MARCH 2019

PROJECT ACCOMPLISHMENT REPORT

Community-driven Artisanal and Small-Scale Gold Mining Remediation Planning in Peru
US DoS Award number: S-LMAQM-14-CA-1154 - Pure Earth

Female miners in Ollachea, Puno learning the non-toxic Filipino Method during a mercury-free training

PREPARED BY

Charles Espinosa, *Program Associate LAC*
Lina Hernandez, *Regional Director LAC*
Bryn Thoms, *Technical Specialist*
Pedro Sifuentes Yepes, *Project Officer*
France Cabanillas, *Project Coordinator in Madre de Dios*

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List of Acronyms

ARM: Alliance for Responsible Mining

As: Arsenic

ASGM: Artisanal and small-scale gold mining

Bgs: Below ground surface

CENSOPAS - MINSA: National Center for Occupational Health and Environmental Protection for Health – Ministry of Health

CINCIA: Amazon Center of Scientific Innovation

CITE: Center of Mining Research and Technology

CREEH: Center for Research in Environmental Health

DGFM – MEM: General Direction of Mining Formalization - Ministry of Energy and Mines

DIGESA - MINSA: General Direction of Environmental Health - Ministry of Health

DOS: United States Department of State

DREM - Puno: Regional Direction of Energy and Mining – Puno

FORTUMIL: Fortuna Milagritos Mining and Commercial Society

Ha: Hectares

Hg: Mercury

Jerome: Jerome Atomic Fluorescence Spectroscopic Mercury Vapor Analyzer

Kg: Kilogram

LAC: Latin America and the Caribbean

MDD: Madre de Dios

MeHg: Methylmercury

MINAM: Ministry of Environment, Peru

NAP: National Action Plan

PPM: Parts per million

RAGS: Risk Assessment Guidance for Superfund

UNDP: United Nations Development Program

UNEP: United Nations Environment Program

US: United States of America

USEPA: United States Environmental Protection Agency

XRF: X-ray fluorescence portable equipment

Executive Summary

This Final Project Accomplishment Report summarizes the primary activities, outcomes and challenges of Pure Earth's four-and-a-half-year project "Reducing the Negative Environmental and Health Impacts from Artisanal and Small-Scale Gold Mining", funded by the Bureau of Western Hemisphere Affairs of the US Department of State (DoS).

Under the Minamata Convention, countries with artisanal and small-scale gold mining (ASGM) are obligated to create a National Action Plan (NAP) to reduce, and where feasible, eliminate the use of mercury. Peru signed the Minamata Convention in 2013 and ratified their agreement to enforce the protocols within the convention in 2016. While Peru's NAP addresses all sectors of mercury use, it includes the creation and implementation of an ASGM-specific NAP. Although this plan is still in development, Pure Earth anticipates that this project's activities will be consistent with the future plan, given that it satisfied many of the core objectives outlined in UNEP's Guidance for Developing a NAP. In particular, this project has endeavored to promote sustainable solutions to not only reduce mercury usage, but also lessen mercury contamination and environmental degradation resulting from ASGM as well as strengthen official capacity to identify and remediate mercury-impacted sites. Primary government partners included the Ministry of Environment (MINAM), the Regional Directorate for Energy and Mines Puno (DREM Puno) and the Center of Mining Research and Technology (CITE). The project followed an innovative, comprehensive approach to produce measurable, lasting results for affected communities and government agencies. Specific activities included:

✓ Select three sites in need of remediation; foster community awareness of the human health and environmental impacts of mercury;

✓ Support development of community-based remediation plans;

✓ Promote alternative livelihoods and profitable mercury-free mining practices;

✓ Remediate and restore three demonstration sites; and

✓ Expanded the capacity of the Peruvian government to replicate similar remediation projects.

In total, the project trained approximately 206 miners in mercury-free techniques, forty of whom have reduced mercury use by 80% or more; raised awareness in 168 community members in the health and environmental impacts of mercury contamination; and built capacity in 27 Peruvian government officials in environmental site assessment methodology. Furthermore, the project excavated and safely removed about eight tons of contaminated soil in the Puno region and restored 3.5 hectares of degraded land in the Amazonian region of Madre de Dios. The outcomes of the project demonstrated that transforming mining practices requires substantial research of site conditions, including an understanding of the local mineralogical characteristics and the cultural and technical strategies employed in the respective ASGM community. Regarding mercury-free techniques, future projects should consider the use of shaking tables or centrifuges instead of panning in Madre de Dios. Peter Plates, a technology previously tested in the Philippines to treat tailings and recover mercury with successful results, proved unsuitable for the project's objectives, as it was inefficient and ultimately recirculates elemental mercury.Overall, the project experience suggests that growing economic, legal and moral pressures are causing an increasing number of ASGM miners to learn and adopt responsible mining practices, provided that appropriate resources and knowledge are made available.

1.0 ABOUT PURE EARTH

Figure 1.1 A degraded mining site in the Amazonian region of Madre de Dios

Pure Earth, formerly known as Blacksmith Institute is a New York-based not-for-profit organization committed to solving pollution problems in developing countries. Pure Earth works around the globe to identify dangerously polluted sites and initiate their clean up, using its Toxic Sites Assessment methodology (Pure Earth, TSIP, 2019) to focus efforts on the most productive interventions. Collaborating with local partners, including environmental authorities, Pure Earth identifies and prioritizes intervention efforts to protect human health. Since 1999 Pure Earth has completed 110 projects in 20 countries and is currently engaged in 29 projects in 24 countries.

Pure Earth works in most regions of the world to find places where pollution is causing substantial human health issues. We survey these sites, review with a Technical Advisory Board, design an implementation strategy that includes funding and appropriate technologies to assist local champions in implementing and completing a remediation process. Projects are conducted in cooperation with all stakeholders.

Pure Earth is a practical, can-do organization committed to improving the health and wellbeing of the disadvantaged of the world, especially children, who are most at risk and who are poisoned by industry and mining.

1.1 Project Team

Figure 1.2 Members of the Pure Earth team with mining stakeholders in Madre de Dios

New York Headquarters

- Bret Ericson, *Director of Operations*
- Lina Hernandez, *Regional Director Latin America and the Caribbean*
- Charles Espinosa, *Program Associate Latin America and the Caribbean*
- Jack Caravanos, *Director of Research*
- Lara Crampe, *Director of Community Outreach*
- Bryn Thoms, *Technical Specialist*

Peru-based Staff

- Pedro Sifuentes Yepes, *Project Officer - Peru*
- France Cabanillas, *Project Coordinator in Madre de Dios*
- Edmundo Moreno, *Site Project Leader in Puno*
- Augusto Yepes Ramirez, *Logistical Coordinator*
- Juvenal Barraza Caballero, Local Ollachea Coordinator
- Sandra Barraza Caballero, Local Ollachea Coordinator

Project Partners

- Ministry of Environment (MINAM: Ministerio de Medio Ambiente) of Peru
- CINCIA (Amazon Center of Scientific Innovation)
- CREEH (Center for Research in Environmental Health)

1.2 ASGM in Peru

Figure 1.3 An ASGM mining operation in Madre de Dios

ASGM is the most significant source of mercury pollution in the world. The United Nations Development Program (UNDP) estimates that there are approximately 15 million artisanal gold miners globally, whose combined operations release up to 1,000 tones per year (UNDP 2019). More than half of global mercury emissions from ASGM activities takes place in South America (UNEP 2019). Peru is the largest gold producer in Latin America and the sixth largest in the world (U.S. Geological Survey 2019). In recent decades, Peru has experienced an explosion in ASGM in the Amazonian region of Madre de Dios and the Andean region of Puno. The high price of gold (>$1,300/oz) has attracted an increasing number of miners, most of whom are driven to turn to mining by extreme poverty and unemployment. As of 2012, an estimated 300,000 Peruvians directly and indirectly depend on the ASGM economy (UNEP 2011).

Artisanal gold miners in Peru combine mercury (Hg) with gold-laden crushed ore to form an amalgam. This is heated, evaporating the mercury and leaving gold behind. Because ASGM often takes place in residential areas, miners, their families and communities directly inhale significant amounts of mercury vapor, which accumulates in the kidneys and brain. Mercury exposures can also cause miscarriages, respiratory failure, psychotic reactions, cardiovascular disease and death (ATSDR 1999). Hg also enters the local environment or remains in the atmosphere, where it can precipitate into other ecosystems, poisoning rivers, fish and crops (Appleton 1999). In Madre de Dios, where authorities declared a state of emergency in eleven districts in 2016 due to elevated mercury poisoning, fish consumption is the strongest indicator of exposure (Ashe 2012). Furthermore, alluvial ASGM, which involves using suction pumps to extract gold from streambeds, has caused the removal of almost 100,000 ha of rainforest in Madre de Dios since 1985, with about 65,000 ha deforested from 2010 to 2017 (Caballero 2019).

1.3 Project Description

In 2013, Peru signed the Minamata Convention and followed with ratification in 2016 (UN Minamata Convention 2019). From September 2014 to March 2019, Pure Earth has supported Peru's efforts to comply with Minamata by strengthening its capacity to remediate mercury-impacted sites and promote sustainable solutions to lessen mercury contamination and environmental degradation resulting from ASGM. Funded and supported by the United States Department of State, the project collaborated with government agencies, civil society organizations, and affected communities to accomplish three main objectives:

1. Select three mercury-contaminated and environmentally degraded informal ASGM sites and conduct detailed remediation needs assessments;
2. Develop a community-driven remediation plan and an alternative livelihood strategy at each of the three selected sites; and
3. Improve quality of soil and natural resources and measurably reduce health risk from mercury contamination in selected sites by implementing a community-based pilot remediation project.

Figure 1.4 A miner holds pieces of gold ore in Ollachea, Peru

To implement the pilot interventions, Pure Earth selected the Ollachea mining community in the Puno region and two mining concessions in Madre de Dios, based on rapid environmental assessments, community support and legal feasibility. In these sites, Pure Earth collaborated with government organizations— MINAM, DREM Puno, General Direction of Mining Formalization - Ministry of Energy and Mines (DGFM – MEM), General Direction of Environmental Health - Ministry of Health (DIGESA – MINSA)— and local organizations— the Amazon Center for Scientific Innovation (CINCIA), the Center for Research in Environmental Health (CREEH), Caritas, the Alliance for Responsible Mining (ARM)— to develop innovative and sustainable strategies to measurably reduce mercury use, contamination and exposure while providing economic benefits to miners.

Three primary activities were conducted in these sites to accomplish project objectives: foster local awareness regarding the risks of mercury pollution through workshops and community events; train local miners in profitable mercury-reducing mining practices; and institute community-based remediation plans that improve community health and natural resources. The experience of these pilots and separate stakeholder workshops supported the Peruvian government's capacity to implement community-based remediation/rehabilitation of ASGM degraded sites, engage directly with ASGM mining populations, and monitor communities for mercury contamination.

1.4 Scope of Work

Phase 1: Site Selection and Assessment

This multifaceted process involved conducting initial and detailed site evaluations of environmental mercury accumulation and signing agreements with each site's corresponding local mining community. The project team assessed several sites and selected the mining community of Ollachea, Puno and the mining concessions of Paolita II and Fortuna Milagritos mining concessions in Laberinto, Madre de Dios to implement the project.

Phase 2: Health Improvement

Raise awareness in the selected communities about the dangers of mercury use and contamination from ASGM through workshops, community events and public pamphlets. Conduct a biological (urine) sampling in miners and the general population of Ollachea in the initial and final phase of the project, in order to evaluate ASGM's impact on human health and the reduction of the exposure over the project's lifetime.

Phase 3: Miner Development:

To provide miners in the selected sites with responsible and economically viable alternatives to harmful artisanal methods, Pure Earth has trained miners in Puno and Madre de Dios in mercury-free mining techniques and shared costs of mercury-reducing equipment. In the initial project phase, Pure Earth trained miners in the mercury-free Filipino Method (Appel and Na-Oy, 2014) which uses panning and borax, a non-toxic substance, in place of mercury. Because many miners in both regions were reluctant to change deeply ingrained practices, Pure Earth expanded its approach to include other gravimetric mercury-reducing techniques, more suited to local conditions. Gravimetric techniques incorporate various means to separate denser material from lighter material by gravity and/or centrifugal action (USEPA International Cooperation, 2019).

Figure 1.5 The Pure Earth team during the remediation in Ollachea, Puno

Phase 4: Remediation and Restoration

Using information gathered during detailed environmental evaluations and feedback from miners, the project team developed a community-driven remediation plan for Ollachea and the Paolita II and Fortuna Milagritos mining concessions. The remediation plan for Ollachea was implemented in different areas of the local mine. The remediation removed eight tons of contaminated soil; improved containment of eleven tailing ponds to safely store mining waste; provided four platforms for storing tailing bags; and installed pipes and channels for rainwater drainage. In Madre de Dios, Pure Earth used research from CINCIA to restore two degraded rainforest sites, in order to provide miners with a model for proper mine closure. The results of each intervention served as pilot projects to monitor and establish a recommended model to rehabilitate environments that have been affected by ASGM activities.

2.0 SITE SELECTION & ASSESSMENT

Overview

The project team selected and assessed the following mercury-contaminated and/or degraded informal ASGM sites: the Ollachea mining community in the Puno region and urban gold shops and three mining concessions in the Madre de Dios region. Nonetheless, due to social and legal challenges, it ultimately was not possible to conduct intervention measures in the Laberinto gold shops and one of the mining concessions.

To conduct rapid and detailed environmental evaluations of each site, Pure Earth used a handheld X-ray fluorescence (XRF) analyzer and a Jerome Atomic Fluorescence Spectroscopic Mercury Vapor Analyzer (Jerome) to collect real time data regarding mercury contamination in air and soil. The site selection process depended on a range of factors, including environmental impact, legal feasibility and community support. Once sites were selected, the project team conducted detailed environmental evaluations in order to isolate areas in need of remediation. Detailed assessments were performed with a technical advisor from partner organization Roux Associates and two officials from MINAM. Officials participated in both assessments and technical workshops to build capacity in pollution identification and prioritization methodology.

Elements of Risk Assessment Guidance for Superfund (RAGS) (USEPA 2019) were followed during site selection and evaluation. These included assessment of the extent and magnitude of hazards, development of a conceptual site model, identification of exposure pathways, and risk evaluation.

Results at a Glance

13
Rapid site asssessments conducted

4
Detailed environmental assessments

3
Community miner agreements signed

27
Officials trained in rapid site assessment methodology

2.1 Site Selection

Site Selection Criteria

✓ Active ASGM operations

✓ Evidence of environmental and health impact by ASGM activities

✓ Miner investment and support in the project via signed agreement

✓ Miners are formalized (legal) or in-route to formalization

Site Selection in Puno

Using the above criteria as a guide, the project team considered three mining communities for project participation in Puno: San Miguel de Untuca, the Mining Company San Miguel Arcangel in the Phara District and the Ollachea Mining Association. Mercury levels in soil exceeded Peru's quality standard for mercury for industrial areas (24 ppm) in all three areas. Although Untuca initially appeared most promising, further engagement revealed that the community wished to industrialize mining operations and use the project's assessments as evidence in a conflict with the neighboring mining community. Due to this and the inaccessibility of the Phara District, Ollachea was chosen in November 2015 for its community support and suitable environmental conditions.

Ollachea contains approximately 5,000 inhabitants, 800 of whom are registered members of the local mining company. Miners in Ollachea extract gold about twenty minutes from the community by removing ore from the mining tunnels with lifting equipment; grinding the ore into fine dust; mixing the ore with water and mercury using crushing stones (quimbaletes); and melting the mercury-gold amalgam. Quimbaletes are meter-sized crushing stones, which are rocked back-and-forth to crush the gold ore before mixing in the mercury, which is converted into a gold-amalgam sponge (Brooks et al. 2007). Because water is added, Hg is released both as an effluent and later as vapor when it is burned and volatized.

Pure Earth investigators evaluated three different mining sectors in Ollachea (Mina Pampa, Concurayoc, and Huayrasiña) and found the two highest mercury concentrations (108 ppm,130 ppm) in the area where miners refine the gold-bearing ore with quimbaletes.

Figure 2.1 A miner rocks quimbalates to refine gold; an investigator measures Hg with an XRF near Qumbalates

Site Selection in Madre de Dios

Pure Earth identified two site types in the region of Madre de Dios to implement the project: rainforest mining concessions and urban gold shops.

Mining Concessions: The gold extraction phase of mining in Madre de Dios results in significant environmental deterioration because it requires removing a significant swathe of forest and soil to form a mining pit. Soil is then suctioned from the test pit, leaving a large crater in the forest, and pumped over a carpet, which captures the heavier particles, including gold. Miners then rinse the carpet and mix it with Hg, forming an amalgam that is burned and sold in urban gold shops. Not only has this process resulted in the deforestation of nearly 100,000 ha of rainforest since 1985 (Caballero 2019), but mercury released from ASGM in this heavily mined area has been linked to human health impacts over 500 kilometers downstream (Diringer, 2015).

Figure 2.2 Mining in Madre de Dios

An initial assessment in the CU&SA2 Mining Concession in La Pampa indicated no significant mercury contamination. This is consistent with similar studies and may be because miners in the area leave waste (black sands) in the work site, where mercury becomes airborne or flushed into the river, or they deposit it into rudimentary storage sites. While the La Pampa concession suited project criteria, miners ultimately withdrew support because they wished to develop and expand their operations. After eliminating another concession due to its illegal operation in agricultural land, Pure Earth selected the Paolita II Mining Concession in Laberinto due to its similar environmental conditions and support by the concession owner Pedro Ynfantes, who is currently going through Peru's legal process to become a formalized ASGM miner.

Gold Shops: After the gold ore is extracted and mixed with mercury, the amalgam is purchased and re-burned in gold shops, using uncontrolled retorts that expose not only employees but also the surrounding population to mercury vapors. Approximately 90% of Hg is lost as toxic vapor during the burning of the amalgam (Brooks et al, 2007). Half of this vapor accumulates in the gold shop's surroundings and individuals living in close proximity to the shops have been shown to have elevated mercury levels (Kuramoto, 2001).

During initial assessments conducted in sixteen gold shops, the mean outdoor air levels exceeded the USEPA standard for ambient air levels (1 ug/m3) in thirteen shops, with one shop in Laberinto reaching as high as 16 ug/m3. Given many of these shops were staffed by family members, childhood exposure was of particular concern.

Figure 2.3 An investigator takes an XRF measurement in a Laberinto gold shop

2.2 Detailed Evaluation: Puno

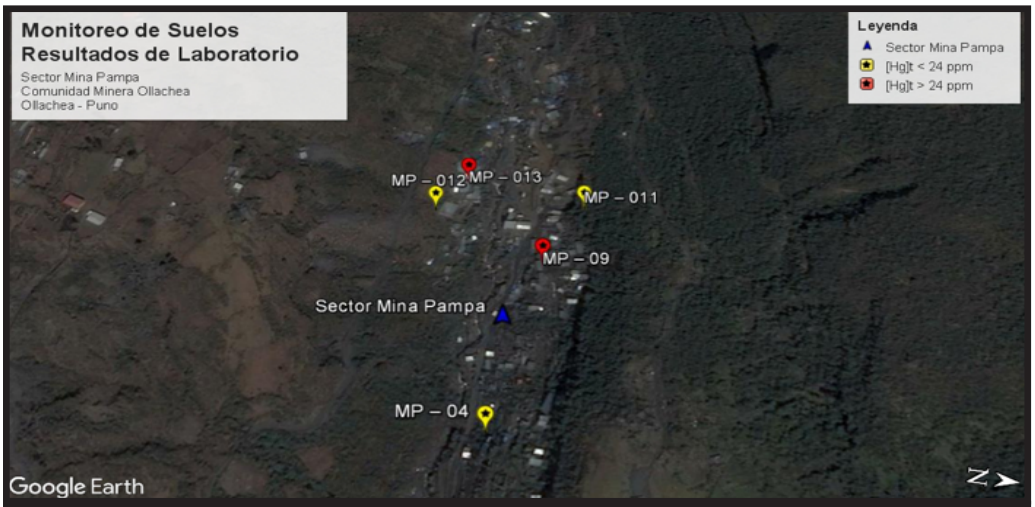

Figure 2.4 Satelite image showing sampling points in Mina Pampa sector of Ollachea

Key Points

✓ XRF readings, soil and water laboratory analysis

✓Samples taken in 3 sectors: Mina Pampa, Concurayoc Huayrasiña

✓8 soil samples > Industrial Standard

The project team conducted the environmental detailed assessment in Ollachea in three sectors of the mine: Mina Pampa, Concurayoc and Huayrasiña. Thirteen XRF readings were taken in each sector while 15 soil samples and 12 water samples were analyzed in the laboratory. Investigators took samples along access roads and mining waste, where previous assessment revealed contamination. As the assessment took place during the rainy season, high moisture content may have affected accuracy of XRF readings. However, soil samples were analyzed in a fixed laboratory to determine XRF result accuracy and, generally, XRF readings did not significantly affect the assessment conclusions.

Each sector contained concentrations significantly above the Peruvian standard of 24 ppm Hg in industrial areas (MINAM - Normas Legales, 2013), typically nearby tailings and the quimbaletes. Of the 15 laboratory readings, eight violated the Peruvian standard while six did not. Huayrasiña had the highest soil concentration (655 ppm), followed by Mina Pampa (172.34 ppm) and Concurayoc (159.36 ppm). Water samples taken in the Oscocachi River showed only trace Hg concentrations (0.0098 and 0.0243 ppm). Arsenic concentrations also exceeded environmental standards, likely because it is naturally found in gold ore.

Table 2.1 The two greatest soil concentrations from each sector

Sector	Sample Type	Sample Code	Hg (ppm)	Hg Standard	As (ppm)	As Standard
Mina Pampa	Mining Road	MP – 09	28.83	24	796.56	140
Mina Pampa	Quimbalates	MP – 013	172.34		5,247.63	
Concurayoc	Quimbalates	CC – 07	27.92		849.47	
Concurayoc	Quimbalates	CC – 09	159.36		3,353.62	
Huayrasiña	Quimbalates/ Tailings	H – 06	655.15		1,166.3	
Huayrasiña	Quimbalates/ Tailings	H – 010	601.48		1,639.15	

2.3 Detailed Evaluation: MDD

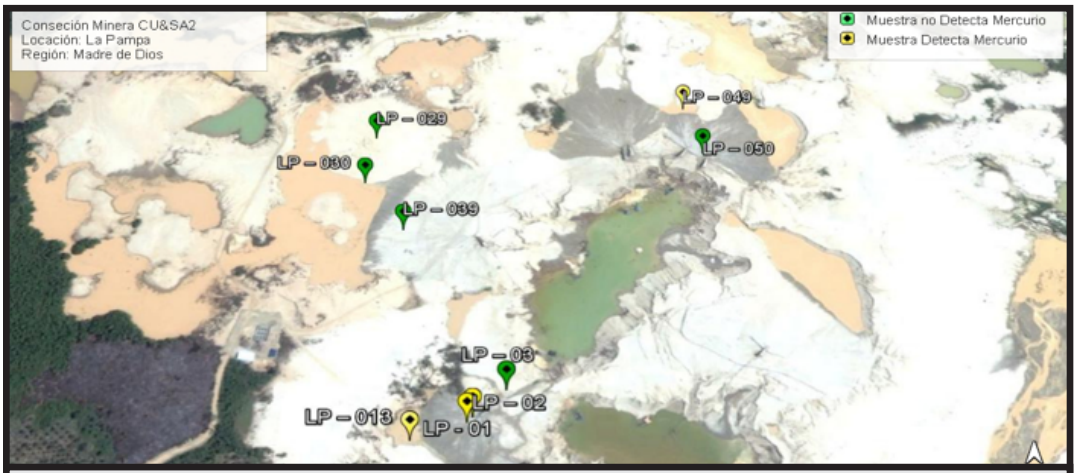

Figure 2.5 Satelite image showing deforestation and sampling points in CU&SA2 concession

Key Points

✓ XRF readings, soil and water laboratory analysis

✓ Mining Concessions: all samples < Industrial Standard

✓ Laberinto Gold Shops: 3 soil samples > Residential Standard

Mining Concessions: Environmental conditions in La Pampa and Paolita II are very similar, as both contain large swathes of deforested rainforest and discarded mining tailings. Between the two sites, 50 XRF readings were taken while 11 soil samples and four water samples were analyzed in the laboratory. Soil samples detected less than 0.02 ppm of mercury concentration, suggesting low contamination in both areas. However, samples taken from river sediment reached concentrations as high as 19.13 ppm. Although readings still fell within the industrial standard, these findings suggest that mining activity accumulates in river sediment due to tailing disposal. These concentrations are also above general standards for bioaccumulation in fish. Mercury bioaccumulation in fish is based on a variety of factors, including concentration in sediment, dissolved oxygen in water, carbon and sulfate content in sediment, and other parameters that continue to be researched (Eckley 2015).

Laberinto Gold Shops: Measurements were taken in the gold shops and urban areas in Laberinto during the wet season (February) and the dry season (September), in order to account for variation from moisture. During the February evaluation, only three of 22 XRF readings, each of which was taken within the gold shops, violated the Peruvian standard in residential soil of 6.6 ppm (MINAM - Normas Legales, 2013). The September visit revealed similar results, with only one sample taken on a road in front of a gold shop violating the standard. From this data, the project team concluded that the polluting retorts in gold shops are the district's primary source of mercury contamination.

Table 2.2 The two greatest soil concentrations from each sector

Sector	Sample Type	Sample Code	Hg (ppm)	Hg Standard	As (ppm)	As Standard
La Pampa	Sediment	LP – 01	0,48	24	<0.02	140
La Pampa	Sediment	LP – 02	19,13		2,663.38	
Paolita II	Soil	PY – 05	0,42		<0.02	
Paolita II	Soil	PY – 07	0,46		<0.02	
Laberinto	Gold shop interior	LAB – 013	11,32	6	<0.02	50
Laberinto	Gold shop interior	LAB – 014	109,2		<0.02	

3.0 HEALTH IMPROVEMENT

Overview

Given the severity of the health impacts resulting from Hg exposure, it is imperative that miners, their communities and other stakeholders are aware of the extensive risk associated with mercury exposure. During the project's lifetime, Pure Earth has fostered local awareness regarding the health and environmental dangers of mercury pollution through workshops, community events and public information in each project site. This included 17 health workshops delivered to a total of 168 community members.

Furthermore, in order to expand knowledge on the health effects of indirect mercury exposure, provide individualized counseling, and assess project impact, Pure Earth conducted urine sampling in affected populations. The preliminary sampling was conducted in March 2016 in Ollachea and Laberinto, with 205 individuals sampled. Both populations reported moderate-to-high mercury poisoning. In February 2019, a follow-up urine evaluation in 120 miners was conducted in Ollachea. While exposure was still evident, the results suggest that levels had decreased, with the mean urinary mercury level falling from 32.8 ug/L in 2016 to 15.8 ug/L in 2019.

Results at a Glance

15

Local health personnel with improved awareness on mercury exposure response and testing procedures

305

Mining community members receiving individualized counseling based on biological sampling

168

Community members with improved awareness of the health impacts of mercury contamination

17

Health workshops held for community members to improve awareness of the health impacts of mercury contamination

3.1 Mercury Exposure Awareness

Mercury Exposure

Mercury is a volatile liquid that can become airborne due to its high vapor pressure. Mercury exists in three forms: elemental, inorganic, and organic, each of which contains distinctive toxicological characteristics. Those working or in proximity to mercury in either its elemental or amalgam form are exposed through vapor inhalation and absorption through the skin and digestive tract (ACGIH 2013).

Exposure to mercury initially affects the central nervous system and the kidneys, with high exposure possibly affecting the respiratory, cardiovascular, and gastrointestinal systems. Chronic exposure to elemental mercury over time can result in loss of motor functions, personality changes, deficits in cognitive function, visual disturbances, and loss of memory (ATSDR, 1999). Additionally, when deposited in rivers, bacteria convert elemental mercury into the highly neurotoxic methylmercury (MeHg), which bioaccumulates up the aquatic food chain and can be absorbed via fish consumption (Appleton 1999).

Health Trainings

Figure 3.1 Ollachea miner during a training event

Pure Earth initiated project efforts by raising awareness in selected communities on the risks and prevention measures of toxic mercury exposure. Partnering with the Peruvian organization CREEH (Center for Research in Environmental Health), Pure Earth delivered four mercury risk workshops and two mining safety training workshops in 2016, with approximately 168 miners participating in total. Furthermore, the project held a workshop in Madre de Dios, training 15 local health practitioners to better recognize the symptoms of and diagnose mercury poisoning. Representatives from the National and Regional Ministry of Health, as well as other NGOs participated, in order to strengthen local capacity in mercury contamination response. In general, the mercury risk workshops and miner health trainings emphasized the following points:

- ✓ General overview of heavy metals and their toxic nature
- ✓ The use, migration and exposure pathways of Hg
- ✓ Health risks for miners and their communities
- ✓ Strategies to safely handle Hg and avoid spills
- ✓ Alternatives livelihoods and mercury-free techniques

3.2 Preliminary Urine Sampling

Exposure to mercury can be measured through its concentration in urine. Mercury has a half-life of about two months, and urinary excretion reaches a steady state after about six months (ACGIH, 2013). General research indicates that levels above 1 ug/L of mercury in urine suggest exposure. Peru's standard for levels of concern are: greater than 5 ug/l for non-occupational persons (i.e. residential exposure) and greater than 50 ug/L for occupational persons (MINSA-Peru 2013). Occupational exposure refers to a specific set of parameters, such as eight hours of exposure per day.

In March 2016, the project team conducted urine sampling in populations in Ollachea and Laberinto to determine the level of mercury exposure in the two selected ASGM sites. The sampling was anticipated to be the first of two studies, with the second to be implemented at the conclusion of the project. In total, 240 people, consisting of miners and residents from each community, were enrolled randomly from the population and informed of the project's objectives. However, as 35 individuals elected not to participate, only 205 individuals provided samples (104 in Madre de Dios and 101 in Ollachea). The study was approved by a Peruvian ethics committee and appropriate measures were taken to guarantee the safety and privacy of each participant.

Before urine collection, patients were asked to wash their hands in order to avoid affecting the sample. Participants provided a urine sample of approximately 20 mL using standard urine collection procedures at a nearby health clinic. Each sample was stored in two vials and prepared for transport by adding a chemical stabilizer. The vials were stored and transported to Lima in a portable refrigerator. The urine analysis was conducted in Lima in the National Center for Occupational Health and Environmental Protection for Health – Ministry of Health (CENSOPAS - MINSA) laboratory.

Figure 3.2 A study participant provides preliminary demographic information

Figure 3.3 A local health expert handles a urine sample

Results

Using Peruvian standards, the study identified that female residents (49%) were more likely than female miners (13%) to have levels of mercury above the standards in both Laberinto and Ollachea. In the case of males, residents (57%) were more likely than male miners (24%) to have levels of mercury above the standards in Laberinto. However, male miners (16%) were more likely than male residents (11%) to have levels above the standards in Ollachea. Values were as high as 209.4 ug/l in Laberinto and 477.2 ug/l in Ollachea. The regional health directorates provided applicable medical services to all participants with mercury poisoning.

These results indicate moderate-to-high mercury poisoning in both communities. This is consistent with the hypothesis that communities in proximity to ASGM are at health risk and that these communities experience multiple sources of exposure, as elevated urinary mercury levels were present in both males and females in addition to both residents and miners. From the scope of this study, it was not possible to determine if the most significant exposure occurs during the amalgamation or amalgam burning process. Furthermore, results suggest that residents are more likely to have levels above the respective standard than miners. However, it is worth noting that delineating miners from residents was at times challenging, given that families often work together in the gold mining process.

Community	Gender	Group	Total Participants	Mean (ug/L)	% of Group above Standard
Laberinto	Male	Miners	8	32.3	13%
		Residents	61	8.7	49%
	Female	Miners	21	34.2	24%
		Residents	14	12.3	57%
Ollachea	Female	Miners	5	85.9	20%
		Residents	38	18.3	32%
	Male	Miners	49	27.4	16%
		Residents	9	1.9	11%

Table 3.1 Representation of exposure and demography of populatation in preliminary 2016 study

3.3 Follow-up Urine Sampling

In February 2019, Pure Earth carried out a follow-up evaluation in Ollachea, where the project also conducted trainings and a soil remediation to reduce mercury exposure in the population. Given that in the previous study it was challenging to delimit miners from residents (non-miners), only official occupational miners were included in this sampling. A total of 120 miners completed a five-page questionnaire on mercury usage, practices and other relevant variables and were then asked to provide a urine sample. A total of 78 men (65%) and 42 women (35%) participated in the three-day sampling. Participants represented over a dozen mining companies working in Ollachea and approximately 63% were from the Ollachea Mining Association. The majority of participants tested have been employed in mining since at least 2017 (74%). The age distribution was similar in men and women, with the dominant group among both genders being the 25-39 age group (43% men and 21% women).

Figure 3.4 Recording demographic data from a female study participant

The study was approved by the Pure Earth Institutional Review Board and appropriate measures were taken to guarantee the safety and privacy of each participant. A similar methodology as the previous study was used for the sampling and analysis phases.

Community	Gender	Group	Total Participants	Mean (ug/L)	% of group above standard
Ollachea	Female	Miners	42	8.7	5%
	Male	Miners	78	19.7	4%

Table 3.2 Representation of exposure and demography of populatation in follow-up 2019 study

The mean urinary mercury level for males was 19.7 ug/L while the level for females was was 8.7 ug/L ($p = 0.05$). In 2016, 20% of Ollachea female miners had levels above the standard while in 2019 this percentage decreased to 5%. Similarly, 16% of male miners in 2016 had levels above the standard while in 2019 this percentage decreased to 4%. During the preliminary sampling, a total of 54 miners working in Ollachea were tested, with a mean urinary mercury level of 32.8 ug/L, while the 2019 group of 120 miners reported a mean urinary mercury level of 15.8 ug/L. Statistical analysis revealed in a probability value of 0.038, meaning the groups were statistically different and 2019 miners had statistically lower urine mercury levels than the 2016 cohort.

4.0 MINER DEVELOPMENT

Overview

Peru imported at least 100 tons of Hg each year from 2010 to 2014, about half of which ended up in Madre de Dios. Evidence suggests that much of this mercury was funneled from Mexico to Bolivia, where it is illegally imported into Peru (YaleGlobal 2018; El Comercio 2015). Nearly all of Peru's imported mercury is used in the ASGM sector (Swenson et al 2011). While the amount of mercury used daily by artisanal and small-scale miners in Madre de Dios varies greatly depending on the ore grade and mine type, quimbaletes mining operations, such as those in Ollachea, use approximately 1-2 kg of mercury daily (Brooks et al. 2007). In general, miners in Peru recover about 1 gram of gold for every 2.8 grams of mercury used (UNEP 2011).

Most small-scale gold miners in Peru either operate informally (in concessions en-route to formalization) or completely illegally. In both cases, they typically face little-to-no regulation or oversight to ensure they are adhering to safe mining practices. To provide miners with a responsible and economically viable alternative to harmful artisanal methods, Pure Earth instituted training programs in the Puno and Madre de Dios regions, which included training in mercury-free mining techniques and support with cost and use of mercury-free equipment.

Results at a Glance

206
Miners trained in Hg-free techniques

40
Miners have reduced mercury use by 80% or more

17
Miners certified in mercury-free method

283
Hours of mercury-free trainings for miners/officials

7
Officials trained in Hg-free techniques

4.1 Gravimetric Mining

Gravimetric methods can eliminate or greatly reduce the need to use mercury by using the high density of gold to remove lighter particles and increase gold concentration in the ore. Gravity methods include any combination of panning, sluicing, shaking tables, concentrators and centrifuges (EPA 2018). Eliminating mercury use provides economic benefit and incentive for miners, both through potentially increased yields and mercury reduction. Based on project experience, the price of mercury/kg in Peru is approximately $210 and an ASGM miner uses about 1 kg of Hg/month.

The Filipino Method: The primary alternative to mercury use in mining introduced by Pure Earth during the project was the Filipino Method, a gravimetric technique which uses borax to smelt the concentrated ore. This method was re-discovered and championed throughout the world by Filipino miners Leoncio Na-Oy and Rudy Onos, who traveled to Peru to deliver project trainings.

Methodology**:** After the gold-bearing ore is crushed into a fine powder, it is processed using sluicing rather than amalgamation. Water is fed into the sluice box, which washes the ore down a series of chutes. The heavier gold particles sink to the bottom onto a cloth, while the lighter material washes away. After several runs, the cloth is removed from the chutes and rinsed in tubs of water, where it is panned to further refine the mixture. Finally, borax is added to the gold mixture to facilitate effective smelting. Borax reduces the melting temperature of gold, aids in removing oxides and minimizes fuel required to smelt.

Figure 4.1 Miners in Ollachea watch gold smelted using non-toxic borax

Strengths and Challenges**:** If implemented correctly, it is possible to recover 15-20% more gold than in the traditional mercury method. The technique also does not require the use of expensive machinery.

Nonetheless, Pure Earth found the technique limiting for miners in both regions who did not operate on a very small-scale, as the panning requires significant manual labor and the method prevents miners from further industrializing their operation. Furthermore, depending on the community, male miners in particular may be reluctant to adopt panning, as it requires less force and can be culturally foreign.

Shaking Tables: Pure Earth found another gravimetric method, shaking tables, to also be effective in compelling miners to reduce mercury use. With this technology, the crushed ore is mixed with water and passed down a tilted table, which traps the gold in collection points and washes lighter material away. The motorized shaking facilitates particle separation. This process eliminates or substantially reduces the need for mercury in the refinement process.

However, the method's efficacy and type of shaking table required depends on the mineralogical characteristics of the ore. The team found that the shaking tables were more suited to the heavier ore found in Madre de Dios. In addition, the equipment is quite expensive, typically $3,000-$4,000, which directly impacts ASGM miner adoption of the technology.

4.2 Ollachea, Puno

Figure 4.2 Female miners in Ollachea were particularly receptive to the Filipino Method

Figure 4.3 Ollachea miners Maximiliano Pari and Olimpia Bellido showing gold recovered from the Filipino Method

In April 2016, project partner and mercury-free mining cooperative Emerald Mountain held demonstrations and training workshops in the Filipino Method. From the start, miners were impressed that the technique was not only safe but could potentially extract more gold, and at less cost. Since this initial visit, miner interest in going mercury-free increased, thanks to the project's educational efforts and other secondary factors, such as the increase in market price of mercury and pressure by the government to obtain formal legalization, which precludes illegal mercury acquisition. Nonetheless, Pure Earth discovered that some miners were reluctant to adopt the panning portion of the technique, either because it was too foreign or because they perceived it as limiting in scale.

By 2017, Ollachea miners who had mastered the Filipino Method began leading trainings for other miners, suggesting a domino effect of local change. To further spread the method, Pure Earth and partners have also provided miners with resources, including cost-share for equipment purchases (sluice boxes), the remediation of contaminated soil and assistance from the Alliance for Responsible Mining (ARM) with assessing their FAIRMINED formalization status.

As a result of these developments, 40 miners in Ollachea have adopted a mercury-free technique and have reduced mercury use by 80% or more. Miners Maximiliano Pari and Olimpia Bellido (Figure 4.3) have consistently supported Pure Earth's efforts and have acted as local champions for the project. Maximiliano reported that he has reduced mercury usage from 4 kg/month to 0.8 kg/month, saving about $682 monthly.

Given the miners' investment in mercury reduction and growing awareness in the population, it is expected that these results will self-replicate beyond the project's conclusion. The train-the-trainer method was shown to be one of the most effective means for changing extraction techniques.

4.3 Madre de Dios

As many as 30,000 ASGM miners operate in Madre de Dios, accounting for about 70% of Peru's total artisanal gold production (Ashe, 2012). This region also contains the greatest number of illegal mining operations in the country. Obtaining a mining permit in the region requires conforming to official environmental impact standards, which very few miners are motivated to do given low levels of enforcement.

Figure 4.4 Madre de Dios miners learning the panning portion of the Filipino Method, which many were reluctant to adopt

Figure 4.5 Mr. Ynfantes recovers gold after it is processed by a shaking table

Pure Earth first trained Madre de Dios miners in the mercury-free Filipino Method in April 2016. Due to interest in the technique and responsible mining practices, three mining associations (Paolita II, FORTUMIL, CU&SA2) signed agreements with Pure Earth to participate in the project. Although these miners were interested in pursuing a safe livelihood, many were reluctant to fully adopt the Filipino Method, primarily because they found it slightly less efficient due to the nature of the gold in the region and the larger scale of their operations. As a result, Pure Earth adapted its approach, developing an altered method that incorporates shaking tables rather than mercury to concentrate gold. A technical expert in gravimetric methods from Peru's Center of Mining Research and Technology (CITE) visited the sites to help fine-tune and promote the method among miners.

As a result of these efforts, Pedro Ynfantes (Figure 4.5), owner of the Paolita II Mining Concession, has become an exemplar of mercury-free mining practices. He has not only adopted a gravimetric method but has also responsibly closed 2.5 ha of his mining concession through the project's restoration initiative. Mr Ynfantes' actions will ideally inspire other members of the community to follow his example.

5.0 REMEDIATION & RESTORATION

Overview

The remediation portion of the project aimed to identify and restore areas negatively impacted by ASGM activities and mercury use. In addition to benefiting affected communities and environments, the remediations functioned as pilot projects to provide future government and non-government stakeholders with tested remediation methodology, which could be incorporated or replicated in similar interventions. The remediation plans were developed using the detailed environmental evaluations, the input of the mining communities and the relevant technical literature on remediation strategies.

The first intervention was conducted in the Mina Pampa sector in Ollachea and included remediation of contaminated soil, improvement of tailing ponds, and installation of platforms for tailing bags storage as well as channels for rainwater drainage. Miners participated in all activities and, in exchange for these benefits, promised to stay mercury-free. For the second initiative, Pure Earth restored two rainforest sites degraded by mining in Madre de Dios. Using research from CINCIA, this is the first reforestation project used to responsibly close a gold mining site. The reforestation served as an example to give miners the knowledge and experience to responsibly close future sites.

Results at a Glance

3.5
Hectares degraded rainforest restored in Madre de Dios

8
Tons of soil excavated and safely removed in Ollachea

85
Community members participated in remediation planning

40
Miners and local students trained in reforestation

15
Government officials trained in reforestation methodology

26
Government officials trained in soil remediation methodology

5.1 Ollachea: remediation planning

The detailed environmental assessments demonstrated that the use of mercury releases gases and liquid emissions, which contaminate soil in areas surrounding the work sites. Soil contamination arises from a combination of the following circumstances: improper tailings storage and handling; improper transport of tailings during tailing pond cleanings; and inadvertent mercury spills during amalgamation.

The objective of the Ollachea Environmental Remediation Plan was to improve environmental quality of the soil by decreasing the concentration of mercury. The project team considered and compared a variety of onsite and offsite strategies to accomplish this objective, including immobilization, phytostabilization, phytoextraction, containment, excavation, thermal desorption and soil washing. The following measures were determined most suited to the contamination context in Ollachea:

✓ Close agreed upon tailing ponds and quimbaletes in proximity to the Oscocachi River

✓ Excavate and safely dispose of contaminated topsoil (10-30 cm) in an offsite facility

✓ Add a layer of waterproof gravel and drainage ditches to roads where soil excavation took place

✓ Improve tailing ponds using bricks and roof repair to prevent rainwater entrance

Peter Plates

The Peter Plates method involves recovering gold from surplus mercury in discarded mining tailings. In this method, mining wastewater flows down amalgamated copper plates, which capture and recover gold-bearing mercury. Pure Earth experimented with the method in the pilot sites and determined that its efficacy depends on the tailings' mercury concentration and its mineralogical characteristics.

Using Peter Plates in Madre de Dios proved difficult, as high temperatures caused mercury to volatize and the region's tailings are "heavy," which increases the processing time required for treatment. Due to its cold temperatures and "light" tailings, Ollachea proved more suitable. However, Peter Plates ultimately were not incorporated into the Ollachea remediation because the large amount of tailings would require considerable labor and there was no adequate means of disposing the captured mercury. Additionally, Peter Plates incorporate the use of elemental mercury which increases the health risks to miners and potential for spills, and continues to support mercury circulation, all of which are inconsistent with the core objectives of the Minamata Convention.

Figure 5.1 Peter Plates technology, which is used to treat mining tailings

5.2 Ollachea: remediation results

Of the four mining sectors in Ollachea, Pure Earth selected the mining sector Mina Pampa to implement the large-scale soil cleanup because of the miners' commitment to the mercury-free method. The intervention kicked off in November 2018 to accomplish the following:

Soil Assessments: First, the team reevaluated the soil and tailings with an XRF device to determine excavation targets. Mercury was not detected at or above the detection limit on access roads, despite the appearance of discarded tailings. In mining work zones, mercury was generally low or undetected in surface soil, with about 25% of samples in the 20-128 ppm range. Nonetheless, contamination tended to increase in depths between 20 cm below ground surface (bgs) and 50 cm bgs. While it is difficult to determine why surface contamination diminished, the subsurface contamination reveals the importance of conducting thorough depth assessments.

Tailing Ponds, Platforms, Drainage: The project team improved 11 tailings ponds for mine owners, who each promised to go mercury-free. The improved ponds contain two concrete masonry tanks, reinforced with steel rebar, that will safely store large amounts of tailings. Miners can expect 5-6 months of deposition before the tanks require removal of waste for offsite disposal. To aid with disposal, miners were provided with four new platforms for storing discarded tailing bags. Pipes and water channels were also installed, given that the rainwater drainage system was insufficient or in some cases absent. Effluent from the tailing ponds, which previously flowed into the Oscocachi River, will be directed into a filter drum to retain all sediments. After the effluents pass through the filter, the water will be monitored before it is released into the river.

Excavation: Using the assessment measurements as a guide, Pure Earth excavated and safely removed about eight tons of contaminated soil. Excavation activities were conducted by hand using shovels and picks. Excavated soil was contained in ore sacks and transported to temporary storage areas for disposal.

Soil Deposition: At their request, Pure Earth delivered the contaminated soil to the mine owners to sell to a cyanidation plant, where it will be deposited in large tailings pond with enough capacity and control to retain residual tailings.

Figure 5.2 One of the platforms provided for storing discarded tailings bags

Figure 5.3 One of the improved tailing ponds for safely handling mining waste

5.3 Restoration Planning

Figure 5.4 Previously lush rainforest scattered with barren craters dure to ASGM in Madre de Dios

As evidenced by previous environmental assessments, mercury concentrations in ASGM Madre de Dios rainforest worksites tends to be low and pose minimum health risks from immediate exposure. Furthermore, due to the nature of alluvial mining in the area, miners tend to abandon the degraded sites after they have completed the gold extraction process. These activities are degrading the Amazon basin at an unprecedented rate, with the worst damage occurring in Madre de Dios, one of the most biodiverse and pristine areas in the world.

Pure Earth's environmental assessments suggested that a high exposure risk occurs in the urban gold shops, where the mercury amalgam is re-burned in primitive retorts, exposing workers and the local population to mercury vapor. Although Pure Earth originally planned to provide gold shops with improved retorts to control emissions and recuperate mercury, further investigation revealed that the gold merchants operate illegally, which prevented the project from conducting this intervention.

Because of these factors, Pure Earth decided to focus instead on an ecological restoration, which would also help miners gain proper mine closure methodology. The project team conducted two restoration plantations in the Paolita II and Fortuna Milagritos (aka Fortumil) mining concessions, each of which is located in the rainforest about thirty minutes by boat from the urban district of Laberinto. In total, 3.5 hectares of the degraded mining land were restored, with 4,166 seedlings and 2.5 ha in Paolita II and 1,700 seedlings and 1 ha in Fortuna Milagritos. As this is the first reforestation to responsibly close a gold mining site, it serves as a pilot plan, which can be drawn on by miners and other local and national government and civil society stakeholders.

5.4 Restoration Methodology

Phase 1: The first step in conducting a reforestation plantation in degraded mining sites is to geographically characterize the area. This was done with a Phantom 4 drone to create an "orthomosaic" map, which allowed the team to classify the site into four categories: bare soil, gravel mounds, soil with natural regeneration, and flood zones. This can be used to identify areas most in need of restoration and create a digital model of the plantation. This characterization also helps determine if heavy machinery should be used to level the landscape for easier plantation. Pure Earth opted not to use machinery, primarily because of logistical complication and sparse miner support.

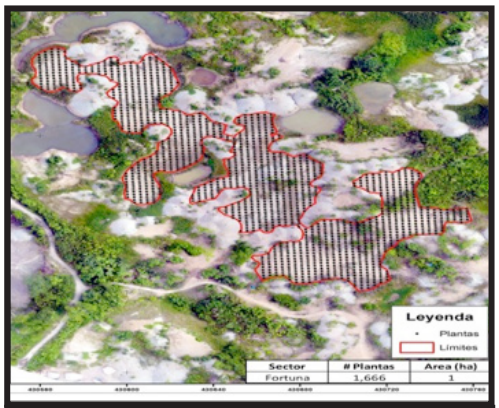

Figure 5.5 Orthomosaic site map

Phase 2: The Pure Earth team selected and planned the plantation of tree species, based on miner input and longstanding research from project partner CINCIA with experimental plots to develop the most sustainable and effective plantation strategy. In addition to selecting species with economic and ecological value, the planted trees must accelerate the process of ecological succession, guaranteeing an increase in diversity as quickly as possible. Fast-growing coverage plants must complement slow-growth diversity species and trees must utilize different resources so as not to compete with one another. CINCIA's research showed that lines of coverage and diversity species should be planted at a distance of 3x2 meters, with 2 meters separating the lines and 3 meters separating individual plants.

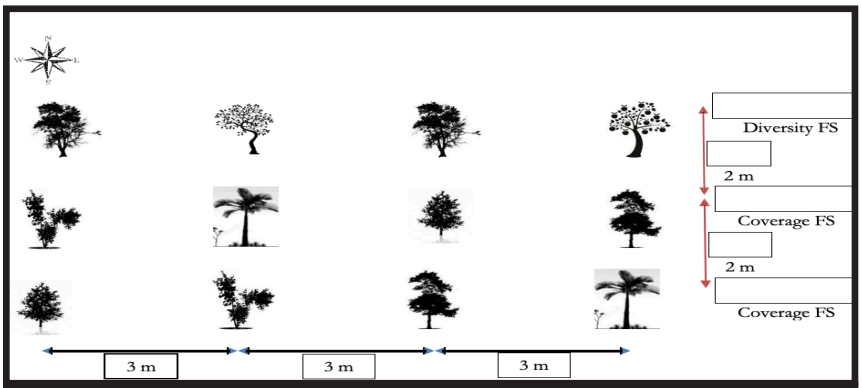

Figure 5.6 Diagram of 3x2 meter plantation model

Phase 3: After seedlings were obtained and transported to the plantation area, species were planted with a combination of amendments to bolster growth, including a base of hydrogel, biochar (enriched with molasses and productive microorganisms) and a ring of fertilizer. Once planted, field workers recorded dimensions of the planted seedlings in order to monitor future growth.

Phase 4: Finally, frequent visits were made to monitor growth and replant any seedlings that have died since the original planation. Gradually, fast-growing pioneer species will be replaced by intermediate and late successional species, developing a vital undergrowth and stratified canopy. Within about thirty years, the eco-system should be self-sufficient and can be considered on the path to complete restoration.

5.5 Restoration in Paolita II

Located on the banks of the Madre de Dios River, the Paolita II mining concession is owned by Pedro Ynfantes, who has worked with Pure Earth throughout the project to reduce mercury use and obtain legal formalization. The concession is around 400 ha in total, with about 2-3 ha of land mined and degraded per year. Environmental assessments reported no significant mercury or arsenic contamination in soil. However, discarded tailings can be found on the site, within which elemental mercury volatizes and is transformed into MeHg that may enter the food chain.

In December 2017, Pure Earth identified and restored 2.5 ha of degraded land in the Paolita Mining Concession. The Paolita II plantation represents the first-ever application of a reforestation mining restoration plan, a technique designed by CINCIA to rehabilitate degraded rainforest.

Figure 5.7 The project team planting seedlings

Figure 5.8 A student applies soil amendments

Field Team: All members of the field team were experienced in reforestation methodology and had previously worked with CINCIA. Seven team members were ecology students from the local branch of the national university system, the Universidad Nacional Amazónica de Madre de Dios.

Transportation: This was an arduous process, as the team needed to transport all project supplies via truck from a nearby city to the Laberinto port, then down the Madre de Dios River and through a backcountry trail to the site. Due to heavy rains, fallen limbs and artificial pools produced by mining activities, the trail was nearly impassable. In several spots, the team constructed makeshift bridges and rafts to successfully transport the supplies across flooded areas.

Plantation: Nine different species were selected, including five diversity (slow-growth) species and four coverage (fast-growth) species. In total, the project team planted 4,166 seedlings and applied 1 kl of compost and 8 ml of NPK (nitrogen, phosphorous, potassium) amendments to each seedling.

Monitoring: Returning a few months later in March 2018, Pure Earth weeded interfering plants and planted an additional 744 seedlings to reinforce initial growth. CINCIA will continue to monitor, study and aid the plantation beyond the conclusion of the project in March 2019.

5.6 Restoration in FORTUMIL

Given that it was not possible to conduct an intervention in the Laberinto gold shops and that the restoration effort in Paolita II was extremely successful, the project team decided to conduct a second ecological restoration. The Fortuna Milagritos (FORTUMIL) mining concession the banks of the Madre de Dios river, was selected due to its community support and ecological degradation from mining.

Pure Earth originally connected with FORTUMIL through discussion with a local Episcopal non-profit organization, Caritas, which was working with the concession. MINAM CAF, a MINAM ecological improvement program focused on Andean regions in Southeastern Peru, provided these miners with five shaking tables to assist them in developing responsible mining practices. Pure Earth supported MINAM CAF's aid by giving miners technical support from CITE on proper shaking table use and responsible mine closure.

In November 2018, Pure Earth identified and restored 1 ha of degraded land in the FORTUMIL concession, using almost identical restoration methodology as Paolita II due to similar environmental conditions. Pure Earth delivered the restoration plan to FORTUMIL miners, so they could replicate the closure technique. These efforts, combined with other adjustments, assisted FORTUMIL in their ongoing effort to achieve formalization.

Figure 5.9 Plantation team, including local university sutdents, in front of the FORTUMIL concession center

Field Team: Workers included students in Universidad Nacional Amazónica de Madre de Dios or in biology from the Universidad Nacional San Antonio Abad del Cusco. They were included to further develop their interest and expertise in reforestation.

Transportation: While the transportation of seedlings and site materials required the same process, the project team implemented the restoration one month earlier to avoid logistical complications associated with the rainy season.

Figure 5.10 Team members transport seedlings in crate to the FORTUMIL plantation site

Figure 5.11 Team members mixing biochar with molasses and microorganisms to support seedling growth

Plantation: In total, the project team planted 1,700 seedlings and applied 5 g of hydrogel and 1 kl of biochar, enriched with 2 liters of molasses and 2 liters of efficient microorganisms. Twelve different forest species were selected, including five diversity (slow-growth) species and seven coverage (fast-growth) species. The differences in species selection pertained primarily to the availability in local nurseries.

An important addition from this plantation was the use of biochar. Made from locally recycled chestnut shells, biochar aided the soil's retention of water and nutrients while preventing the plant from absorbing mercury in the soil. It is an increasingly popular soil amendment and has potential to increase carbon sequestration (Woolf et. al 2010).

Monitoring: Project leader France Cabanillas returned in February 2019 to weed all interfering plants and replace any dead seedlings. As with Paolita II, CINCIA will continue to monitor, study and aid the plantation beyond the conclusion of the project in March 2019.

6.0 Sustainable Progress

Figure 6.1 Members of the Pure Earth team with mining stakeholders and government officials in Ollachea, Puno

Over the course of this four-and-a-half-year project, Pure Earth has instituted an innovative approach of partnership and collaboration to benefit populations affected by ASGM. This included educational awareness about the dangers of mercury exposure as well as intervention efforts, planned and implemented with miners and their communities. Furthermore, the project worked with miners to develop mercury-free alternatives, uniquely adapted to their local conditions, that protect their communities while providing economic benefits.

The positive effects of these achievements will continue to grow in years to come. Progress made in raising health awareness, developing alternative livelihood strategies and instituting remediation initiatives were made in close collaboration with the regional and national government, providing officials with the knowledge and connections to sustainably reduce the negative impacts of ASGM. The benefits of intervention efforts will also continue to expand, as Pure Earth expects to raise additional funds to extend engagement with miners in Ollachea and project partner CINCIA plans to continue monitoring and maintaining restoration sites in Madre de Dios for several years.

While the road to safe and profitable small-scale mining practices is long and arduous, Pure Earth's sustained engagement with mining communities and government entities has built a foundation for a mercury-free future in Peru.

7.0 Conclusions

During the initial project phase, Pure Earth assessed thirteen sites and conducted four detailed evaluations. During this process, 27 Peruvian government officials, primarily from MINAM and MINEM, were trained in rapid site assessment, consisting of pollution identification and risk assessment. Rapid assessments as well as post-remediation confirmation were conducted using XRF and Jerome mercury vapor technology, as well as offsite fixed lab analysis for quality assurance. Primary lessons learned included:

✓ Illegality is a key obstacle, especially in Madre de Dios. The project ultimately was forced to abandon investment in the Laberinto gold shops because they were operating illegally and were ineligible for official support. On the other hand, miners pursuing formalization proved to be the best candidates for site selection.

✓ Complete community commitment to project efforts is essential. The CU&SA2 Mining Concession in La Pampa and the San Miguel de Untuca mining community in Puno expressed initial support but ultimately withdrew due to conflicting interests.

✓ Environmental site assessments should be extended to consider factors, including river sediment, surface water, bioavailability and mobility of heavy metals, water treatment alternatives, biological samples (fish, plankton, benthic invertebrates), mineralogical characteristics of the ore, remedy performance monitoring, etc. This will provide a more thorough evaluation of the impact to human health and ecological receptors, thus guiding more effective and efficient remedial action.

Pure Earth trained 15 local health personnel and held 17 workshops for 168 community members on the risks and prevention measures of mercury exposure. Results from urine sampling suggested that ASGM activities elevated exposure and that the project intervention may have been effective in reducing exposure. This hypothesis was supported by a mean urinary mercury level decrease of 17 ug/L (more than 50%) in the Ollachea mining population after intervention. The primary lesson learned from this phase was that it can be difficult to delineate whether participants are miners or non-miners because families often operate jointly. This also suggests the importance of developing additional exposure information to support risk assessment to more vulnerable sectors, including children and pregnant women.

Regarding miner development, the project team trained seven Peruvian government officials and 206 miners in mercury-free practices, forty of whom have reduced mercury use by 80% or more. Various combinations of gravimetric methods were encouraged with varying success, including the Filipino method (sluice boxes, panning, smelting with borax) and shaking tables. Because miners generally trust one another, the miner-to-miner training model was successful in both project sites. Challenges and possible improvements include:

✓ Logistics of obtaining and transporting project materials to remote sites should be considered. Large bulk transport of equipment is preferable to reduce transport costs. Furthermore, implementers may need to develop contacts in Lima, as materials, particularly smelting equipment, can be quite expensive elsewhere.

✓ The Filipino method works best for small-scale miners who are not going to industrialize using large gravimetric equipment and cyanidation. The project team also found it difficult to persuade miners to adopt the panning, as it required a novel and somewhat tedious form of labor. This technique, although not specific to borax, could be improved by using shaking tables or centrifuges to replace panning. Communal use of shaking tables and gravimetric equipment through renting or sharing may be a viable solution to high expense.

✓ Interest in mercury-free techniques depended strongly on economic incentives and the shifting price of mercury. Costs can be decreased by using borax because there is no cost for mercury and reduced cost in fuel for smelting.

Figure 7.1 Ollachea miners during an Hg-free training

In Ollachea, Puno, Pure Earth remediated eight tons of contaminated soil, improved containment of eleven tailing ponds to safely store mining waste; provided four platforms for storing tailing bags; and installed pipes and channels for rainwater drainage. In Madre de Dios, Pure Earth re-stored 3.5 ha of deforested land in order to provide miners and stakeholders with a pilot site to de-velop and replicate proper mining closure. During this process, twenty-six Peruvian government officials were trained in soil remediation and fifteen in restoration methodology. The following les-sons were learned during this stage:

✓ The use of Peter Plates technology to treat mining tailings and recovery mercury proved very challenging. If the technology is used, a consistent process needs to be considered (e.g. strong mixing of the tailings using powered-equipment) to make tailings light enough to pass efficiently through the amalgamated copper plates. Furthermore, the technology incorporates the use of elemental mercury, which increases health risks and is inconsistent with the Minamata Convention.

✓ The project team proposed to send the contaminated soil from cleanup activities in Ollachea to a hazardous waste landfill. However, miners opted instead to send it to a cyanidation plant to generate additional revenue. This desire should be expected in future cleanup efforts.

✓ Like Laberinto, Ollachea has a significant number of gold shops, which pose similar health risks. While this situation requires further investigation, it is probable that these shops are purchasing illegally and will be reluctant to modify smelting operations.

✓ The detailed environmental assessments in Madre de Dios suggests that mercury contamination accumulates in river sediment, rather than in soil, and also occurs due to volatilization from high temperatures, where it moves into the food chain through methylation.

✓ Interventions in mining communities can be formed through partnerships with local organizations, as seen by the project's collaboration with the local Episcopal organization CARITAS, which ultimately facilitated the FORTUMIL restoration effort.

Finally, regime transitions within the national and regional government cause frequent personnel rotation. As a result, the project team was often forced to repeat information, despite consistent high-level official support. Furthermore, regional and local authorities must strengthen their legal framework in order to regulate the gold market. To reduce negative health impacts, it is essential that all gold shops acquire a permit or authorization. Similarly, DREM in Puno and Madre de Dios must increase supervision and enforcement of mining operations, including enforcing economic penalty. Despite these challenges, sustained commitment by miners like Pedro Ynfantes in Madre de Dios and Maximiliano Pari and Olimpia Bellido in Ollachea suggest that miners are willing to learn and adopt responsible practices, as long as appropriate resources, knowledge and incentives are made available.

The project "Community-driven Artisanal and Small-Scale Gold Mining (ASGM) Remediation Planning in Peru" faced many challenges. However, through sustained collaboration with government officials and local stakeholders, Pure Earth's technical expertise, and an understanding that interventions are a gradual process, the project succeeded in reducing the negative impact of ASGM in Peru.

Figure 7.2 Members of MINAM and the Pure Earth team during a remediation methodology training in Puno

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