# ANTAMINA: TRANSFORMING 25 YEARS OF ENVIRONMENTAL DATA INTO A SYSTEMATIC EMS

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**Abstract**

Antamina, the largest mine of Perú and fourth of South America, is a copper & zinc mine located in the white range of northern Peru. Operating since 2001, Antamina has been conducting numerous environmental surveys and baseline studies since 1996, collecting data for water, soil, air, noise, biodiversity, among other environmental features. That is 25 years of environmental performance data of a copper mine world class.

In 2019, Antamina embarked on a journey to produce a new EIA Modification due to changes needed for its mining facilities, which included an actual characterization of environment to complement the periodic monitoring surveys. This led to massive databases that were put together and analyzed to understand the condition of the environment surrounding Antamina.

This comprehensive analysis proved that Antamina's surroundings, which are mostly comprised of natural habitats, were thriving right next to the mining activities. Demonstrating, therefore, that Antamina's current EMS meeting its objectives, and the impacts of mining activities were mostly limited to its actual footprint.

Besides, this thorough analysis also identified new opportunities to improve its EMS and focus on specific habitat factors, which was accepted and approved by Peruvian State in February 2024.

The new EMS will allow Antamina to have a robust system to monitor its impacts on its surrounding environment and have readily available information to ensure an adequate follow up of its performance.

*Keywords: Environment management system (EMS), mine, Environment Impact Assessment, databases.*

## 1. Introduction

Antamina is large polymetallic mining complex operating by Compañía Minera Antamina, that primarily produces copper and zinc concentrates, also molybdenum, silver, and lead by-products. Located in the Andes Mountain of north-central Peru at an altitude of 4,200 meters above sea level in the Ancash Region, approximately 270 kilometers north of Lima. The mine is operated as an open pit using truck and shovel methods, including a conventional concentrating process plant. The copper and zinc concentrates produced are then transported by a 302-kilometer pipeline to Puerto Punta Lobitos (PPL), Antamina's port located in the coastal province of Huarmey, Ancash Region, from where are shipment to smelters and refineries world-wide.

The Antamina project was initiated in 1998 after the approval of the first Environmental Impact Assessment (EIA 1998), and commercial production began in mid-2001. Over the years, 17 environmental management documents of varying scope have been approved, the most recently being the Environmental Management Instrument (EMI, 2025) and the Environmental Impact Assessment Modification (EIAM, 2024). The EIAM (2024) considers as particularly significant due to the incorporation of actual and new data plus results of environmental monitoring surveys conducted over the past 25 years, providing an extensive and significant evaluation of environmental conditions surrounding the mine.

The systematic integration of information has enabled multiscale analysis, providing a holistic understanding of environmental conditions and evaluating the impacts associated with Antamina's operations. This approach has been essential for assessing the effectiveness of existing management strategies and implementing innovative measures to ensure long-term environmental sustainability. Therefore, this study shows how an integrated environmental analysis data is a key tool for ensuring sustainability and optimizing decision-making in large-scale mining projects.

## 2. Study area

Antamina mine features a mountainous terrain, primarily situated on the Jumasha and Celendin geological formations, located over a Skarn deposit overlain by Cu-Mo porphyry mineralization (Redwood, 2004) (Figure 1). This topography influences the local climate, characterized by a wet season (October–April) with monthly rainfall exceeding 100 mm and a dry season (May–September) with values below 50 mm. The relative humidity varies seasonally, promoted diverse microclimates and supporting biodiversity, while the temperature fluctuates minimally (<1.5°C), with slightly higher values during the wet season.

The geographic and climate conditions promoted a diversity of ecosystems, distributed across five natural ecosystems, equivalent to vegetation units described as a "dynamic complex of plant, animal, and microorganism communities and their living environment that interact as a functional unit" (MINAM, 2019): grasslands, wetlands, high Andean forest, shrubland, rocky outcrops, and with two anthropogenic ecosystems (agricultural and forest plantations). In the aquatic ecosystems, three natural freshwater ecosystems are identified: streams, rivers and lakes, which host a diverse range of organisms, from planktonic species to endemic fish of the high Andean region.

## 3. Integrating 25 years of environmental data

The EIAM (2024)'s actual environment characterization involved the systematic of information from various studies, ranging from the EIA (1998), with data from 1996 and 1997, to the most recent records from 2021. This integration included internal monitoring and environmental compliance data collected by Antamina, as well as secondary sources from Peruvian institutions such as the National Service of Meteorology and Hydrology (SENAMHI), the National Water Authority (ANA), and the Environmental Evaluation and Oversight Organization (OEFA) (Table 1). Throughout this period, the quality of the data collected by Antamina met rigorous national and international technical standards, aligning with global best practices.

This integration of data enables a robust environmental characterization, identifying key spatio-temporal trends and patterns. Furthermore, it facilitates a comprehensive analysis of environmental impacts and the effectiveness of management measures.

## 4. Patterns, trends and perspectives

The environmental data analysis was based on the systematic processing of 25 years of Antamina's information. Meteorological data integrated records from stations operated by Antamina and SENAMHI (including its calibration with Wheater Research and Forecasting models), optimizing the representativeness temporal climate series. This led to a robust climatic and hydrological characterization, enabling a precise estimation of an integral water balance that considers surface water contributions, mining operational requirements, and the maintenance of ecological flow and population water uses.

Air quality analysis shows $PM_{10}$, $PM_{2.5}$ and metal levels within Peruvian environmental standards, with occasional some exceedances linked to external anthropogenic sources (burning of grass and wood, and vehicle traffic). Noise, vibrations, and non-ionizing radiation recorded values within permitted standards, with occasional exceptions related to external factors such as vehicle traffic, animal presence, and climatic phenomena (hail).

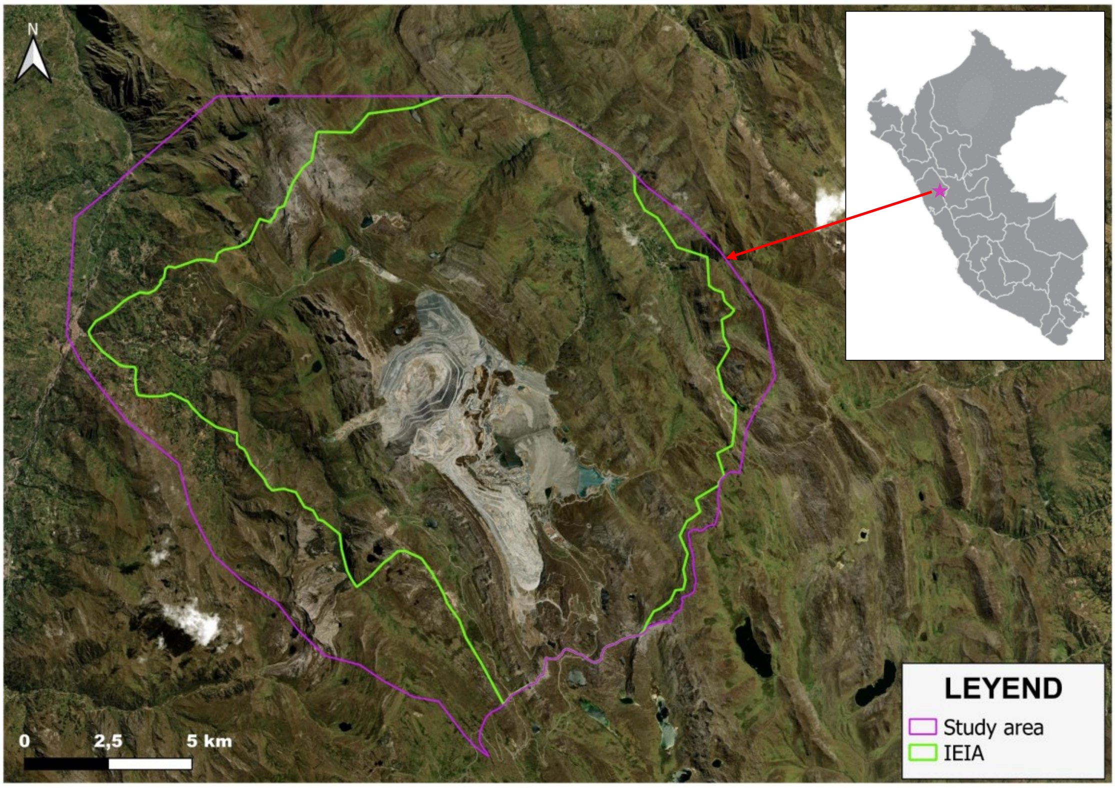



**Figure 1: Antamina mine location**

Local geology and mineralogy (polymetallic Skarn deposit) significantly influence soil conditions, water quality, and hydrogeology. The presence of limestone and the Cordillera Blanca Batholith contribute to naturally elevated concentrations of cadmium, copper, molybdenum and zinc, wich in some cases naturally exceeding regulatory standards. Hydrogeological analysis shows groundwater levels are associated with deep structures (>200 m), conditioned by geological formations and structures that influence infiltration and groundwater storage. Biodiversity in the area remains resilient. In terrestrial ecosystems, this resilience is linked to environmental complexity and existing vegetation units, which provide refuges and resources for endemic and conservation-priority species. Over 650 flora species (95 of conservation interest), 143 bird species (45 of conservation interest), 25 mammal species (8 of conservation interest), five amphibian and two reptile species (all of conservation interest), and 282 insect species have been identified. Aquatic ecosystems host over 600 phytoplankton species, 140 zooplankton species, 800 periphyton species, 300 macrobenthos species and four fish species (in *Trichomycterus*, *Astroblepus* and *Orestias* genus), endemic to the Peruvian Andes and distributed linked to hydrological dynamics.

***Table 1: Environmental data available from the last 25 years at Antamina mine***

| Discipline | Information period | Stations | Information |
|---|---|---|---|
| Meteorology | 1965 - 2020 | 7 | Local (Antamina) and regional (SENAMHI) |
| Air quality | 1997 - 2021 | 20 | EIA (1998), Environmental Monitoring Program (EMP), |

| Discipline | Information period | Stations | Information |
|---|---|---|---|
| | | | Environmental Management Instrument (EMI) base line |
| Noise | 2006 - 2021 | 22 | EIA (1998), EMP, EMI base line |
| Vibrations | 2011 - 2021 | 10 | EMI base line |
| Soil | 2006 - 2019 | 110 | EIA (2008), IGA base line |
| Soil quality | 1997 - 2019 | 314 | EIA (1998), EMP, EMI base line, OEFA, Antamina's internal monitoring |
| Non-ionizing radiations | 2010 - 2019 | 17 | PVA, IGA base line |
| Water quality | 1996 - 2021 | 61 (superficial) | EIA (1998), EMP, EMI base line, Antamina's internal Monitoring |
| | | 57 (subterrain) | |
| Hydrology | 1965 - 2020 | 7 | Local (Antamina) and regional (SENAMHI) |
| Hydrogeology | 2001 - 2019 | 147 (piezometers) | Antamina's internal monitoring |
| Terrestrial ecosystems | 1997 - 2021 | 153 flora | EIA (2008), EMP, IGA base line, Antamina's internal monitoring |
| | | 92 large mammals | |
| | | 82 small mammals | |
| | | 93 birds | |
| | | 174 amphibians & reptiles | |
| | | 23 arthropods | |
| Aquatic ecosystems | 1996 - 2021 | 31 | EIA (1998), EMP, IGA base line |

Source: AtkinsRéalis, 2025

Furthermore, the EIAM (2024) assessed both punctual impacts, resulting from specific modifications and cumulative impacts, integrating all expansions and operational activities of the mine to provide a comprehensive understanding of the changes that occurred. The results show the impacts are principally localized within the mining footprint and limited to the environmental influence area. Regarding noise, the effects were restricted to specific zones, influencing temporary birds and mammals' displacements in zones with noise levels below 55 dB (IFC, 2007), without compromising the resilience or long-term sustainability of the populations, highlighting their adaptive capacity. A similar pattern was observed in aquatic ecosystems and water resources; changes manifested within the mining footprint, where the impacts on water quality and quantity were confined to the operational zone. These changes were localized and controllable, allowing the ecosystems to maintain their adaptability over time, even with the presence of sensitive species, demonstrating the environment's resilience capacity and efficient impact's management.

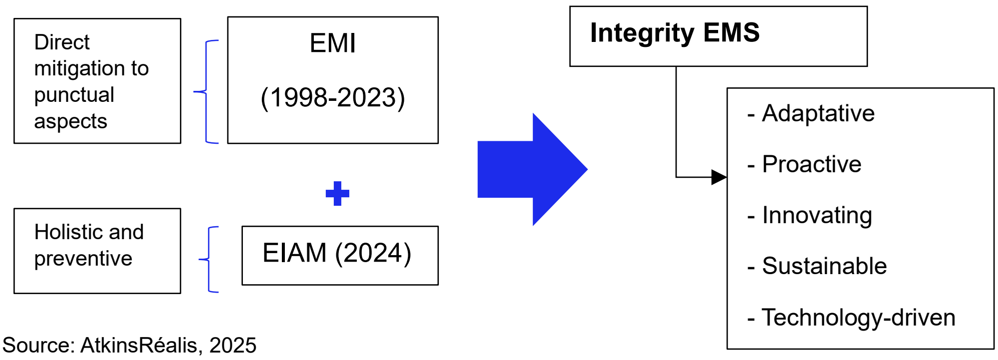
This information has been systematically disseminated to stakeholders through various channels, including audiovisual material, brochures and publication over the years. This highlights Antamina's efforts to effectively disseminate important information, as threatened species, impacts and environmental quality, fostering transparency and shared understanding among stakeholders.

## 5. Design and implementation of systematic EMS

The design and implementation of an integrated EMS at Antamina involved the historical environmental data analysis, impacts assessment, and the review/update of previous management measures. This process incorporates innovative measures that transcend traditional approaches, adopting an integral, adaptive, and holistic model (Figure 2). Furthermore, the integrated EMS introduces a preventive approach in replace of corrective actions, aligning with current challenges in technological innovation and environmental sustainability (Sira, 2024), which highlights the importance of a systematic EMS in mining projects.

Some notable measurements are automated dust control systems, acoustic barriers and silencers to reduce noise, electronic detonators to minimize vibrations, and subdrainage systems for efficient water management and groundwater levels protection. Rehabilitation was another critical aspect considered within the EMS framework, aiming to ensure long-term ecological functionality and resilience by revegetating with native species and establishing protocols for the rescue and relocation of threatened fauna.

Additionally, the 124 monitoring station establish in the Environmental Monitoring Program (98 physical and 16 biological) near the mine and within the indirect environmental influence area (IEIA) (20 366 ha) represented a key strategic improvement. Located close to the mine area, in control areas and configured under a BACI design (Before-After-Control-Impact) (Underwood 1992, 1994), as the biological monitoring, improve data interpretability and enabled robust environmental characterization. This approach strengthens data reliability, supports decision-making, and ensures effective impact assessment and adaptive management throughout the project lifecycle.




Source: AtkinsRéalis, 2025

***Figure 2: Evolution to the EMS implemented by Antamina on the last years***

In this sense, the systematization of information has enabled the implementation of an integrated EMS, demonstrating how the consolidation of databases, the use and enhancement of robust monitoring networks, the integration of reliable secondary information, and strict adherence to high environmental quality standards are essential for a rigorous characterization of the environment. These inputs have enable the design of a comprehensive, dynamic, and adaptable EMS, capable of addressing environmental challenges and ensuring sustainable management aligned with international best practices. Specially, because this ESM has been development to support Antamina's mining expansion until 2036, covering 36 years of operation activities, it will ensure long-term regulatory compliance, minimize environmental impacts, and promote ecological sustainability.

## 6. Conclusion

The integrated Antamina's EMS, supported by 25 years of environmental studies, represents a significant advancement toward an integral, preventive, and adaptative approach that ensures long-term sustainability. This system not only implements measures to mitigate impacts but also guarantees ecosystem resilience through strategies backed by rigorous technical standards. In this context, Antamina's EMS positions itself as an innovative model, contributing to technical knowledge and sets a benchmark for similar mining projects, highlights the importance of responsible resource management and conservation ecosystem.

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