative unit of analysis.
This Model presents in its conception, elements that promote its inclusion from the Environmental Management, through the strategic planning that is conducted with the purpose of the Sustainable theory in search of opening and adjustment of public policies, as well as the effective execution through Sustainable Development Goals (SDGs) and Legislative Parameters.

The SDGs selected, based on their direct implementation in practices that benefit the environment are: (1) industry, innovation and infrastructure (2) sustainable cities and communities (3) responsible production and consumption and, (4) Life of terrestrial ecosystems.

These objectives were considered in the Sustainable Management Model, in which they become the main axis of the study.

The regulatory analysis takes into account the environmental aspect to mitigate impacts, which is why companies in the mining sector must describe the impact risks in official reports. On this basis, government agencies evaluate their veracity in the document called Environmental Impact Manifest (EIM).

Theoretical bases

Mining Sector

This industrial sector covers land preparation activities, ore extraction through drilling, explosions, clearing, loading and transportation, processing and handling of tailings and gangue (SEMARNAT, 2016).

The value and grade of the ore, size, shape, depth, location of the ore body or deposit, physicochemical properties, environmental conditions of the exploitation area, environmental impact of the operation, geological, hydrogeological, geochemical conditions of the rocks, seismic and particular conditions of the terrain or area (biotic and abiotic aspects), availability or use of land, variable infrastructure (financial, permits, taxes, investment, compensation, operating cost); safe working conditions, mineral value recovery fraction, operation continuity and productivity among many other factors and elements, which are derived and described after in-depth technical studies of a given project, are those that condition or provide the information that must be gathered to decide if the studied unit will have a underground mine or an open pit mine type (SEMARNAT, 2016).

The processes or stages covered by the mining industry, according to the General Coordination of Mining (2014) are: (1) *Exploration*, recognizing the area to verify that mineral deposits exist. (2) *Exploitation*, preparation of the area to extract the ore. (3) *Mineral Beneficiation (metallurgy)*: preparation and treatment work, for the separation of the ore from the sterile material or other minerals. (4) *Closure*: end of mining-metallurgical operation (Martínez, Bednarek, Rivera, Ojeda, 2019).

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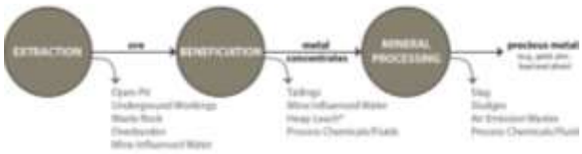

Figure 1. Mining process diagram
Source: EPA, Public Domain (2021)

Open pit mine

Open pit mining consists of the execution of extractive activities of economically valuable material, using techniques such as excavation of pits and shafts on the surface of the earth where there are significant deposits of the material to be extracted (Morán, 2013). This form of extraction expands in the 70's and current decade.

When the rock is removed from the slopes of a hill, the mineral deposit is located on slopes, when the rock is removed from a certain depth from the ground level, the deposit is in pits. For its exploitation, dynamite and crushing machinery are used which occupies reduced spaces, which are located at levels below the upper edges of the exploration; noise is minimized when there are wooded areas around, as a screen effect is generated (Correa, 2000).

Once the excavation has been dynamited, heavy machinery is used to remove waste and recover valuable material, which is transported by trucking to the processing plant or leaching yards. The soil that has been removed is stored in stockpiles or piles for separation; sterile material is also stacked for later use in backfill (restoration).

This method of mineral extraction is more economical and faster, however it produces more waste rock and dust and, devastation of landscape, as well as the consumption of large amounts of large quantities of water (Morán, 2013).

There are four elements to be considered in open pit mining to minimize risks of environmental impacts (Correa, 2000): (1) geographical location, detailing the place of extraction and relationship with neighbors, (2) treatment of the material, measuring noise, vibration (transverse and longitudinal), (3) landscape, changes in it, produce in the physiography, impacts that translate into negative aesthetics (transformation of volumes, earth movement, stripping, loss of vegetation and soil, increased erosion) and, (4) vegetation, allowing selection of species adaptable to the climate, considering meteorological data (precipitation, temperature, humidity, radiation, wind).

Environmental Impacts

Environmental impacts, refer to the adverse effects on ecosystems, climate and society, can be caused by extractive processes, use and deposit of hazardous waste, emission of pollutants into the atmosphere, water, soil and land use change. Classified as direct or indirect according to the side effects they cause, they are also studied on the basis of three dimensions: magnitude, importance and significance (Perevochtchikova, 2013).

De la Maza (2007), describes the character of environmental impacts, which defines the sense of change produced by a project action on the environment, further dividing them into: (1) beneficial or positive impact, (2) harmful or negative impact, (3) neutral impact and (4) foreseeable impact. It also states that they are rated according to their magnitude and expresses it in percentages; it measures them according to human meaning, through levels of importance and certainty.

Environmental impacts can be considered as effects of a project´s actions, in which the time frame to manifest itself is described according to evolution studies, the duration it will have, which may be temporary or permanent and, whether these effects are reversible or irreversible (De la Maza, 2007).

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Environmental impacts of mining processes

Mining activity can generate substantial changes in the relief, modifying the geological structure as a result of exploitation, it can cause destruction of the soil or degrade it, and both, surface and underground water resources can suffer altered; the biological environment can be partially or completely destroyed during mining operations (Arranz, 2015).

SEMARNAT (2016), describes the possible impacts by stages of the process of the sector: the extraction stage can destroy the orography, flora and fauna, in addition to generating dust and particles and during the explosions, combustion gases; underground mines vents emit solid particles containing metals; liquid emissions of residues, there are also traces of compounds from the use of reagents and / or inputs in the extraction and beneficiation process.

There is generation of combustion gases from engines inside and outside the mine, explosive residues. For the benefit of the mineral, flue gases are generated, and the use of water that mitigates dust emissions, will drag particles to the ground, especially in the case of dry operations (SEMARNAT, 2016).

The landscape can undergo modifications, some of them severe, so much so that authors such as Tandy (1979), point out that mining impacts are more aggressive than any other human activity.

Environmental impact risks from mining activities are the combination of the probability of occurrence of an event and the magnitude of its consequence. A risk of lesser magnitude is an event with a low probability of occurrence and negligible consequences, while a risk of greater magnitude has a high probability of occurrence and a catastrophic consequence. The literature that contemplates the impact of the mining industry is usually very broad, inquisitive and directed mainly to liabilities that generate degradation of old mining works.

Mining Environmental Liabilities

The environmental impacts generated by abandoned mining operations or in units where there has not been a regulated and certified mine closure by the corresponding authorities, are known as Mining Environmental Liabilities -MEL-, (Oblaser and Chaparro, 2008); these represent significant or permanent and potential risks.

SEMARNAT (2016), defines MEL as sites contaminated by the release of hazardous materials or waste that were not remediated in a timely manner to prevent the dispersion of contaminants, but involve a remediation obligation.

Mining MEL are usually sites, buildings, surfaces affected by spills, mining waste deposits, sections of disturbed watercourses, workshop areas, machinery or ore yards (Arranz, 2008); these may, depending on their characteristics and those of the context, be arisk of environmental impact.

Abandoned mining

Throughout history, the impact that has produced the old or abandoned mining activity, has been a world reference of damages generated in various places: land without destination or owner, holes that can become traps, aquifers, rivers and contaminated soils, land susceptible to breakage or erosion, destroyed landscapes (Arranz, 2008).

The major difference between active mining and abandoned mining is that the allocation of responsibilities is uneven, and it is an obstacle for the programs, plans, authorities and agencies involved to define the distribution of these among landowners, government agencies, business groups, former beneficiaries and other stakeholders (Arranz, 2008).

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Closing units

Operations in the mining industry can last for decades, accumulating waste (tailings dams) and extracted sterile material (earths or mounds -dumps-) long after the closure of operations. Sometimes these do not represent a danger to the environment, since they do not contain toxic substances, so during closure, in the case of waste, the dam must be drained, the surface flattened and then covered with soil and vegetation and, with respect to the mounds, they must be removed for use as fill, construction or other, avoiding damage to the landscape; on the other hand, if these wastes are considered environmental risks, measures must be taken focused on their stabilization, also reducing the need for monitoring (Adam, 2002, quoted in SEMARNAT, 2016).

When a closing date of a mining unit is stipulated, it should be considered that a re-opening is possible in subsequent years, so it is common that the tailings are deposited in an accessible way, since the unit may recover value due to new mineral deposits, new exploitation techniques or recovery (beneficiation), including the solvency of economic, legal or environmental events (BREF, 2009 quoted in SEMARNAT, 2016).

The aspects that must be followed in a mining unit closure are: (1) physical stability of the buildings, (2) chemical stability of tailings and sterile material and, (3) future land use (SEMARNAT, 2016).

Tailings dams must be prepared for uncontrollable events such as earthquakes, floods and other less drastic but equally destructive events such as air and water erosion; both sterile material and waste, can contain sulfides, causing acid drains, which must be treated even during operation, since if these are discharged and the water level drops, this phenomenon allows the oxygen in the air to react with the sulfides.

The site occupied by the unit, with acid drainage, high metal or sand content, and those not suitable for retaining nutrients or water, hinder closure works such as reforestation.

Mining unit closure plans

At the end of operations, the mining company, government and society, must take measures to protect the safety of people and the environment from harmful effects. Closure planning involves integrating the entire mine area into the closure design, setting times, and considering disposal techniques and methods and economic activities with a social aspect (Sánchez, 2014).

This planning is an environmental management instrument that includes technical and legal actions to be carried out to ensure that the remediation objectives described in it are effective; its strategy includes the rehabilitation of the areas impacted by the mining activity, reaching ecosystem characteristics compatible with healthy environments for the development of life and conservation of the landscape (Chávez, 2015).

Arranz (2008), states that the closure plans, in addition to rehabilitation, contemplate activities concentrated in diverse programs of: *restoration* (activities to return altered land to its original state), *reformation* (activities that managed to approach the original composition), *rehabilitation* (activities to acquires appearance according to a previous plan, ecologically stable and adapts the landscape) and, *remediation* (refers to the removal, reduction or neutralization of substances, residues, materials, in order to prevent adverse effects on the environment.

The purpose of the closure plans is to conserve, improve, recover and rehabilitate resources, ecosystems or landscapes for other uses: To this end, the intervention of agencies that evaluate the damage and promote direct or indirect programs or activities for proper remediation is necessary; these agencies will also be responsible for monitoring on these plans.

Closure plans consistently describe the appropriate programs: restoration, reformation, rehabilitation, or remediation. Companies will try to resolve the most urgent thing in a context of economic and material means, and then continue with a prior list of established priorities.

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Thus, a closure mining plan, or even an abandoned mine plan, is a general outline of actions to be carried out as a part of its environmental management strategy in a given territory: analysis of scientific-technical documentation, analysis of the suitability of budget items for sampling, characterization by means of field and laboratory equipment, contact with organizations, agencies or investors, design of field sheets and verification of validity of land design, field visits to obtain inventories, delimitation of inventory elements on cartography, analysis of information to interpret analytical data, environmental assessment, editing of results and conclusions (Arranz, 2008).

Methodological bases

Case study *Open pit mine in closing stage*

Description of the problem

Open pit mining can generate substantial changes in the landforms: it modifies geological structures, destroys or gradually degrades the soil, alters surface and subway water resources due to the use of explosives, the formation of pits or banks of 3 meters or more height and/or the use of heavy machinery (Arranz, 2015).

From the point of view of environmental alteration, the type of open pit mining is more impacting, since there are visible devastation to the sites and establishment of important areas of deposit of sterile material (earth pits) and others of material for beneficiation (*patios -open yards*). Some authors have called these impacts: disturbed areas, since they have eliminated vegetation and animal communities (Arranz, 2015).

Mining activity has contributed to the foundation, establishment and economic growth of the regions of the state of San Luis Potosí, so that from being an activity that initially generated economy, it extends and manages to incorporate several dimensions: political, social, cultural and environmental (Sánchez, 2014).

Foreign investment in this industry has not been long in coming in the country and in the state, the unit of analysis, object of study, has been in charge of several transnational mining companies acquiring the rights to exploit, and has done so in excessive ways in the absence of legal limits, extracting the mineral resource in an irrational way, obtaining from it, high economic benefit and leaving desolate landscapes, i.e., high environmental impact (Sánchez, 2014).

Faced to this devastation, between the 1980s and 1990s, numerous social activist movements emerged both to claim peoples´ rights over the territory occupied by the unit and to reverse the degradation of the environment (Sánchez, 2014).

Mining legislation in Mexico, in its execution and description, is widely contained in legal ordinances, presents contradictions and there is a notorious lack of mechanisms to follow up on effective compliance. Throughout history, socio-economic difficulties, political disputes and external pressures have prepared information that has generated that the regulations on mining activity have been constantly exceeded and attacked (Sánchez, 2014).

Contextualization of the analysis unit

The mining unit in the process of closure, is in a town 18 km in a straight-line northwest of the capital of the state of San Luis Potosí. The origin of this mining unit, dates before the foundation of the city, when the Huachichiles Indians notified the friars of the time of the existence of mineral, who in turn informed Captain Caldera, a character that history describes as the one who carries out the registration under his command. There are documents that assure that already in 1595, gold and silver were extracted from this place in considerable quantities, in addition to manganese, mercury, lead and copper (Sánchez, 2014).

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The capital of the state was founded in 1592, when the operation of the mine, which was very coarse, was in need of water for the benefit of the minerals; for its part, the mining town suffers from over-population or abandonment since its foundation, there was no stable number of inhabitants, because of has depended on the success or failure of the mine, which through the years has been a bonanza at the national level as in the time of the crown and has been managed by different companies who have invested in search of new deposits and technologies for mineral extraction in quantities superior to the competitive ones of several times in the world (García, 1992).

It is worth mentioning the importance of this unit in the social sphere of the state, since some historians point out that the name of the town and of the capital of San Luis Potosí, is due to the characters who "discovered or managed" the initial operations, thus, there are versions that the full name was dedicated to a Saint, to foreign landowners and to the similarity with mines of that time with coarse deposits of gold and silver in Bolivia (García, 1992).

Throughout the history of the analysis unit, national companies have been at the forefront of operations and in continuous exploration, however, international companies, especially Canadians, have been protagonists of the boom and detrimental situation, leading to its closure.

Particular problems

It was not until 1997 that the mining unit, operated by a Canadian corporation, formally presented procedures to the authority that at that time governed by means of an Environmental Impact Manifest -EIM-, however it does not contemplate land use, 75% of which is for the conservation of wildlife; the appearance of buildings considered heritage, with the explosions, activists argue deterioration, in addition to the hill itself, which is enigmatic for the area, these, among many other irregularities not contemplated in the legislation are added as problems (Sánchez, 2014).

In 2004, in a series of legal, environmental, cultural and, above all, political conflicts, the unit obtained authorization to change land and to operate by means of the open pit mining and leaching system, which is the process of recovering or separating gold from other minerals and sterile material by means of cyanide, which is considered highly polluting and lethal to life (Sánchez, 2014).

After more than a decade and a half of litigation, irregularities, conflicts, impunity and corruption, variants in charge of all the actors of this unfortunate event in the country´s mining industry, the current company that owns the operations of the unit, of Canadian denomination, announces the closure of the unit, leaving behind important projects for the remediation, rehabilitation and restoration of the area , injuries to aquifers, harmful effects due to the use of cyanide and destruction of the hill, among others for which they are being denounced in spite evidence of proving to be an operationally, socially and environmentally responsible company, even with international awards (Sánchez, 2014).

Justification

The research is *original*, since it considers a case study that, in turn, is part of an integral multiple case study (Yin. 2013), in which four representative units of the Mining-Metallurgical Industry in Mexico, called unis of *analysis for the research,* are examined individually with a standardized methodology and instruments, in their environmental practices to formalize the validation and proposal of a sustainable model that obeys international guidelines and the country's regulations, favoring the minimization or eradication of environmental impacts or risks of impact, which promotes the *relevance* and *relevance* of the research.

Objective

The general objective of the case study of the analysis unit undergoing closure is to determine, through the articulation of sustainability principles with the nation´s legislative parameters, the Environmental Management practices described in the closure *plan* presented to the authorities, for retribution to the population, the remediation, rehabilitation and restoration of the environment.

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Specific objectives

1. Make the connection between the parameters of the law and the sustainable principles that the unit of analysis determines, given its closing situation.

2. Describe the observations of each sustainable principle in the closure stage, as a direct expression of the closure *plan* determined in the environmental management of the unit.

Development

The methodology implemented systematically in the four case studies, in this unit of analysis in the process of closure, has variants with respect to the treatment of the personnel, which is very little and, derived from numerous socio-political problems, they are usually skeptical, so that the visits to the unit were more spaced, more limited, the collection of evidence was complex, that is, they showed it to validate them, but do not allow them to be publicly exposed due to policies established within the corporation that is in charge.

The operational area was visited, i.e., the hill from which the ore was extracted, the leaching yards and facilities in general, as well as reforested fields bodering other municipalities.

The application of the observation guides and checklists were meticulously studied, considering that they have the arguments to respond for the productive process even when it is no longer being exercised, so that the information of this unit does provide data to respond in all the principles and parameters, in addition to generating the most information for the final stage considered by SEMARNAT for the Mining-metallurgical Industry -closing- (Coordinación General de Minería, 2014).

Implementation of the sustainable management model

The Sustainable Principles assessed in the fieldwork are four, extracted from the Agenda 2030, which considers 17 Sustainable Development Goals, proposed by the UN (2016), as a result of a hard work of leaders of the countries involved, these are selected mainly because they directly involve the environment:

(1) *Industry, innovation and infrastructure:* Growth and urbanization generate the need for new investments in sustainable infrastructure that make cities more resilient to climate change and drive economic growth and social stability.

(2) *Sustainable cities and communities:* opportunities, access to services, energy, housing, transportation and other facilities. Cities are characterized by being centers that concentrate commerce, culture, science, productivity, creativity, social and economic development.

(3) *Responsible production and consumption:* Promote efficient use of resources and energy efficiency, sustainable infrastructures and facilitate access to basic services, ecological and decent jobs, improve quality of life. Create more and better things with fewer resources, increasing net profits by reducing resource use, degradation and pollution, achieving better quality of life.

(4) *Life of terrestrial ecosystems:* Promote the sustainable use of terrestrial ecosystems, act against desertification, try to stop and reverse land degradation and slow down the loss of biological diversity. The challenges to sustainable development are deforestation and human desertification, through ecosystem restoration.

The legislative parameters observed are taken from the EIM, where the companies are required to describe in detail how they will carry out the activities for each of the 109 items requested therein. Fifteen of them are extracted, which are: useful lifetime, technical responsible, nature of the project, dimensions, land use, urbanization of the area, site preparation, construction of works, operation and maintenance, abandonment, use of explosives, waste generation and management, infrastructure for waste management and disposal, abiotic aspects, biotic aspects and, landscape (Martínez y Bednarek, 2018).

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Generals of the unit of analysis

It is considered a mine with an open pit mining system of metallic ore, mainly gold and silver, however, manganese, lead and copper were also extracted; the metallurgical process was by means of leaching, i.e., using zinc powder and cyanide for the recovery of precious metals through precipitation.

Located 18 km from the capital of the State of San Luis Potosí, it belongs to a municipal seat with 4021 inhabitants. The mining concessions amount to 407 hectares geologically located in a metallic Trend.

The main inputs of the project were: fuel, electricity, explosives, reagents and water. The water needs of the project were covered from nearby wells, for which the National Water Commission (CONAGUA) had issued authorizations, in the same way, for the exploitation it was necessary for the National Defense Secretariat (SEDENA), to grant permits; they also describe the use of thousands of tons of cyanide (MIA, 2010, quoted in Correas, 2014).

Since 1996, the unit was operated and benefited by a Canadian-invested corporation. It had 500 direct employees. The operational projection was stipulated for the year 2021, however, social and political pressures, lead to the decision to close operations between 2016-2019.

Results

The results of the case study of the unit of analysis, a *mine in the closure stage* is presented, which for the purposes of the complete research, are considered preliminary.

The results of the field work show the articulation of the Sustainable Principles and Legislative Parameters, under the described theoretical basis of Sustainability adhered to Environmental Management (Martínez, Bednarek, Rivera, Ojeda, 2019).

1. Articulation between Sustainable Principles and Legislative Parameters:

Table 1 shows how this case study covers all the productive stages of the mining-metallurgical sector, unlike the three units included in the complete study, which only present aspects of prevention before a closure stage, since they operate normally. However, in the case presented in this document, the stages (exploration, exploitation and profit) are established in a historical way, with the emphasis on obtaining information in the last stage, that of closure, as described by the General Coordination of Mining (2014). Therefore, for the purposes of this document, the final relationship that of the closure stage is presented, which was found with each universal principle and the 16 legislative parameters:

Closing Stage / Legislative parameters	Principles of Sustainability II&I	SCC	RPC	LTE
Lifetime				
Technical manager	x	x	x	x
Nature of the project			x	
Dimensions	x	x	x	x
Land use	x	x	x	x
Urbanization of the area	x	x	x	x
Site preparation			x	x
Construction of works	x	x	x	
Operation and maintenance	X	x	x	x
Abandonment	x	x	x	x
Use of Explosives				
Gener-manag of waste	x	x	x	x
Infraestruct manag of waste	x	x	x	x
Abiotic aspects		x		x
Biotic aspects		x		
Landscape	x	x	x	x

Table 1 Relation of closing stage with principles and parameters
Source: Own elaboration

2. Description of Sustainable Principles based on information generated in fieldwork:

After obtaining, analyzing and interpreting the articulation between Sustainable Principles and Legislative Parameters, through the possible generators of environmental risks for each stage of the productive process, there are descriptions on what has been observed of each Sustainable Principle; the results described here denote the mining-metallurgical process as a whole, however, the description focuses on the closure stage.

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Industry, innovation and infrastructure:

There have been no exploration activities since 2012, which is why drilling is not active either. The unit's current reserves are classified with exploration studies carried out in the past and are not economically exploitable. Control of oil material, equipment leaks, spills from deposits in both workshops and exploration squares, led to the construction of concrete containers and mobile tray-type receivers. For mobile equipment such as front loaders and/or similar, it was envisaged that the engine equipment, hydraulic oil pressure hose joints would be checked and, in case of leakage in remote locations and, on dirt roads, immediate notice is given to special leak containment crews, who lift the contaminated soil to a healthy surface and coordinate movements of the equipment until it is repaired on site and/or dragged to the workshop. All maintenance is performed on concrete slabs with oil collection by gutters to the general containment and control site. A safety and control measure was to build a general storage container with a basin at the bottom that has a normal or regular maximum capacity plus 20% which ensures that any spill can be contained.

There are warehouses that are registered, separated and prepared in order to request shipment for confinement by third parties. According to procedure, the waste is recorded within a delivery-reception manifest, which stipulates the type, weight, quantity, unit of measurement, data´s generator, name, delivery date, seal and data of the company, transport company, operator´s general information. This procedure for each collection.

The formation of plots of land is no longer a current activity, in addition, they show that in relevant time in view of the closure, they took into consideration some internal rules: not to start plots of land without complying with the "change of land use", land clearing (respect for flora and fauna), not to build plots of land with invasion of watersheds that obstruct rainwater flows, among others.

At this stage, no tailings are generated, a final waste product that can be considered a landfill, due to the particle size of the material that is not pulverized and / or ground with in the tailings, since the treatment of mineral benefit is carried out by means of the leaching method and the applied reagent is controlled by piping for its distribution and the land is protected with membranes to prevent leaks inside the container (which in this case are basins and containment of curbas with precise specifications in their construction). This was made possible by means of design programs and calculations of volumes to be treated and stored.

With regard to registered technical studies and investments for project closure, they are elaborated in agreement with the corresponding authorities, likewise, they contract and sign agreements with some companies that officially represent them for diverse activities, as evidenced in the case of the "Official mine and environmental safety Representative " with the company Minera Tierra Adentro.

Operating procedures are very strict in their application, both for employees, suppliers and visitors, and are aligned with governmental other standards, such as ISO.

Sustainable cities and communities:

Historically, the unit of analysis in the closure stage, has been subject to social problems, which have become highly volatile political problems, having started these conflicts with leaders who at the time did not comply with financial and environmental regulations; the accumulation of bad corporate strategies and the process of devastation of an open pit mine so close to the capital of San Luis Potosí, have led the current capitalist company to submit closure documents, scheduled for 7 years from 2014.

Through verbal and media communication, which exhibited and still exhibits deficiencies and consequences of frequent work stoppages, is how the leaders of this unit know about the organizations that hinder and damage the operation; these are known as non-governmental organizations (NGOs).

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Access to the operating unit was duly channeled and protected by perimeter fences, plant to mine crossings that even provided a road to the town that houses it, in addition to an elevated bridge, designed to support heavy equipment, these and other works to link the town, which were supervised and authorized by municipal and state authorities.

There are no active powder magazines, so the community has not vibration and the part of the hill that houses the mineral has not undergone physical changes for this concept since 2015.

Regarding the budget items generated for closure, they consider quite onerous items applied mainly to the nearby towns of the operational zone and several activities are scheduled in the closure plan. The application of this resource is remarkable and is executed with the consent of the corresponding authorities. They detail that in spite of considering these items as sufficient, on some occasions NGOs have caused them not to be applied, and these facts have been negatively observed due to the expectations of authorities and communities.

Responsible production and consumption:

As for the operation of the unit in the closing stage, this principle is basically completed, so the description will be focused on the activities scheduled in the closure plan regarding the removal of the unit in the physical plane and / or facilities.

The mine was exploited as "open pit", the exploitation stage has ended and the deposits of sterile material have been identified. As for the beneficiation process, they refer to the buildings and equipment, warehouses and laboratories which obeyed a specific design and were authorized at the time by technical specialists, contemplating what was necessary for its operation and respect for the environment.

At present, no material is received from the mine, only reprocessed material accumulated in yards and pools, without recirculation, only reagent irrigation is maintained to collect values for the leaching system, which has a controlled dosage.

For the control and handling of reagents, the dimensions of the warehouses, as well as places for preparation and addition, are determined by the suppliers, the company and are based on the specific standards for the products and their treatment; currently these dimensions are overrun, since the capacity is reduced to the reprocessing of ore.

The tailings dam was designed, built and operated under high design and practicality standards to store hazardous reagents wastes and ore without economic value; it is in its final stage.

Life of terrestrial ecosystems:

There are internal roads that were built to meet operational needs, they are described in programs contemplate characteristics and reported to agencies such as SEMARNAT, following Official Standards. The landfills, their useful life and their impact on the landscape, are described by means of closure activities in the plan, contemplating how the impacted spaces will be left accordance with the area.

The abandonment of the operating area, as well as its impacts, are described in the closure plan, which also details social, economic, environmental, and conservation of beneficiation works. The community members are constantly being trained for possible development activities in preparation for closure.

It has been establish that the use of current facilities, so as not to leave them in abandonment, will be removed except for those that the community believes are relevant for future use, being responsible for them at the time determined by both parties. It is expected that, the NGOs will intervene during the execution of the activities programmed in the closure plan, especially in the aspect of ecosystem care, so it is decided to resort to the experience that has been have with them during the operative time in which they were dormant.The closure plan program, from the outset, established an accumulating economic fund to cover end-of-operation and abandonment costs. These figures are currently reviewed and compared to the value of money over time. For this purpose, they also contemplate activities such as the use of the land they have, either for sale or rent, according to their economic value in mineral deposits.

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Conclusions

This unit of analysis represents the end of a mining unit, so the description focuses on the closing stage and emphasizes what is described in the *closure plan* and what was observed by the researchers. The field work of this case study was decisive in the research, since it is an open pit mine that was forced to close its operations after a social-environmental controversy that was unleashed by NGOs, but which in its foundation contemplates severe landscape damage and operating practices that were not consistent with the company´s official standards.

The unit has canadian capital, which led it to maintain high operating systems, even in the final stage. The case study contains representative information for global research, which once the four selected analysis units are integrated and interpreted together, in addition to meaning that the sustainable model is validated, will provide the opportunity through a guide of best practices, to collaborate with the minimization of impacts and risks of environmental impacts (Martínez, Bednarek, Rivera, Ojeda, 2019).

The general perception of the researchers, in this unit of analysis in the closing stage, becomes peculiar in the attitude of the staff in general; the operatives, it should be clarified that there are very few, with multiple roles and functions and also, with the singular characteristic of belonging to the nearby towns, are calm in the face of the imminent decision of dismissal in the short term, which confirms the effectiveness of the company´s activities in this aspect; on the other hand, the information they have access seems to be limited. For their part, the trusted personnel, who occupy decision-making positions, are not permanently in the unit, but travel with certain frequency, those who are in charge of the operational functions, also multiple, are totally distrustful, susceptible even to provide information and seem not calm before the possibility of dismissal , it should be clarified that some of them may be willing to change in other units that belong to the corporate that represents them.

The evidence, therefore, is reduced to media plans, they were not flexible in showing the official closure plan and documents such as current permits or procedures. This observation is attributable to the multiple social and NGO problems that have arisen throughout history, which have been politized without control: for this reason, they have developed very strict and very conservative internal policies for the exhibition of their operation to society.

As a particular conclusion, it is considered that the budget items to carry out a closure plan must be developed since the unit starts operations, due to the high cost for the company in economic value, for the country in loss of mining production and, the environmental cost, which involves the community , the operating area, the operability itself and the environment, reflected in the ecosystems, being these precisely the sustainable principles measured in this study under the proposed model.

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