Methodology for the implementation of an environmental management system in a mining operation

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***Abstract*– Mining operations often generate a range of waste and effluents that must be managed and disposed of safely for company personnel, surrounding communities and the environment. In this sense, a mining company must implement an environmental management system in accordance with Peruvian legislation. This paper shows the methodology to follow to implement an environmental management system that can resolve and prevent potential environmental impacts already generated or about to be generated. For the case study, an underground mining operation was chosen that is one of the world's leading producers of zinc, silver and lead. This methodology includes the following steps: 1) developing the company's environmental commitment and policy, 2) planning the activities to be developed at each stage of the production process, 3) implementing the management system, 4) measuring and evaluating the implemented system, 5) proposing a continuous improvement plan.**

***Keywords*-- Environment, environmental impacts, environmental liabilities, environmental management, mining industry.**

I. Introduction

Management systems, whether quality, environmental or safety, are tools that facilitate the administration of companies and, consequently, achieve greater efficiency and effectiveness in each of them [1-5]. That is, a company with a well-implemented management system incorporates the concept of continuous improvement in all its activities, which means that every day it does things better in a planned manner and with clear objectives.

A mining organization that has not implemented an environmental management tool will face, in addition to diminishing its competitiveness in the market, environmental deficiencies or problems [6-16]:

- by not implementing pollution prevention actions or ensuring the minimization of environmental impacts from the design stage, only corrective environmental management can be carried out. This is, in most cases, slow and expensive processes.
- poor communication on environmental issues between the different areas of the company and third parties (contractors, suppliers, communities, etc.) due to the lack of specifications and organization of properly defined good environmental practices.
- environmental management is little explored since creative platforms are required.
- behavior that is not oriented towards achieving objectives and goals, given that most areas of the organization cannot identify their own environmental objectives or goals, much less those of the organization itself and especially those that are relevant from an environmental point of view.
- little effort in research and management of environmental liabilities.
- decreased chances of attracting new investors, given that companies without environmental policies are not well regarded in the international market.
- payment of fines for not respecting the respective environmental legislation.
- disrespected in the national and international mining community.
- increase in socio-environmental problems with neighboring communities.

An environmental management system (EMS) is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency [10,11,17-19]. In fact, EMS, which is the component of the overall management system that includes organizational procedures, environmental responsibilities, and processes, helps an industry comply with environmental regulations, identify technical and economic benefits, and ensure that environmental policies are adopted and followed [1,20-23].

In the mining industry, its various stages of operations face on the one hand socio-environmental complications and on the other hand the challenge of meeting planned production. In order to harmonize both aspects, it will be necessary to implement an EMS to achieve cleaner industrial production [24-27].

II. Methodology

The implementation of the manual and procedures must be based on the requirements specified by ISO 14001, which indicate that it is necessary to define a policy and planning, implementation and operation, verification and corrective actions (Table I and Figure 1) [3]. Then, to design a strategic plan for the implementation of an environmental management system in a mining operation, it will be necessary to choose the following methodology:

- Select a mining operation
- Define the company's Environmental Policy in conjunction with company management
- Description of the site's environmental characteristics
- Activities description (including responsibilities and legal requirements definition and description)
- Gather information on the environmental management of the operation's processes (including energy and raw materials consumption analysis and abnormal operating conditions definition and description)
- Identify and prioritize the potential environmental impacts of the previously identified processes
- Develop an environmental management program plan with preventive and corrective actions
- Establish the chain of command for each process to define levels of responsibility for each preventive or corrective action
- Identify the operation's stakeholders to ensure the sustainability of the implementation
- Develop an action plan with the area managers, including the necessary budget to monitor the progress of preventive and corrective actions, and execution timelines
- Propose a schedule for continuous review of the results obtained and the improvements to be implemented
- Documentation of relevant environmental aspects

TABLE I
MINERAL RESERVES OF THE MODEL UNIT [3].

Step	Requirements ISO 14001
Background to the standard	1. Scope 2. Normative references 3. Terms and definitions
Planning	4. Context if organization 4.1 General Requirements 4.2 Environmental aspects 4.3 Planning 4.3.1. Environmental aspects 4.3.2. Legal and other requirements 4.3.3. Objectives, targets and program(s)
Implementation and operation	4.4 Implementation and operation 4.4.1. Resources, roles, responsibility and authority 4.4.2. Competence, training and awareness 4.4.3. Communication 4.4.4. Documentation 4.4.5 Control of documents 4.4.6. Operational control 4.4.7. Emergency preparedness and response
Checking and corrective action	4.5 Checking 4.5.1. Monitoring and measurement 4.5.2. Evaluation of compliance 4.5.3. Nonconformity, corrective action and preventive action 4.5.4. Control of records 4.5.5 Internal audit 4.6. Management review

Fig. 1 ISO 14001 structure [24].

III. RESULTS

The mining company decided to establish, document, implement, maintain and continually improve an Environmental Management System (EMS) in accordance with the requirements of the international standard ISO 14001 and determined how to meet these requirements by periodically reviewing and evaluating said system to identify opportunities for improvement and its implementation. The results obtained throughout the implementation are detailed below.

A. Case study

For the implementation of the ISO 14001 Environmental Management System (EMS), a mining company located in central Peru was chosen, as it is one of the world's leading producers of zinc, silver, and lead. This mining company has 4 operations and 7 mines, so it was necessary to define an operation for the implementation of the EMS. The operational unit of the Economic Administrative Unit of the mining company, chosen for the study, which we will refer to from now on as the "model unit", is located in the Province and Department of Pasco in the Andrés Avelino Cáceres Region and is located at an altitude of 4,340 m above sea level, 130 km from La Oroya and 310 km from Lima (Figure 2). Due to its long operational history, this mining operation presents challenges. Most of the operators are unaware of the environmental implications of their own work. Which could simultaneously represent a space of opportunities and improvements.

The model unit has a total of 2,400 employees (workers and contractors). Mining operations are carried out in an

underground mine and an open pit. The production of the underground mine is 105,000 tons/month and the production of the open pit is 170,000 tons/month, which represent 46% and 54% of the production, respectively.

The 275,000 tons/month are processed in the concentration plants A (8,500 tons/day) and B (520 tons/day), obtaining 340,000 tons of Zinc concentrates and 108,000 tons of Lead concentrates annually.

Fig. 2 Location of underground mining operation.

B. Definition of environmental policy

The board committee of the mining company defined the environmental policy of the organization, reflecting in it its commitment to comply with the applicable legal requirements and other requirements. It also committed to preventing pollution through a process of continuous improvement, all within its scope and in accordance with the ISO 14001 Standard [29].

Environmental policy should cover important aspects as:

- Understand and evaluate the environmental implications of the various stages of the mining process carried out by the company and its contractors.
- Commit to implementing, maintaining, and improving the requirements of the ISO 14001 standard.
- Comply with Peruvian environmental regulations and adapt accordingly.
- Prevent environmental pollution by ensuring continuous process improvement based on existing technologies.
- Organize regular training courses, workshops, or seminars related to the environmental management system.

C. Planning

1. Environmental aspects

The mining company created, implemented and maintained an Environmental Aspects Identification procedure whose main objective is to identify, evaluate, classify and record the environmental aspects generated by the various activities of the operation. This procedure would serve to determine, prevent and control those environmental aspects that have or may generate significant impacts on the environment. This information will serve as a baseline to propose preventive or corrective actions, as appropriate.

The documents associated with the Procedure for Identification of Environmental Aspects are:

- Scoring Table for the Evaluation of Environmental Aspects.
- Scoring Table for the Evaluation of Requirements.
- Evaluation Table of Probabilities in Abnormal Conditions.
- Evaluation Table of Probabilities in Emergency Conditions.
- Summary of the Global Conclusion of Environmental Aspects.
- Environmental Liabilities Identification Plan.
- Design of New Projects.

With a global flow chart of the entire mining operation, it was possible to identify the environmental aspects generated by the various activities of the Model Unit (Figure 3).

For this purpose, the environmental impacts were grouped into four categories:

- soil impact
- atmospheric impact
- noise generation
- energy demand

By collecting information in the model unit, it was determined that there was a total of 212 environmental aspects. Of these 212 environmental aspects, 77 are considered significant environmental aspects (urgent to correct or mitigate), of which 58 correspond to environmental aspects of the underground mine. Of these 58, 25 are considered significant environmental aspects. Additionally, legal requirements, corporate requirements and interested parties are taken into consideration [30].

These 77 significant environmental aspects served as the basis for the implementation of the EMS. Also, each environmental aspect was assigned an area manager in order to ensure the evaluation and monitoring and/or implementation of corrective actions once the EMS was implemented (Tables II, III, IV and V). It can be observed that the largest number of environmental impacts are related to soil pollution (15 items), followed by air pollution (6 items).

Conversely, only 2 and 1 items were identified for noise pollution and energy demand, respectively.

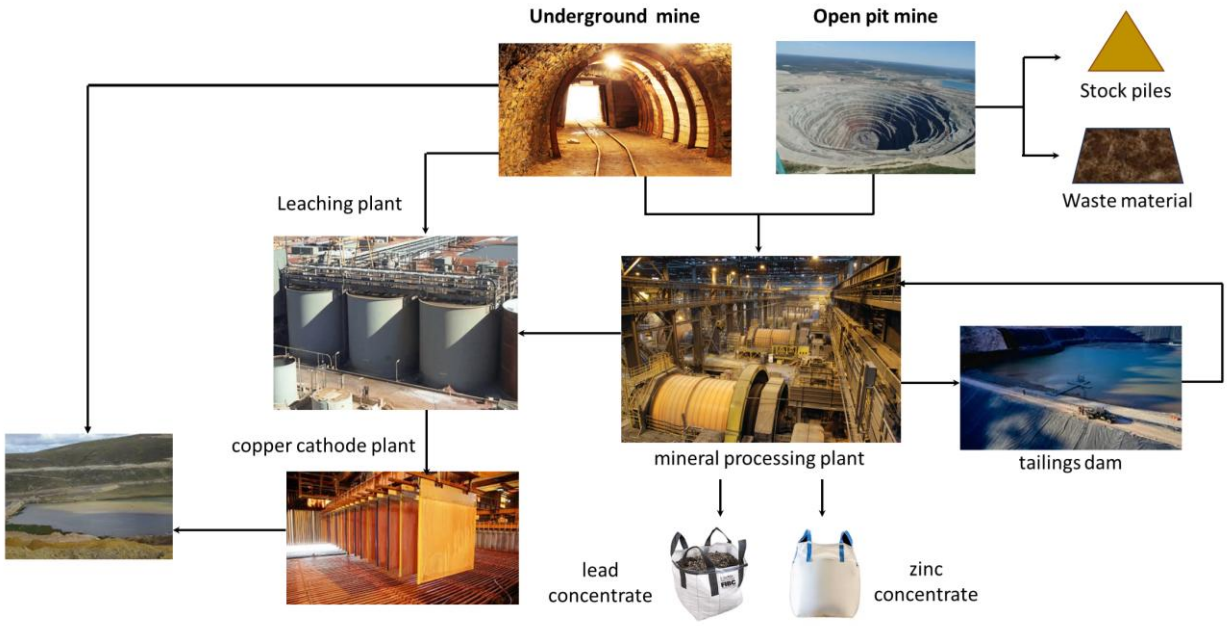

Fig. 3 Operations in the model unit.

TABLE II
POTENTIAL ENVIRONMENTAL IMPACTS ON THE SOIL DUE TO MINING OPERATIONS IN THE CASE STUDY. [30]

Item	R[a)]	Group	Environmental Aspect	Responsible
1	5	Chemicals	PCB (Askarel)	Head of electrical maintenance/maintenance superintendent
2	15	Liquid Waste	Hydraulic landfill	Hydraulic Landfill Manager/ Mine Superintendent
3	18	Explosives	Emulsion	Mine Chief /Mine Superintendent
4	19		Ammonium nitrate	
5	20	Fuels and Lubricants	Diesel Oil No2	Maintenance Manager / Maintenance Superintendent
6	24	Explosives	Fulmesa blasting head	Mine Chief / Mine Superintendent
7	31	Solid Waste	Debris Removal	Mine Manager / Mine Superintendent
8	32	Explosives	Dynamite (specific gelatin + semexa)	Mine Chief / Mine Superintendent
9	40	Explosives	FAMESA Connector	
10	41		Detonating cord	
11	42		Detonator	
12	44		Fanel (includes dual fanel)	
13	47	Fuels and Lubricants	Used oil	Maintenance Manager / Maintenance Superintendent
14	69	Solid Waste	Grease (all types)	
15	57	Natural Resources	Wood	Mine Manager /Mine Superintendent

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.

TABLE III
ENVIRONMENTAL IMPACTS IDENTIFIED AS POTENTIAL NOISE POLLUTANTS IN THE UNDERGROUND MINE – MODEL UNIT. [30]

Item	R[a)]	Group	Environmental Aspect	Responsible
1	52	Ethereal Waste	Noise of fans	Head of Services
2	53		Drilling noise	Mine Manager / Mine Superintendent

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.

TABLE IV
ENVIRONMENTAL IMPACTS IDENTIFIED AS POTENTIAL RESOURCE DEPLETATION IN THE UNDERGROUND MINE – MODEL UNIT. [30]

Item	R[a)]	Group	Environmental Aspect	Responsible
1	27	Electrical energy	Electrical energy	Electrical maintenance manager/ Maintenance superintendent

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.

TABLE V
POTENTIAL ENVIRONMENTAL IMPACTS ON THE AIR DUE TO MINING OPERATIONS IN THE CASE STUDY. [30]

Item	R[a)]	Group	Environmental Aspect	Responsible
1	8	Gas to the Environment	Gas Emissions (SOx)	Services Manager/ Mine Superintendent
2	9		Gas Emissions (CxHy,VOCs)	
3	10		Gas Emissions (COx)	
4	26	Gas to the Environment.	Gas Emissions (NOx)	
5	33	Natural Resources.	Indoor ventilation mine	
6	35	Ethereal Waste	Vibration	

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.

2. Legal and other requirements

The mining company implemented and maintained the Procedure for the Identification of Legal Requirements and Regulations Associated with the Environment whose main objective is to identify and access in a timely manner the legal requirements and regulations associated with the environment (audits and inspections, EIA, emissions and discharges, mine closure, dust, vapors, gases, etc.).

3. Objectives and goals

In addition to reducing, minimizing, and eliminating some of the impacts described above, the mining company decided to create, implement, and maintain a Procedure for Establishing and Controlling Environmental Objectives and Targets. This allowed them to establish environmental objectives, specific targets, responsible parties, and performance indicators. The implementation of the EMS will require:

- Identify the significant environmental aspects of the activities, products and services.
- Identify the legal and other standards to which the organization adheres.
- Establish objectives and goals that respond to these requirements.

Tables VI, VIII, IX and X present the objectives and goals of the environmental impacts organized by group to comply with the ISO 14001 standard.

TABLE VI
ENVIRONMENTAL OBJECTIVES AND GOALS TO ELIMINATE OR REDUCE ENVIRONMENTAL IMPACTS OF SOIL. [30]

Item	R[a)]	Environmental Aspect	Objectives	Goals
1	5	PCB (Askarel)	Eliminate its use	Replace 30% of the equipment that contains or uses PCBs
2	15	Hydraulic landfill	Control leaks	Prevent leaks 100%
3	18	Emulsion	Comply with the regulations and current law	Comply 100% with D.S. 046-01-EM[b)]
4	19	Ammonium nitrate		
5	20	Diesel Oil No2	Improve supply control	Perform maintenance/inspection and/or change accessories for D2 supply
6	24	Fulmesa blasting head	Comply with current regulations and laws	Comply 100% with D.S. 046-01-EM[b)]
7	31	Debris Removal	Locate it in appropriate areas	Transfer it 100% as open pit fill inside the mine
8	32	Dynamite (specific gelatin + semexa)	Comply with current regulations and laws	Comply 100% with D.S. 046-01-EM[b)]
9	40	FAMESA Connector	Comply with current regulations and laws	Comply 100% with D.S. 046-01-EM[b)]
10	41	Detonating cord		
11	42	Detonator		
12	44	Fanel (includes dual fanel)		
13	47	Used oil	Market	Market 100%
14	57	Wood	Reduce consumption	Reduce consumption by 10%
15	69	Grease (all types)	Market	Market 100%

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.

[b)]D.S. 046-01 EM: Peruvian Mining Safety and Hygiene Regulations (In Spanish).

TABLE VII
ENVIRONMENTAL OBJECTIVES AND GOALS TO ELIMINATE OR REDUCE ENVIRONMENTAL IMPACTS OF AIR. [30]

Item	R[a)]	Environmental Aspect	Objectives	Goals
1	8	Gas Emissions (SOx)	Comply with the regulations and current law	Comply 100% with D.S. 046-01-EM[b)]
2	9	Gas Emissions (CxHy,VOCs)		
3	10	Gas Emissions (COx)		
4	24	Gas Emissions (NOx)	Comply with current regulations and laws	Comply 100% with D.S. 046-01-EM[b)]
5	32	Dynamite (specific gelatin + semexa)	Comply with current regulations and laws	Comply 100% with D.S. 046-01-EM[b)]
6	35	Vibration	Comply with environmental guidelines for drilling and blasting in mining operations	Comply 100% with the LMP[c)] (<2 pg/s.)

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.
[b)]D.S. 046-01 EM: Peruvian Mining Safety and Hygiene Regulations (In Spanish).

TABLE VIII
ENVIRONMENTAL OBJECTIVES AND GOALS TO ELIMINATE OR REDUCE ENVIRONMENTAL IMPACTS OF NOISE. [30]

Item	R[a)]	Environmental Aspect	Objectives	Goals
2	52	Noise of fans	Comply with current regulations and laws	Comply 100% with D.S. 046-01-EM[b)]
3	53	Drilling noise		

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.
[b)]D.S. 046-01 EM: Peruvian Mining Safety and Hygiene Regulations (In Spanish).

TABLE IX
ENVIRONMENTAL OBJECTIVES AND GOALS TO REDUCE ENERGY CONSUMPTION. [30]

Item	R[a)]	Environmental Aspect	Objectives	Goals
11	27	Electrical energy	Reduce consumption	Reduce consumption from 74.10 to 73.70 Kw-h/TM Head

[a)]Uppercase Ranking according to the score obtained with respect to the 77 significant environmental aspects of the Model Unit.

4. Environmental management programs

The mining company created, implemented and maintained the Procedure for the Establishment and Control of the Environmental Management Program, whose main objective is to establish and implement the environmental management program (EMP) in order to comply with the ISO 14001 standard.

D. Implementation and Operation

1. Organizational structure and responsibilities

The mining company created, implemented and maintained the Procedure for Establishing Structure and Responsibility (Tables X, XI, XII and XIII), whose main objective is to establish and implement organizational charts, describe positions, create procedures on lines of communication, calculate budgets to cover organizational needs, submit regular reports to senior management and regular communication between senior management and employees.

Top management must provide the essential resources for the implementation and control of the EMS. These resources include both human resources and specialized knowledge, as well as technological and financial resources.

TABLE X
ORGANIZATIONAL STRUCTURE WITH RESPECTIVE RESPONSIBILITIES FOR GENERAL REQUIREMENTS OF THE ENVIRONMENTAL MANAGEMENT SYSTEM. [30]

Elements	Generation of the procedure	Review	Approval
Environmental Policy	Central operations management	Central operations management/deputy general management.	General management

TABLE XI
ORGANIZATIONAL STRUCTURE WITH RESPECTIVE RESPONSIBILITIES FOR THE PLANNING OF THE ENVIRONMENTAL MANAGEMENT SYSTEM. [30]

Elements	Generation of the procedure	Review	Approval
Environmental Aspects	Head of Environment	Central Operations Management	Central Operations Management/Deputy General Management
Legal and Regulatory Requirements	Head of Legal Department	Safety Superintendent	
Objectives and Goals	Head of Environment	General Superintendent	
Environmental Management Program	Head of Environment	Central Operations Management	

TABLE XII
ORGANIZATIONAL STRUCTURE WITH RESPECTIVE RESPONSIBILITIES FOR IMPLEMENTATION AND OPERATIONS OF THE ENVIRONMENTAL MANAGEMENT SYSTEM. [30]

Elements	Generation of the procedure	Review	Approval
Structure and Responsibility	Environmental Manager	General Superintendent	Central Operations Manager/Deputy General Manager
Training, Knowledge and Competence	Training Manager	Security Manager	
Communications	Environmental Manager	Office of Labor Relations and Human Resources Manager	
EMS Documentation	Environmental Manager	General Superintendent	
Document Control	Environmental Manager	Security Superintendent	
Operational Control	Environmental Manager	Security Superintendent	
Emergency Plans and Training	Security Manager	Security Superintendent	

TABLE XIII
ORGANIZATIONAL STRUCTURE WITH RESPECTIVE RESPONSIBILITIES FOR CHECKING AND CORRECTIVE MEASURES OF THE ENVIRONMENTAL MANAGEMENT SYSTEM. [30]

Elements	Generation of the procedure	Review	Approval
Monitoring and Measurement	Environmental Manager	Safety Superintendent	Central Operations Management/General Sub-Management
Non-Conformity, corrective and preventive actions	Environmental Manager	Engineering and Planning Superintendent	
Records	Environmental Manager	General Superintendent	
EMS Audit	Environmental Manager	Central Operations Management	
Management Review	Environmental Manager	Central Operations Management	

2. Training, awareness and professional competence

The organization created and implemented a General Training, Awareness and Competence Plan whose main objective is to maintain continuous comprehensive training for awareness and training of personnel directly linked to environmental issues and thus comply with the ISO 14001 Environmental Standard. Definitely the most difficult part of implementing the EMS is ensuring continuous improvement in environmental issues for the company's staff (Table XIV).

3. Records.

The organization created, implemented and maintained a procedure for the Control of Environmental Records whose main objective was to identify, archive, maintain and dispose of the records in order to enable their traceability and show objective evidence of compliance with the operational procedures, all in order to comply with the ISO 14001.

TABLE XIV
TRAINING PROGRAM ON SPECIFIC TOPICS FOR ENVIRONMENTAL MANAGEMENT ACCORDING TO THE ENVIRONMENTAL MANAGEMENT SYSTEM.

Specific topics	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Control and Management of Gases.			x			x			x			x
Control of Liquid Waste		x			x				x			x
Disposal of waste gases.			x			x			x			x
Drilling and Blasting Techniques	x					x						
Elements of the EMS		x					x			x		
Environmental Management Techniques		x					x					
Equipment Operation Techniques	x		x		x		x		x		x	
Hydraulic Engineering Techniques				x				x				
Legal Requirements	x			x				x				
Liquid Management and Control Techniques		x			x			x			x	
Sustainability Techniques			x			x			x			x

E. Control and Corrective Action

1. Monitoring and measurement.

Environmental monitoring equipment must be calibrated and properly maintained. A calibration log has been implemented. This documentation procedure allows for a periodic assessment of compliance with applicable environmental legislation and regulations.

2. Non-conformity, corrective and preventive actions.

The organization created and implemented a Non-Conformity; Corrective and Preventive Actions procedure whose main objective was to establish and specify the systematic steps to carry out corrective and preventive actions in relation to the ISO 14001 standard. Any corrective or preventive action adopted to eliminate the causes of non-conformities, real or potential, must be appropriate to the magnitude of the problems detected and proportional to the environmental impact recorded.

3. Audit of the environmental management system.

The organization created, implemented and maintained an Internal Audit Procedure of the Environmental Management System whose main objective was to carry out internal audits

according to a schedule established by the Environmental Superintendent.

F. Management Review

The organization has created and implemented a Management Review procedure whose main objective is to make an annual review of the Environmental Management System, in order to comply with the ISO 14001 standard.

The Management review process must ensure that all information necessary for Management to carry out this assessment is collected. This review must be documented.

The Management review must consider the possible need for changes in the policy, objectives and other elements of the EMS, in light of the results of the audit of the environmental management system, changing circumstances and the commitment to continuous improvement.

G. After the implementation of the ISO 14000 system

The year after implementing ISO 14000, the mining company, in order to guarantee a sustainable operation over time, has taken a further step by implementing a management system in the areas of Safety, Occupational Health, Environment, Communities and Corporate Governance [31]. The SOMAC system will allow the following:

- Scope: The system encompasses health, safety, and community leadership across all its mining operations.
- Management Approach: Based on the PDCA (Plan, Do, Check, Act) continuous improvement cycle, focused on operational discipline.
- Continuous Evolution: The company has strengthened this model over the years, with significant updates in 2023 and 2025 to reinforce critical risk controls.

In addition, the implementation of ISO 14001 at the model mining company has been fundamental in structuring its environmental management, achieving significant improvements in operational efficiency, risk reduction, and sustainability. As part of these efforts, the mining company launched the CleanWork system in 2023, an initiative that standardizes good environmental practices and aligns with the requirements of ISO 14001, the International Council on Mining and Metals (ICMM) standards [32], and the Sustainable Development Goals (SDGs) [33].

According to the company's 2024 sustainability report [34], the implementation of the ISO 14000 system and its updates have resulted in:

- Saving 566,113 gallons of water
- Reducing used oil generation by 63,350 gallons
- Decreasing space usage by 2,646 m³
- Saving 654,506 kWh of energy demand
- Increasing recirculated water to 51%
- Saving 12.6 million m³ of fresh water
- Using up to 20% renewable energy consumption
- Generating only 9% non-industrial waste
- Rehabilitating 4.5 hectares of impacted areas.

The key results of the ISO 14001 system implementation can be summarized as follows:

- Improved Sustainable Performance: In 2024, Volcan achieved a sustainability performance score of 60%, representing an 11% increase over the previous year, driven by improved risk management and efficiency.

- Emissions Reduction: The company achieved a 7% reduction in greenhouse gas emissions in 2024 compared to 2023, thanks to energy management strategies aligned with ISO standards.

- Water Management and Circular Economy: Through its management systems, Volcan focuses its efforts on water recirculation and has reported the reprocessing of more than 4 million tons of mining waste.

- Strengthening CleanWork: In 2025, the performance index under the CleanWork framework (based on ISO 14001) increased by 8%. Monitoring and compliance: There are 89 air quality monitoring stations and water treatment systems at their units.

NEXT STEPS

To obtain complete research results, it will be necessary to:

- conduct a cost-benefit analysis of the implementation.
- update the mining company's data.
- add a section with actual performance data.
- analyze the subsequent integrated implementation of a safety and environmental management system.
- comparison with the Safety, Occupational Health, Environment and Quality (SOHEQ) system.
- link the environmental management system with the company's sustainability reports.

IV. Conclusions

It is possible to implement the ISO 14001 Environmental Management System in the model unit of the underground operation studied. The most difficult part of the implemented EMS was to identify the environmental impacts at each stage of the mining operation. As well as to determine the degree of each impact on the environment. Environmental impacts on the soil are the most significant, followed by impacts on the atmospheric environment.

A matrix containing the list of Hazardous Materials was developed. With this information, a Waste Management Plan, Environmental Emergency Response Plan, Environmental Audits and Inspections could be implemented.

The participation of the company's Senior Management is important in order to distribute responsibilities, raise awareness among the operation's workers and manage adequate budgets for the implementation of the EMS.

Implementing an Environmental Management System (EMS) will allow the company to be more competitive in the market while focusing on cleaner production.

The implementation of the ISO 14000 system and its subsequent updates have allowed the company to:

Standardize its Processes: Adopting the standard enabled the establishment of clear policies, hazardous waste monitoring programs, and environmental emergency response plans at units such as Cerro de Pasco and Paragsha.

Implement a Culture of Prevention: Implementation has facilitated the transition to a preventative culture, mitigating impacts on water, air, and soil.

Improve Community Relations: Environmental awareness has been incorporated into surrounding communities, including emergency response simulation workshops.

The mining industry should encourage greater participation in research with academic institutions to propose sustainable mining solutions for waste management. Mining waste should not only be reduced in volume, but can also be sustainably reused. Research could be conducted on the reuse of end-of-life tires (ELTs), given that off-the-road (OTR) tires from large-scale mining represent a high volume of waste. Mining tailings could be repurposed as a secondary source of metals or as raw material for other industries such as construction.

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