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Corresponding author:
Pablo A Garcia-Chevesich;
Email: pablogarcia@mines.edu

Gold mining-derived water pollution and treatment in Latin America

Pablo A Garcia-Chevesich[1,2], Francisco Alejo[3], Julia Zea[3], Carlos Zevallos[3], Linda Figueroa[1], Roberto Pizarro[4,5,6] and Chris Bellona[1]

[1]Department of Civil and Environmental Engineering, Colorado School of Mines, CO, USA; [2]Intergovernmental Hydrological Programme, United Nations Educational, Scientific, and Cultural Organization (UNESCO), Montevideo, Uruguay; [3]Facultad de Química, Universidad Nacional de San Agustín de Arequipa, Arequipa, Peru; [4]UNESCO Chair Surface Hydrology, University of Talca, Talca, Chile; [5]Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD) - ANID BASAL FB210015, Pontificia Universidad Católica de Chile, Santiago, Chile and [6]Facultad de Ciencias Forestales y de la Conservación de la Naturaleza, Universidad de Chile, Santiago 8820808, Chile

Introduction

The extraction of gold may have environmental consequences depending on the reagent used and the scale of the operation (e.g. Hancock 1973). The rise in artisanal gold-mining operations, which use mercury, is directly or indirectly related to varying levels of contamination (e.g. Wade 2013). Moreover, the current status of gold mining-derived water pollution and treatment in eight countries (Argentina, Brazil, Chile, Colombia, Ecuador, Nicaragua, Peru and Venezuela) from Latin America and the Caribbean (LAC) has just been reviewed in Spanish (Alejo et al. 2023). That work focuses on water pollution and its treatment related to both formal and informal gold mining, reporting national-level efforts to address the environmental challenge. The primary objective of that book was a regional analysis emphasizing the methodologies and practices that have yielded positive results, serving as examples at both political and technical levels. This Comment aims to inform the English-speaking scientific community of the key findings of that significant book.

Types of mining

The gold-mining sector plays a vital role in the economies of all involved countries through formal mining, benefitting thousands of low-income people engaged in informal and illegal mining. For instance, in Argentina, gold constitutes 47% of national mining and 65% of mining exports, making it a crucial economic sector. In Chile, gold is the second most developed metallic resource, with almost 34 tonnes obtained in 2021 as a by-product from copper mining and from smaller gold deposits. In Colombia, gold production contributes c. 2% to the country's GDP, 20% to exports and 16% to foreign investments, although the majority of production comes from informal operations. Gold mining is essential to Ecuador's economy, while in Peru gold is the second most important metal resource after copper, with most production coming from medium- and small-scale mining and 10–20% from informal operations.

Informal (and illegal) gold mining is prevalent in all eight countries examined, although the proportions vary among nations (Alejo et al. 2023). For example, Argentina and Chile, where most gold-mining activity comes from the formal sector (large, medium and small scale), differ from Colombia, Ecuador, Nicaragua, Peru and Venezuela, where the illegal sector represents the majority of national productivity. The gold recovery methods used in LAC are diverse, with mercury amalgamation and cyanide leaching being the most common. Currently, gold ore is extracted in the region using open-pit, seam or vein (underground) or alluvium mining operations.

Pollution

The potential for environmental pollution caused by gold mining in LAC is a growing problem, primarily stemming from informal mining and exacerbated by the widespread distribution of locations with limited environmental control. However, reported pollutant releases usually pertain to the formal operations. For example, the largest reported mining accident in the history of Argentina occurred in 2015, when more than 1 million litres of cyanide solution leaked from the Veladero mine in the province of San Juan. There were additional spills in the country in 2016 and 2017, although of smaller volume, while in 2003, 612 m^3 of cyanide compounds were spilled in the Cerro Vanguardia deposit. In the das Velhas River in Brazil, arsenic from formal gold-mining operations is the main pollutant of water resources. In Chile, mercury levels of almost 100 g/t were reported in active tailings dams located in the Atacama Desert (there are 740 tailings dams throughout the country, representing a total mass of 10 600

tonnes of contained materials). However, in general, formal operations adhere to strict regulations and have minimal impacts on pollution compared to environmental damage caused by informal mining in countries where illegal operations are an issue. For example, mercury contamination is present in different aquatic ecosystems in Colombia, and its impact has been documented, as reported for fish, wildlife, inhabitants, agriculture and water. Nearly 90% of the national gold production comes from illegal operations, and studies estimate that 156 tonnes of mercury have been discharged into water by the artisanal gold industry sector in Colombia, dangerously polluting more than 200 rivers, with particularly alarming cases being the Telecom (67 µg/L) and Amarillal (33 µg/L) rivers. Similarly, the lower sections of many Ecuadorian rivers (e.g., Siete, Calera, Amarillo and Puyango rivers) are dead due to the presence of mercury. Approximately 3.5 tonnes of mercury are released annually through informal mining in Nicaragua, of which a significant amount contaminates surface waters. All Venezuelan rivers where illegal mining is present are highly contaminated with mercury; it has been calculated that 5 tonnes of this pollutant were discharged into the Caroní River (which supplies the Venezuelan city of Guayana) in the last three decades of the twentieth century.

Treatment

Gold-mining operations in LAC have implemented methods to treat wastewater. For example, in Argentina, various mitigation processes treat total cyanide and cyanide–metal complexes from tailings. Mitigation processes include monitored natural volatilization, complexation and precipitation reactions, oxidation to less toxic by-products (e.g., cyanate, ammonium) using hydrogen peroxide/ultraviolet, a sulphur dioxide/air process or peroxomonosulfuric acid, engineered precipitation using iron-complexing agents where cyanide is transformed to solid-phase $Fe_4(Fe(CN)_6)_3$, and biodegradation. In Colombia, removal of heavy metals is typically carried out through chemical precipitation, forming insoluble metal hydroxides at alkaline pH, a process recommended for medium- and large-scale mining. Colombia also employs constructed wetlands where heavy metals are reduced through absorption by macrophyte plants and microorganisms present in the wetland such as diatoms and bacteria (e.g. Morales et al. 2023). In Nicaragua, sedimentation ponds manage processing waste generated by artisanal exploitation, retaining the solid material present in the effluent and preventing mercury from reaching surface waters, although the liquid fraction often reaches surface waters during storms. However, in certain countries and regions, minimal treatment of mining wastewaters prior to discharge has been reported; for example, while countries where formal mining represents most of the national gold extractions (Argentina, Brazil, Chile) report well-established cyanide treatment activity using methods commonly applied in the industry, Colombia, Ecuador, Nicaragua, Peru and Venezuela report the greatest mercury pollution issues due to illegal activity, despite the treatment methods cited above. Ecuador reports the absence of treatment from any operations nationwide, and although various Ecuadorian universities are developing pilot and small-scale projects to provide solutions, they still do not receive the support necessary to scale the work up. Treatment methods for mercury in Colombia, Nicaragua and Peru have been reported, but specific data are lacking. Despite efforts in these countries, mercury is not being managed effectively. The treatment approaches in use are outdated, and there is a notable lack of newer technologies for recovering pollutants of concern.

Legislation

Legislation related to gold mining and processing in LAC appears to be robust and well-articulated, but stringent regulations apply only to formal mining, leaving unregulated the informal sector's contribution to water contamination. Since water pollution is mainly generated by informal activities, legal instruments targeting these operations to regulate and eliminate discharges (mercury and cyanide) into surface and underground water bodies are essential. In this regard, noteworthy examples include Colombia, which aims to eradicate mercury from its territory, and Brazil, which has created regulations to control the use of mercury and cyanide. However, clandestine gold extraction often obstructs access, monitoring or control of operations, impeding progress in water decontamination.

Conclusions and recommendations

Water contamination linked to the gold production industry requires urgent resolution due to the extensive impact on surface and groundwater resources and the escalating water supply shortages. While most of the eight LAC countries assessed have adequate legislative systems, they apply primarily to formal mining, and there is a pressing need to regulate the informal sector effectively to protect the region's waters. New and more efficient treatment technologies to remove cyanide, mercury and other chemicals used in gold extraction processes are also urgently required, especially in the informal mining sector.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0376892924000237.

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