Key Points:

⇒ Artisanal and small-scale gold mining (ASGM) has resulted in higher mercury levels in water bodies in the Madre de Dios region of the Peruvian Amazon.

⇒ Concentrations of mercury in river water downstream from artisanal mining areas were found to be 10 times higher than in upstream areas.

⇒ ASGM has created a large number of mining ponds in Madre de Dios. Between 1984 - 2018, the total surface area of mining ponds in heavily mined areas increased by 670% (1,600 ha).

⇒ Mining ponds are likely more effective than rivers for converting mercury to the more toxic methylmercury. The fraction of methylmercury to total mercury in mining ponds was found to be up to 7 times higher than in downstream rivers.

⇒ The creation of mining ponds, and the high rates of methylmercury production in those ponds, amplifies the risk of mercury exposure to vulnerable populations of people and wildlife that rely on fishing in and around post-ASGM landscapes.
INTRODUCTION

Artisanal and small-scale gold mining (ASGM) is the main contributor of mercury pollution to the atmosphere globally. Mercury (Hg) is a potent neurotoxin that can have harmful effects on both people and wildlife. ASGM is also responsible for high amounts of deforestation and loss of biodiversity as land is cleared in the process of mining. In the Madre de Dios region of the Peruvian Amazon, ASGM has caused a loss of more than 100,000 hectares of forests over the past 35 years and accounts for approximately 180 tons of elemental Hg emissions annually, according to a recent report.

In the ASGM process, small groups of miners pump gold-laden sediments from rivers, lakes, and floodplains. Miners mix this sediment with Hg, some of which selectively binds to the gold. This mixing forms a Hg-gold alloy, called an amalgam, that can be easily separated from the rest of the sediment. However, not all of the Hg attaches, and the surplus Hg is dumped into ponds and rivers. The Hg that does attach to the gold in the amalgam ball is later burned off, releasing Hg into the atmosphere.

To get the sediments for this process, miners dig large pits in the landscape. These pits fill in with rainwater and groundwater, effectively creating thousands of small post-mining ponds. As a result, the land cover in this region is drastically altered from forested to ponded. In the most heavily mined areas in Madre de Dios, an average of 30% of post-mining landscapes are abandoned mining ponds.

This research brief outlines ongoing research conducted by Duke University, the University of North Carolina at Chapel Hill, and the University of Florida.
Hill, Wake Forest University, and the Center for Amazonian Scientific Innovation (CINCIA). It examines how ASGM changes the number of mining ponds on the landscape between 1984 and 2018 and describes the amounts of Hg found in these mining ponds and other water bodies in Madre de Dios. It also studies the impact that mining ponds have on the conversion of elemental Hg into the more toxic form of methylmercury (MeHg) in watersheds.

METHODS

This study combined an analysis of landscape change, using high-resolution satellite data to quantify the increase in mining ponds over time, with an analysis of water column Hg levels in locations both upstream and downstream of ASGM activity to describe how ASGM affects the levels of Hg in aquatic environments in Madre de Dios.

Water column samples were collected from mining ponds as well as aquatic habitats upstream and downstream of mining activities in the Madre de Dios river and its tributaries, during the dry season in July and August of 2019. We analyzed all water column samples for total Hg content, which represents all forms of Hg using EPA Method 1631 at Duke University on a Tekran 2600 Automated Total Mercury Analyzer. Water column MeHg was measured using EPA Method 1630 at Duke University on an Agilent 770.

To measure changes in total surface water coverage for rivers compared to ponds in the study area, we used Landsat satellite images from 1984 to 2018 to identify the extent of surface waters over the entire region on an annual basis. Within the areas defined as water, we identified all rivers greater than 30 meters wide and identified all the water bodies that were connected to a river. Water that was connected to a river was identified as a riverine or lotic system; otherwise, it was classified as a lentic system that could be either a mining pond or a natural lake. Total surface coverage for lotic and lentic systems areas was calculated for each year to examine changes in the distribution and amounts of water body types as ASGM activities increased over the study period.

RESULTS

Levels of total Hg in rivers downstream from artisanal mining are 10 times higher than upstream river areas.

Total Hg concentrations in river water downstream from mining sites were about ten times higher than upstream river sites (downstream river: 10.1 ± 2.8 ng Hg/L vs. upstream river: 0.9 ± 0.5 ng/L) (Figure 3). Hg is generally transported bound to particles in water. ASGM increases the amount of these suspended particles through active excavation and soil erosion of the deforested areas, increasing the potential for Hg to move downstream in adjacent rivers. The combination of these processes and Hg pollution leads to higher levels of Hg in ASGM-impacted river waters than in areas upstream of ASGM activities.

Lentic system (mining ponds and natural lakes) converted Hg to the more toxic MeHg at rates 5-7 times higher than rivers.

Lentic systems were more efficient at forming MeHg. Mining ponds contained 5.8 ± 1.2% of Hg as MeHg and downstream oxbow lakes contained 7.9 ± 2.1%, compared to 1.1 ± 0.3% in downstream river water. Since even small amounts of MeHg are highly toxic, this increase in MeHg production in ponds has serious implications.
Lentic water bodies have been found to process Hg differently than river environments. The higher amount of MeHg produced in lakes and ponds likely occurs because these systems have lower oxygen levels\(^8\). Since the microbes that convert Hg into MeHg are more abundant at low oxygen, Hg methylation rates in lakes and ponds tend to be higher compared to rivers which are more oxygenated.

In heavily mined areas (Inambari and Colorado watersheds), the total surface area of mining ponds increased by 670% (1,600 ha) between 1984 – 2018.

In contrast, the total surface area of lentic water bodies in areas without heavy mining increased by an average of only 20% (80 ha) (Figure 1 and 2). The conversion rate of forest lands to mining ponds in heavily mined areas has accelerated since the year 2008, when artisanal gold mining sharply increased in the region in response to increased global gold prices.

**The combined effect of increasing areas of mining ponds and the higher amount of MeHg produced in these ponds likely increases the risk of MeHg exposure through the consumption of fish caught in these water bodies.**

Higher MeHg production rates in mining ponds and lakes may have serious implications for human and environmental health. MeHg enters aquatic food chains, magnifying in top level predators such as certain fish\(^9\) and mammals. People who rely on the consumption of these species, such as indigenous communities, are at increased risk of Hg exposure and the health problems associated with Hg exposure.

This pattern of increased extent of mining ponds and increased MeHg production is not isolated to the Peruvian Amazon. We found similar trends in other countries throughout the world with ASGM, suggesting that Hg toxicity associated with ASGM is widespread and threatens vulnerable populations of people and wildlife\(^10\).

**CONCLUSIONS**

Our results show that the risk of Hg to humans and wildlife associated with gold mining is amplified by the creation of thousands of ponds across the landscape. These ponds effectively transform Hg into the more toxic MeHg. The
combined effect of increased lentic systems and Hg loading poses a serious threat to local communities. Thus, in evaluating the risk of Hg from ASGM, we need to consider not just the overall amount of Hg inputs to the aquatic ecosystem, but also how changes in mining ponds and lakes extent influence the processing of this Hg, particularly in global biodiversity hotspots such as Madre de Dios.

REFERENCES


RESEARCH BRIEF SERIES

CINCA Research Briefs contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues. Most research briefs are eventually published in another form and their content may be revised.

AUTHORS

Jacqueline Gerson is a PhD student in Ecology at Duke University.

Simon Topp is a PhD student in Geological Sciences at the University of North Carolina at Chapel Hill.

Claudia M. Vega is the Coordinator of the Mercury Program at the Centro de Innovacion Cientifica Amazonica - CINCA.

John Gardner is a postdoc at the University of North Carolina at Chapel Hill.

Xiao Yang is a PhD student in Geological Sciences at the University of North Carolina at Chapel Hill.

Luis E. Fernandez is CINCA’s Executive Director, research professor in the Department of Biology at Wake Forest University, and Director of the Carnegie Amazon Mercury Project (CAMEP) at the Department of Global Ecology at the Carnegie Institution for Science.

Emily Bernhardt is the James B. Duke Distinguished Professor in the Department of Biology at Duke University.

Tamlin Pavelsky is an associate professor in the Department of Geological Sciences at the University of North Carolina at Chapel Hill.

RESEARCH PARTNERS

Duke University
University of North Carolina at Chapel Hill

CENTRO DE INNOVACIÓN CIENTÍFICA AMAZÓNICA

The Centro de Innovación Científica Amazonica (Center for Amazonian Scientific Innovation, or CINCA) was created in 2016 by Wake Forest University in partnership with USAID with the aim of generating scientific capacity to identify, recover and mitigate threats to ecosystems, biodiversity and public health in the Peruvian Amazon. CINCA aims to strengthen research capacity in Amazonian institutions and improve the application of scientific knowledge to solve current and future environmental problems in the Amazon basin.

ACKNOWLEDGMENTS

We would like to thank the following people for their contributions and assistance in carrying out this research: Francisco Phuno Soncco, Bryan Huamantupa Rivera, Arabella Chen, Annie Lee, Fernanda Machiaco, Melissa Marchese, Cecilio Huamantupa, and local Peruvian miners and community members for field assistance; Helen Hsu-Kim, Nelson Rivera, Faye Koenigsmark, Natalia Neal-Walthall, and Austin Wadle for laboratory assistance; Miles Silman for feedback in study design; and SERNANP, Ejercito Peruano, and the Policía Nacional del Peru for access to the mining ponds in La Pampa.

DISCLAIMER

This publication is made possible, in part, by the generous support of the American people through the United States Agency for International Development (USAID) under the terms of USAID/WFU Cooperative Agreement No. AID-527-A-16-00001. The contents do not necessarily reflect the views of USAID or the United States Government.

Preferred Citation: Gerson J., Topp S., Vega C.M., Gardner J., Yang X., Fernández L.E, Bernhardt E., Pavelsky T. (2021) Artisanal gold mining ponds amplify mercury risk in the Peruvian Amazon (Research Brief CINCA #7) Puerto Maldonado, Perú: Centro de Innovación Científica Amazonica