

# Landslide-induced dispersion of arsenic-rich mining wastes in abandoned mining areas

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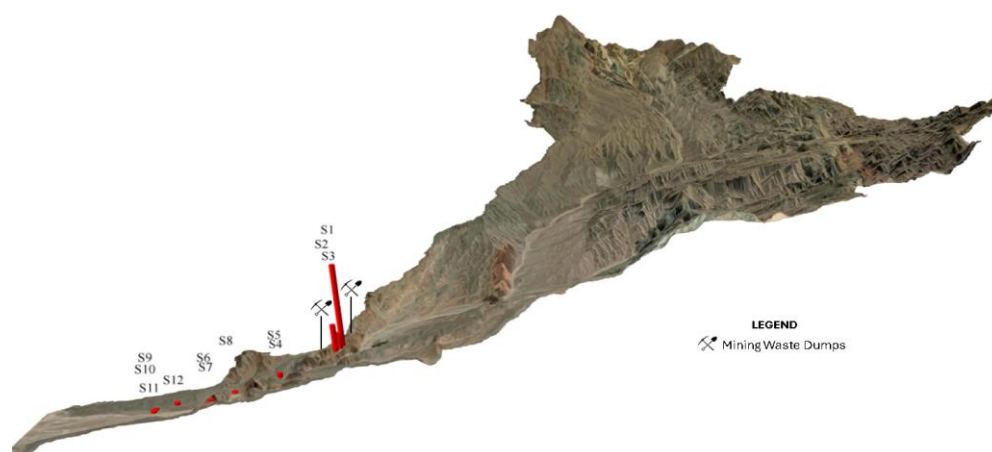
## INTRODUCTION

This study addresses soil contamination through the geochemical analysis of sediments derived from a landslide located in a mountainous area of the Argentine Andes, east of Angualasto (San Juan). The study area is influenced by a former mining site that is currently inactive, whose residual materials represent a potential source of contamination. Arsenic (As) has been identified as the main contaminant, released from mining materials and subsequently transported along the landslide deposit (Esper-Angillieri, 2007). The mobility and distribution of this element are strongly controlled by sedimentary processes as well as by the granulometric characteristics of the materials involved. In this context, assessing As dispersion is essential to understand its environmental behaviour and the associated risks.

## MATERIALS AND METHODS

### Study Area

The study area is located in a mountainous region of the Argentine Andes, characterized by the presence of deposits associated with mass movements and the influence of past mining activity. The mining site is located within a drainage basin (Fig. 1), which favors the mobilization and dispersion of contaminated materials through both gravitational and hydrological processes. The analyzed landslide constitutes the main pathway for the transport of potentially contaminated sediments, acting as a key vector in their redistribution throughout the system.



*Fig 1. Study site and As concentrations in sediments.*

### Sampling and Analysis

A systematic sampling campaign was carried out along the landslide deposit, covering proximal areas near the mining source as well as distal zones. Arsenic concentrations were determined using inductively coupled plasma mass spectrometry (ICP-MS) after acid digestion using HNO<sub>3</sub>, HCl and HF. Additionally, granulometric analyses were performed using wet sieving. The finest fraction (<63 μm) was further characterized by laser diffraction (Coulter)

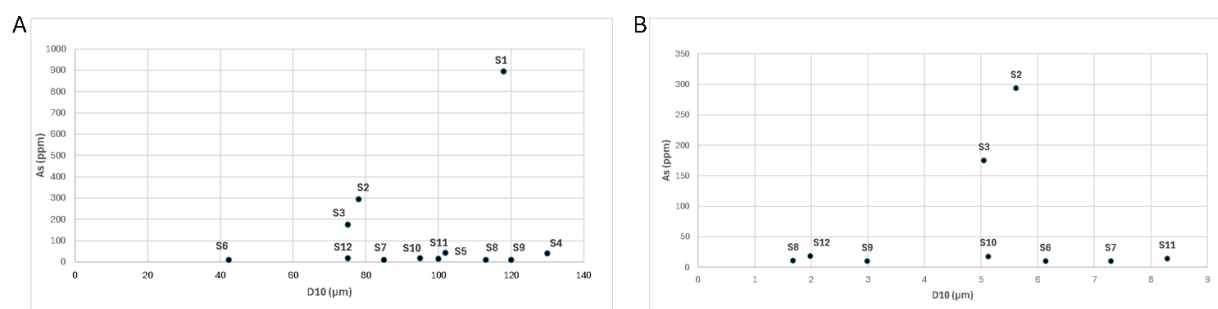
to obtain a high-resolution grain-size distribution, with particular emphasis on the particle size fraction most closely associated with elevated arsenic concentrations.

In parallel, samples from the mine waste dumps were collected and geochemically characterized to determine their arsenic content. A mineralogical study was also carried out using X-ray diffraction (XRD) and scanning electron microscopy (SEM) on prepared specimens, in order to identify the mineral phases hosting arsenic.

## RESULTS AND DISCUSSION

The results revealed a clear decrease in As concentration with increasing distance from the contamination source. In proximal areas near the former mining site, concentrations range from 175 ppm to 895 ppm, indicating strong enrichment associated with mining-derived materials. In contrast, distal zones of the landslide deposit show significantly lower values, ranging between 10 and 18.7 ppm. This pronounced gradient reflects a typical dispersion pattern from a point source and highlights the direct influence of mining activity on system contamination. The spatial evolution of As concentrations suggests a well-defined geochemical gradient along the landslide deposit (Fig. 1), primarily controlled by sediment transport processes and progressive dilution with less contaminated materials. Minor local deviations from this trend are observed and can be attributed to heterogeneities in landslide dynamics, including localized redeposition and secondary accumulation processes.

Granulometric analysis demonstrates a strong relationship between particle size and As concentration (Fig. 2A), with the highest values consistently associated with finest fractions. Moreover, the correlation between As concentration and the D10 parameter (the grain size corresponding to the finest 10% of the particle size distribution) (Fig. 2B) further confirms that fine-grained sediments act as the primary carriers of As. These results indicate that sediment transport, sorting, and deposition processes exert a dominant control on contaminant distribution, with fine sediment fractions representing preferential accumulation zones and potential sources of future remobilization under changing physicochemical conditions.



**Fig 2.** (A) As concentration variability according to finest particles content in the coarse grain size fraction (<2mm) of the sediments; (B) As concentration variability according to finest particles content in the finest grain size fraction (<63µm) of the sediments.

The mine wastes exhibit extremely high arsenic concentrations, with some samples exceeding 1 wt.%. Mineralogical analyses of waste dump samples indicate that arsenic is hosted within two main mineral groups. The first group comprises primary sulfides, including pyrite, arsenopyrite, chalcopyrite, and covellite, which represent the original sources of arsenic. The second group consists of secondary arsenate minerals, such as scorodite and pharmacosiderite, along with minor sulfate phases including natrojarosite, gypsum, and jarosite, reflecting weathering and oxidation processes. Additionally, the presence of arsenic-enriched goethite has been identified, suggesting that iron oxyhydroxides play a significant role in arsenic sequestration through adsorption and co-precipitation mechanisms.

Overall, our findings highlight the combined influence of primary mineralization, secondary weathering processes, and sedimentological dynamics in controlling arsenic mobility and distribution. The integration of geochemical and mineralogical data provides critical insight into the mechanisms governing contaminant transport in mining-impacted mountainous environments.

## REFERENCES

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