MERCURY EXPOSURE OF WOMEN IN FOUR LATIN AMERICAN GOLD MINING COUNTRIES

June 2021

BRI
Biodiversity Research Institute
innovative wildlife science

IPEN
for a toxics-free future

MERCURY EXPOSURE OF WOMEN IN FOUR LATIN AMERICAN GOLD MINING COUNTRIES

ELEVATED MERCURY LEVELS FOUND AMONG WOMEN WHERE MERCURY IS USED IN GOLD MINING AND CONTAMINATES THE FOOD CHAIN

Lead Author
Lee Bell, *IPEN Mercury Policy Advisor*
Dave Evers, *BRI, Executive Director, Chief Scientist & Co-Director Center for Mercury Studies*
Mark Burton, *Contributing Author, BRI*

JUNE 2021

IPEN is a network of non-governmental organizations working in more than 100 countries to reduce and eliminate the harm to human health and the environment from toxic chemicals.

www.ipen.org

Biodiversity Research Institute is a nonprofit ecological research group whose mission is to assess emerging threats to wildlife and ecosystems through collaborative research, and to use scientific findings to advance environmental awareness and inform decision makers. BRI is the leading international institute supporting the global mercury monitoring efforts for the Minamata Convention on Mercury.

www.briloon.org

ISBN: 978-1-955400-05-3

IPEN Production Team: Tim Warner, Betty Wahlund. Cover photos: Daniel Flores R.

Cite this publication as:
Bell, L. and Evers, D. *Mercury exposure of women in four Latin American gold mining countries: Elevated mercury levels found among women where mercury is used in gold mining and contaminates the food chain*. International Pollutants Elimination Network (IPEN), June 2021.

KEY FINDINGS

- Of the 163[1] women of childbearing age who participated in the study, 58.8% exceeded the 1 ppm USEPA threshold level at which negative effects may be detected in the fetus and 66.8% exceeded the 0.58 ppm level which is a recently derived level at which researchers believe negative effects may start to occur.
- The women of the Bolivian indigenous Eyiyo Quibo and Portachuelo people had, by far, the highest levels of mercury in the cohort assessed in this study, with a mean of 7.58 ppm ± 4.75 ppm (fw). The 1 ppm threshold level and the 0.58 ppm proposed level for mercury, were exceeded in 93.7% of the women tested. As these were indigenous women who do not engage in gold mining and have fish as the mainstay of their diet, it is clear that their very high mercury levels arise from consuming contaminated fish of the Beni River system.
- Women in the Brazilian gold mining village of Vila Nova had the second highest mean levels of mercury in hair at 2.98 ppm ± 3.37 ppm (fw). Women in the Venezuelan gold mining town of El Callao had the third highest mean levels of mercury in hair at 1.1 ± 1.09 ppm (fw). Women in the non-mercury gold mining town of Iquira had the lowest mean levels of mercury in hair at 0.25 ± 0.15 ppm (fw).
- Many women had significantly elevated levels with 43% of all participants exceeding a level of 3 ppm, 35% exceeding 5 ppm, and 7% over 10 ppm, the latter mostly among the Bolivian participants.
- A significant number of women also had elevated levels that could not be attributed to direct mercury exposure in mining including housewives, merchants, office workers and nurses in gold mining towns. These women all regularly consumed local fish suggesting that dietary exposure to mercury-contaminated fish may be responsible for their elevated body burden.
- Despite national bans on mercury use in gold extraction in some of the countries studied, the practice continues and regionally fish are contaminated by historical and current mercury contamination from mining activities.
- Women in communities where mercury use in gold mining has been ended for some years reported some of the lowest mercury levels seen in IPEN's global biomonitoring program.
- Weaknesses in the Minamata Convention on Mercury continue to facilitate the global trade in mercury and its diversion to ASGM despite national prohibitions on the practice.
- Amendments to the convention which dramatically reduce global supply are necessary to restrict legal and illegal shipments of mercury destined for ASGM.

1 The result of one participant was excluded on the basis that it was an outlier reading at 181 ppm. A level of this order is generally associated with external surface contamination of the hair with mercury and will require further assessment.

CONTENTS

EXECUTIVE SUMMARY

This study is the latest compilation of data in IPEN's global mercury biomonitoring program. As for previous studies IPEN worked with NGOs on the ground to collect hair samples from women of child-bearing age to analyse for total mercury. In previous biomonitoring studies IPEN has analysed hair samples from women in a range of exposure scenarios across the globe and surveyed participants on their dietary intake of fish, occupation and any known exposures to mercury. In this study, information was sought on mercury body burden levels in localities within Latin America where artisanal and small-scale gold mining (ASGM) is prevalent.

Four locations were selected based on advice from local IPEN Participating Organisations and associated NGOs. These included the mining towns of Vila Nova, Brazil and El Callao, Venezuela where mercury is used by miners to amalgamate gold particles from mined ore. For comparison, sampling was also conducted in Íquira, Colombia where gold miners, organised in a cooperative, stopped using mercury at least five years ago. A fourth region around the Beni river system in Bolivia was also investigated, with two groups of women from the Esse Ejja indigenous ethnic group participating. The Portachuelo group and the Eyiyo Quibo group live in communities along the Beni River Basin around 380 km apart. The results for the Bolivian women were especially concerning: they have no engagement with mining or contact with mercury and are reliant on a subsistence fish diet. This suggests that many more women who have a fish rich diet in this region are at risk of high levels of mercury exposure through their diet.

The hair sampling was conducted in identical fashion at all four sites by NGOs using a verified and approved methodology and a science-based protocol to ensure comparability of results and minimisation of cross contamination. The hair samples were shipped to the Biodiversity Research Institute (BRI) in the USA for analysis and the results of mercury concentrations reported in parts per million (ppm) for comparison against the USEPA threshold level of 1 ppm. The methodology, analysis and comparison to reference levels are described in chapter 2.

ASGM activity using mercury is currently the leading source of global mercury pollution accounting for 38% of global anthropogenic emissions and introduced about 1,220 tons of mercury into terrestrial and freshwater environments in 2015 (UNEP 2018). In some locations in countries of Latin America there is limited data available about the impact of mercury use on the environment, ecosystems and the people who live there. IPEN responded to invitations from its Participating Organisations to conduct a pilot study of sensitive sub-populations in four locations. Women of childbearing age are considered to be a particularly sensitive sub-group as the fetus is especially susceptible to the developmental impacts of mercury which acts as a powerful neurotoxin. The results demonstrate that indigenous women reliant on fish for protein as well as a significant number of women in other occupations living in proximity to the gold mining activity, have elevated mercury levels. Analysis of the questionnaires provided by the participating women suggests that dietary exposure through contaminated fish is the primary source of elevated mercury levels in women.

Disturbingly high results were found among most of the Esse Ejja women who participated from the Beni River Basin in Bolivia, which were the highest assessed among all the participants in this study. The levels were equal to or exceeded the highest levels detected in any previous IPEN studies. The town of Vila Nova in Brazil recorded the next highest average levels of mercury among the participants, followed by El Callao, Venezuela. The average levels of mercury in Íquira, a town in the Huila Province, Colombia, were very low and this is due to the fact that no women surveyed ate fish and that mercury was phased out of gold mining several years ago. While mercury contamination of local ecosystems from historical mining is still present in the Huila province, the non-consumption of fish by participants eliminated this significant exposure pathway.

Despite national bans on mercury use in some of these countries, the Minamata Convention on Mercury still allows the global legal trade in mercury to continue and does not prohibit the use of mercury in ASGM.

Until the Convention is amended to eliminate these weaknesses, the legal and illegal trade in mercury for ASGM will continue and the impact on the environment and human health will continue to grow.

INTRODUCTION

The Minamata Convention on Mercury (the Mercury Treaty) was adopted in October 2013 and entered into force on the 16th August 2017, giving it the power of binding international law for those Parties that have ratified it. The creation of the Mercury Treaty serves to remind us that the global community now recognizes mercury pollution as a global threat to human health, livelihoods, and the environment, and are now prepared to commit to further action to reduce global exposure to mercury. IPEN was closely engaged with the negotiations leading up to the adoption of the Minamata Convention, seeking to strengthen its provisions wherever possible and providing support and information to Treaty delegates to inform them of the wide range and severity of mercury pollution issues faced globally, as well as potential solutions.

Since the Mercury Treaty entered into force, IPEN has remained active in the ongoing Treaty negotiations around technical matters related to implementation of the Treaty and in the gathering of data to support mercury-reduction activities. IPEN continues to conduct a range of Mercury Treaty-related enabling activities, release publications and develop awareness-raising campaigns that include mercury monitoring and biomonitoring. Parties to the Treaty recognize that specific data is required to establish baselines of global mercury contamination levels so that the effectiveness of the Treaty measures may be assessed over time. Biomonitoring activities are crucial to fill the data gaps on potential mercury impacts, particularly in developing countries and countries with economies in transition.

This study is the latest in a series of mercury exposure studies of women of childbearing age conducted jointly by IPEN and BRI. It was undertaken to generate mercury biomonitoring data in locations where significant data gaps exist on women's exposure to mercury and where sources of mercury pollution are suspected. Specifically, these are sites in Latin American countries where small-scale gold mining is conducted using mercury[1]. Previous studies by IPEN and BRI have found that women living in locations or regions where artisanal and small-scale gold mining (ASGM) is conducted often have an elevated body burden of mercury through either handling mercury, living in proximity to mercury extraction of gold, or eating contaminated fish from lakes and rivers contaminated with mercury from gold processing. In this study 163 women from communities in Bolivia, Brazil, Venezuela and Colombia volunteered to provide hair samples for analysis of total mercury concentration.

1.1 BIOMONITORING

Mercury biomonitoring is an important element of any strategy to assess, monitor and reduce global mercury pollution while highlighting local hotspots that may require urgent attention if exposure levels are high. Global data on mercury biomonitoring has been fragmented with many data gaps especially from developing countries and countries with economies in transition. In response to the need for better data IPEN has developed an important collaboration with the Biodiversity Research Institute (BRI), a non-profit, ecological research group with more than 25 years of experience assessing emerging threats to wildlife and ecosystems. BRI is a world leader in ecological research related to mercury monitoring and toxicology and provides expertise and advice to many parties to the Mercury Treaty. This study adds to the long list of locations across the globe where IPEN and BRI have collaborated using their technical expertise and broad reach through a global network of IPEN Participating Organizations (POs). Previous joint projects have included mercury monitoring in women of childbearing age in the Asia and Pacific region, Small Island Developing States, Eastern Europe, Africa, and many other locations. It is anticipated that this pilot study of Latin American locations may be expanded in the near future to include a range of new locations.

The sample results for this study will be added to the database of hundreds of previous samples analysed by BRI at their laboratory in Maine, USA, provided voluntarily by women concerned about their mercury body burden and any potential future impacts on their unborn children. Mercury is a potent neurotoxin to which the fetus is highly susceptible and providing women with data on their mercury body burden empowers them to make informed decisions on reducing their exposure to mercury in order to better protect their health.

1 In this study one location was selected in Colombia where gold mining was historically conducted using mercury to extract gold from ore but where miners have now implemented mercury free gold extraction methods to compare mercury exposure and body burden of women from areas where mercury is still used to extract gold.

Hair samples in Latin America were collected by IPEN Participating Organizations as well as civil society organizations, in cooperation with local communities. This form of mercury monitoring can act as an impetus for countries to ratify and implement the Mercury Treaty and reduce mercury pollution while establishing a baseline to observe any future reductions in mercury among their populations as a result of reduction measures. Parties to the Mercury Treaty have agreed that there is a need to generate mercury monitoring data from around the globe that can be used to evaluate the effectiveness of the Treaty over time in reducing mercury pollution.

In 2014, IPEN launched the International Mercury Treaty Enabling Activities Program (IMEAP), with the aim of supporting preparations for developing countries and countries with economies in transition for rapid ratification and early implementation of the Mercury Treaty. IPEN successfully completed mercury-related research projects and associated activities in 29 countries via IMEAP. Through this process, member organizations communicated to IPEN the need to conduct targeted mercury biomonitoring to address widespread data gaps, to further elevate mercury awareness, and to promote ratification of the Mercury Treaty. In 2015, IPEN developed a mercury biomonitoring program focusing on vulnerable sub-populations identified in the Mercury Treaty preamble, as well as in Article 16 (Health aspects), Article 18 (Public information, awareness and education), Article 19 (Research, development and monitoring), Article 22 (Effectiveness evaluation) and Annex C – Artisanal and small-scale gold mining (ASGM) and National Action Plans (NAPs) of the Treaty. In many developing and transition countries, there is a paucity of mercury biomonitoring data with which to inform policy decisions and generate public awareness about the hazards of mercury exposure.

IPEN, through its earlier mercury biomonitoring project collaboration[2] with BRI, gained valuable insights into potential locations for monitoring while building capacity within its network to implement a broader range of monitoring activities. The IPEN/BRI Project Team determined that there was a need to generate data from around the globe, with emphasis on small-scale mining activity in Latin America.

1.2 EXPANDING IPEN'S HAIR MONITORING PROGRAM

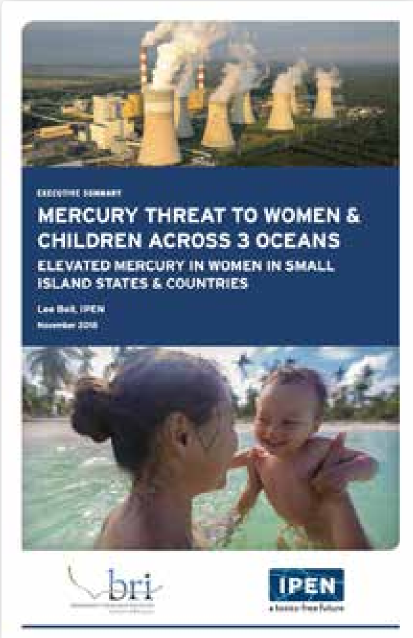
In a 2015/16 study[3] (published in 2017), IPEN and BRI partnered with UN Environment (formerly UNEP) to conduct mercury biomonitoring of women of childbearing age. Sampling was conducted in four Pacific Small Island Developing States (SIDS) and two non-Pacific countries. Data from that report for the countries of Cook Islands, Marshall Islands, Kiribati, and Tuvalu were later combined with a much larger 2018 IPEN SIDS sampling report[4], as they used identical methodologies and sampling protocols, to provide a more complete picture of the Pacific SIDS situation and for comparison with non-pacific SIDS.

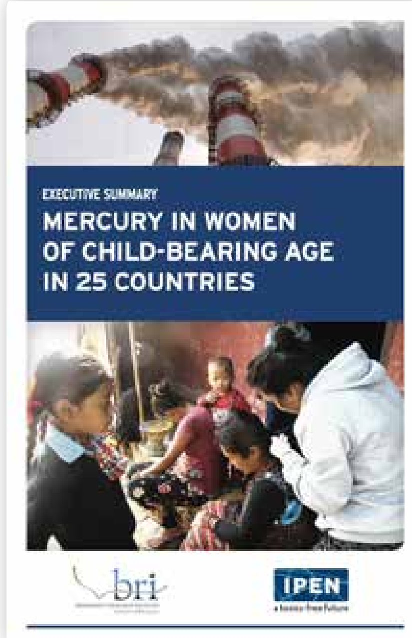
In the subsequent IPEN/BRI global study, *Mercury in Women of Child-bearing Age in 25 Countries*, the Solomon Islands, Tonga and Vanuatu, Samoa and Fiji were added to the sampling database. The mercury monitoring results from the 2015/16 study and subsequent global study were significantly elevated for nearly all Pacific Islands. Given the lack of local pollution sources, this could be attributed to mercury contamination of fish, which is a key component of island diets and the predominant protein source for hundreds of thousands of Pacific Islanders. The main finding of the collaborative study between IPEN, BRI and UN Environment was that the Pacific Islanders studied face a serious problem with mercury contamination of fish which comprises a major part of their diet. The problem may have significant ramifications for all Pacific Islanders, as

2 Evers, D. *et al.* (2014). Global mercury hotspots: New evidence reveals mercury contamination regularly exceeds health advisory levels in humans and fish worldwide. Biodiversity Research Institute. Portland, Maine. IPEN. Göteborg, Sweden. BRI-IPEN Science Communications Series 2014-34. 2 pages.

3 Bell, L., (2017) Mercury Monitoring in Women of Child-Bearing Age in the Asia and the Pacific Region. A joint study by UN Environment, Biodiversity Research Institute and IPEN. April 2017. Berkeley, California.

4 Bell, L., (2018) Mercury Threat to Women and Children Across 3 Oceans. Elevated Mercury in Women in Small Island States and Countries. A joint study by Biodiversity Research Institute and IPEN. April 2017. Berkeley, California.





nearly all of those assessed exceeded the 1 ppm threshold level for mercury contamination of their hair. The elevated results across most SIDS, where fish is a dietary staple, suggest a widespread contamination issue which may be having population-level effects that require additional monitoring and reduction measures.

The results of the global and SIDS studies clearly demonstrated that a fish-rich diet (and in some cases including sea mammals such as seals) is a direct and potent exposure pathway for methylmercury to enter the human body and raise the mercury body burden. However, while a fish-rich diet contributes significantly to the mercury body burden it is not the only form of exposure that can result in an elevated mercury body burden. Artisanal and small-scale gold mining is the primary source of mercury releases to the atmosphere, land, and water in the world today. IPEN biomonitoring in ASGM communities in Southeast Asia and Africa recorded some of the highest body burdens of mercury among any of the women of childbearing age in our monitoring program to date. Reports of expanding ASGM activity in Latin America, increased trade in mercury supply to the region and requests from NGOs on the ground for up-to-date biomonitoring data led IPEN and BRI to initiate pilot sampling studies in ASGM-related locations in Bolivia, Colombia, Venezuela, and Brazil. More countries in the region may be included in future studies.

ASGM

Artisanal and small-scale gold mining is estimated to be practiced by between 14-19 million people worldwide (Steckling *et al.* 2017). Most are impoverished subsistence miners and some are even indentured in a system where they must work off debt to those higher up in the system in rudimentary mining sites with little to no safety precautions or personal protective equipment. Mercury is widely used to extract small particles of gold from ore and ore concentrate and exposure to mercury is such settings can be significant. It is estimated that this practice currently results in the release of up to 2,000 tons per annum of mercury into the environment (UNEP 2020).

Mercury may be added to ball mills (see Fig. 1), which are rows of steel vessels rotated by pulleys from a small motor. Inside the vessels are steel balls or rods which serve to grind and break down rocks and release gold particles from the ore. Mercury is added to the ball mills and amalgamates with gold particles. When the ball mill has run for a few hours the amalgamated mercury and gold is separated from waste ore inside and burned with a blowtorch to evaporate the mercury and recover the gold. Mercury is often also added when panning for gold to amalgamate small particles of gold from the ore. The tailings or waste from the process are contaminated with mercury and are generally dumped in the environment where the mercury evaporates as vapor and spreads through soil into waterways.

In some locations the tailings with mercury contamination are then processed through cyanidation to extract the remaining gold. This is especially dangerous, as the mercury cyanide complexes that are generated through this activity are extremely toxic to human health and the environment. While cyanide is a toxic chemical, carefully managed cyanidation without mercury while using protective equipment and taking precautions is relatively safe and the cyanide breaks down rapidly on exposure to atmosphere and does not accumulate in the environment.

The use of mercury in gold extraction can lead to a variety of exposure scenarios. Miners who handle the mercury are exposed to mercury vapours which can be inhaled. Operators of ball mills are also exposed to vapours. Intoxication by mercury vapours rather than ingestion through diet can lead to a condition known as chronic metallic mercury vapor intoxication (CMMVI), which causes similar health impacts to other forms of mercury poisoning (Steckling *et al.* 2017). Handling of tailings from the ball mills can also leave mercury residues on the clothes of miners, which may cause exposures to them as well as to their families if they return home in the contaminated clothes. Miners often operate in more remote areas and rely on local wildlife and fish to supplement their food supplies. Where

Figure 1. Example of an Indonesian ball mill 'processing centre' for gold ore.
Photo: Lee Bell, IPEN

mercury has entered local waterways from gold processing waste the fish can become contaminated with methylmercury. Miners may be exposed to both metallic mercury vapor inhalation and dietary methylmercury from eating contaminated fish (Junaidi *et al.* 2019). In some cases, it has been demonstrated that even rice (Novirsa *et al.* 2019) can become contaminated with mercury from mining activities, especially if the processing is conducted in villages close to rice paddies. This provides yet another exposure route for miners and their families to accumulate mercury.

As the environment of miners becomes progressively more contaminated with the mercury they use, the potential for exposure to mercury in dust, vapours, and their diet increases. When the gold supply in a specific location is exhausted, the mercury waste is left behind, creating a legacy contaminated site that continues to represent a threat to human health, impacting the local environment for decades to come.

1.3 HEALTH IMPACTS OF MERCURY EXPOSURE FROM ASGM

Mercury is a potent neurotoxin to humans and can affect the central nervous system of the developing fetus months after the mother's exposure. The harmful effects that can be passed from the mother to the fetus include neurological impairment, IQ loss, and damage to the kidneys and the cardiovascular system. Symptoms of intoxication include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. At high levels of mercury exposure this can lead to brain damage, mental retardation, blindness, seizures and the inability to speak (Grandjean *et al.* 1997, Murata *et al.* 2004). The predominant exposure pathway for mercury to impact on the health of ASGM workers is mercury vapor inhalation leading to chronic metallic mercury vapor intoxication (CMMVI). Their health can also be impacted by eating local food sources contaminated by mercury such as fish and rice (Feng *et al.* 2008). Women are often employed in ASGM activities and in some locations are more exposed to mercury than men as the men are engaged in the extraction of ore while women may process the ore with mercury.

Even if women are not engaged in ASGM they may have family members who are, or they may live next to ball mills, amalgam burning activity or simply eat the local fish and rice contaminated by ASGM activity. Due to the sensitivity of the fetus to the neurotoxic impacts of mercury, IPEN takes hair samples from volunteers who are women of childbearing age and who may potentially be considering having children. As a sensitive sub-group of the local population, the mercury body burden of women in this cohort is an important indicator as to the potential effects of mercury on the local communities near the gold mining sites.

1.4 ECONOMIC IMPACTS OF MERCURY BODY BURDEN

While the health impacts of elevated mercury levels in the human body are well documented, a recent ground-breaking study[5] by Trasande *et al.* has also estimated the economic losses attributable to lost productivity in those populations where levels of mercury body burden exceed 1 ppm. The study analyzed hair samples from 15 developing countries and countries in economic transition. The results showed that 61% of all participants had hair mercury concentrations greater than 1 ppm. Using a linear dose-response relationship and an assumed 0.18 IQ point decrement per part per million (ppm) increase in hair mercury concentrations, an estimate of

5 Trasande L, DiGangi J, Evers D, Petrlik J, Buck D, Samanek J, Beeler B, Turnquist MA, Regan K (2016) Economic implications of mercury exposure in the context of the global mercury treaty: hair mercury levels and estimated lost economic productivity in selected developing countries, Journal of Environmental Management 183:229 - 235, doi: 10.1016/j.jenvman.2016.08.058 https://www.ncbi.nlm.nih.gov/pubmed/27594689

lost productivity was developed. This data was used to estimate increases in intellectual disability and lost Disability-Adjusted Life Years[6] (DALY). A total of USD $77.4 million in lost economic productivity was estimated assuming a 1 ppm reference level, and USD $130 million if no reference level was used. For many of the 21 countries identified in the report, the human health issues revealed through the sampling process are critical to address, but the Trasande *et al.* study points to far-reaching economic impacts from mercury pollution that will be borne by those countries least able to address the source of the mercury pollution and least able to bear such costs. Therefore, it is important to consider the whole scope of mercury pollution impacts in terms of human health, economic burden and ecological integrity.

It has also been estimated (Steckling *et al.* 2017) that on a global scale, 3.3-6.5 million miners suffer from moderate CMMVI. The burden of this disease in terms of Disability Adjusted Life Years (DALYs) is estimated to range from 1.22 to 2.39 million DALYs. This makes mercury intoxication a major global public health problem and economic burden.

6 DALY is a measurement of years of life lost due to premature death, plus years lost to severe disability.

1.5 THE MINAMATA CONVENTION MUST BE AMENDED TO BAN MERCURY USE IN ASGM

The Minamata Convention text was negotiated over several years between many parties and as such represents a product of compromise negotiations. This led to a number of weaknesses in the convention that hamper its ability to rapidly reduce global mercury pollution. Three major weaknesses combine to allow the trade in mercury for use in ASGM to continue unabated.

1. Mercury is permitted to be traded on the international commodity market for a 'use allowed' under article 3 of the convention. Allowed uses include dental amalgam, laboratory research, and certain other products and processes requiring the use of mercury where alternatives are not available. Some of these processes such as chlor-alkali plants (phase-out date 2025), acetaldehyde production (phase-out date 2028), and vinyl chloride monomer plants use large quantities of mercury. Parties can extend the phase-out dates by five years by exemption, with an option for a further five years in addition. This effectively allows large flows of mercury to be legally traded internationally for another decade and makes the task for customs officers of identifying any illegal shipments of mercury intended for ASGM use very difficult as shipments are often labelled as being intended for an 'allowed use' such as dental amalgam.
2. Primary mining of mercury from cinnabar mines is permitted under article 5 for up to 15 years from the date of entry into force of the convention for a party. New mines cannot be opened, but existing mines can continue to operate for this period (and possibly extended via exemption). This allows new primary supplies of mercury to be traded on the international commodity market. Although mercury from this source is only permitted to be used in the manufacture of mercury-added products in accordance with article 4 of the convention and in manufacturing processes listed in article 5 of the convention, shipments can be labelled for a false end use and redirected to ASGM.
3. Use of mercury is 'allowed' for ASGM although each country with significant ASGM activity must develop a National Action Plan (NAP) to reduce mercury use in this sector. While many countries may domestically make mercury use in ASGM illegal, the convention does not. This acts as a signal at international level that mercury use in ASGM is to be tolerated to supposedly provide a livelihood for the millions of people engaged in this activity. If mercury use in ASGM were banned by the convention, then parties to the convention could take stronger action on the ground to enforce the ban.

These three factors combine to permit the illegal and legal supply of mercury to the ASGM sector. If global trade in mercury was illegal, supply would be dramatically curtailed, the price of available mercury would likely increase beyond the capacity of ASGM miners to use it and illegal shipments would be much easier to detect as they could not be so easily disguised for 'allowable uses' and cross international borders. Where countries have a legitimate domestic need for mercury use it could be obtained through recovery/recycling of mercury already in circulation within that country in products or processes destined for phase-out. The US and the EU have banned exports of mercury, but export and import bans[7] need to be adopted by all countries in order to have a decisive effect on its use in ASGM.

The ongoing allowance of primary mercury mining activity simply injects a greater volume of mercury into the global commodity market to be siphoned off to ASGM activity. Countries should be required to focus on domestic recovery of mercury from a growing stockpile of end-of-life products, phased-out processes and treatment of mercury waste from the oil and gas sector and other available sources for any essential uses of mercury. Increased prices of domestic mercury would accelerate substitution of mercury in most products and processes.

7 Specific exemptions should apply where mercury and mercury waste is being imported for environmentally sound treatment and final disposal and where the exporting country does not have the infrastructure and capacity to manage the mercury safely.

2. METHODOLOGY

In preparation for the implementation of this project, IPEN and BRI adapted a methodology based on the framework for hair sampling previously developed by IPEN, BRI and UNEP in a 2016 mercury biomonitoring project for the Asia and the Pacific Region[8] and for a much larger 2017 IPEN/BRI global hair monitoring study.[9] The methodology takes into account scientifically sound and acknowledged human hair monitoring protocols, including both technical and practical matters as well as an ethics review by the Institutional Review Board of the University of Southern Maine in Portland, US. The methodology covers sampling method, collection of data, mercury measurements, sample storage and shipping, as well as assessment and evaluation of the results and feedback to participants.

2.1 SAMPLING METHOD

2.1.1 Target group

The focus of this project is the vulnerable sub-population group of women of childbearing age in Latin American communities impacted by ASGM activities. The definition of 'childbearing age' differs to some degree between various institutions. Studies undertaken by United States researchers use the age range of 18 - 44 years due to US Federal government limitations on sampling of biological material from minors. For this project, the target group for sampling is women of childbearing age from 18 - 44 years, as it would allow comparison with other studies using this range while meeting legal requirements of the BRI laboratory based in the US. The gender-specific impacts of toxic pollutants on women are increasingly being recognized as a global priority for investigation and redress. IPEN

8 Bell, L. (2017) Mercury Monitoring in Women of Child-Bearing Age in the Asia and the Pacific Region. A joint study by UN Environment, Biodiversity Research Institute and IPEN. April 2017. Berkeley, California.

9 Bell, L., *et al.* (2017) Mercury in Women of Child-bearing Age in 25 Countries. A joint study Biodiversity Research Institute and IPEN. November 2017. Berkeley, California.

and UN Environment announced the establishment of a partnership[10] on this issue at the 3rd United Nations Environment Assembly in Nairobi, Kenya. This study seeks to further the information on the impacts of mercury on women.

2.1.2 Participant selection

Female participants were selected based on the criteria of (1) their age (18 - 44 years); (2) willingness to participate; and (3) having sufficient hair to provide a sample for analysis. IPEN Participating Organizations (POs) and non-affiliated civil society organizations (CSOs) identified and convened participants at each location to administer the consent forms and questionnaire, and conduct hair sampling according to the specified protocols. The POs and CSOs gathered samples in a scientifically sound manner that is consistent with recognized standards for sample collection of human hair for mercury monitoring[11]. All were issued with the standardized methodology and protocols developed by BRI and IPEN to ensure consistency and comparability between this study and previous hair mercury monitoring studies conducted by IPEN and BRI. Locations where sampling took place were based on advice from local POs and CSOs, which considered issues of access, cultural sensitivities, timing and cooperative approaches with local communities and civil society organizations that supported the sampling.

2.1.3 Ethics review and confidentiality of participants

Prior to implementing this sampling project, the overall methodology was reviewed and approved by the Institutional Review Board of the University of Southern Maine in the US to ensure it met contemporary standards for ethical implementation of studies involving human subjects. The sample collection protocol incorporated documents and procedures consistent with this ethics approval. Participants were asked to sign a consent form if they were willing to have a hair sample collected for analysis.

A questionnaire was then administered to the participants by the IPEN PO or CSO representative, supported by a local, native language-speaking volunteer to ensure that the process was understood by the participants and that accurate information could be collected from the questionnaires. Where English was not an appropriate language, participants were provided with a translation of relevant documentation, including

10 The full statement regarding the partnership on women and chemicals is available at https://ipen.org/documents/statement-partnership-between-ipen-and-unep-focus-women-and-chemicals

11 United Nations Environment Programme and the World Health Organization (UNEP/WHO), (2008) Guidance for identifying populations at risk from mercury exposure.

waivers, questionnaires and sample results. The right of confidentiality was granted to each individual participant unless she voluntarily decided to sign a document to waive it. To protect confidentiality of participants, several controls were implemented.

Project-related data is presented as an aggregated analysis that does not enable public identification of individual participants. Each hair sample shipped to the BRI laboratories was labelled with an individual sample ID code and country location code so that BRI did not have access to the identity of individual sampling participants. The same ID code is affixed to the front page of each completed questionnaire, allowing the data from questionnaires to inform the interpretation of sample analysis by IPEN without compromising confidentiality. The PO or CSO that conducted the sampling holds the master list linking the ID code to the name of the participant to allow them to provide contextual, health-related feedback to the individual participant along with the results of their individual hair sample analysis for total mercury concentrations. Once individual participant sample data is generated and communicated back to the participant, that individual has the right to release that information and publicly identify herself if she chooses to do so. This is consistent with an individual's right to know about their personal health information and disclose it if they wish to.

2.1.4. Sample collection protocol

All POs and CSOs tasked with coordinating the collection of samples were provided with detailed sample collection, packaging and shipping protocols to ensure minimization of any cross-contamination and to standardize sample collection for comparative analysis. Before taking any samples, the participant was invited to sign the consent form. If the participant declined, no sample was taken. After the participant signed the consent form, the sampler then administered the questionnaire.

Following the completion of documentation, the sampler, while wearing a pair of nitrile examination gloves (for collecting and handling each sample), would use an alcohol wipe to clean the cutting surfaces of the stainless-steel scissors for cutting the hair sample. Hair samples were obtained from individuals by cutting a small bundle of hair approximately 8 - 10 cm long and the thickness of a pencil (about 30 hair strands) from the occipital region of the skull as close as possible to the scalp. The hair sample was then secured with a small self-adhesive label, using an arrow to indicate the direction of the scalp and leaving 3 - 4 cm of hair exposed from the label.

2.1.5. Sample analysis – mercury measurement

Once correctly packaged and labelled the samples were shipped by courier along with a data sheet listing each sample origin and a corresponding sample ID code. As soon as shipments arrived in the US, the hair samples were analyzed for total mercury at BRI's Wildlife Mercury Research Laboratory following EPA method 7473 by gold-amalgamation atomic absorption spectroscopy following thermal desorption of the sample using a Milestone DMA-80. A blank and two calibration standards (DORM-3 and DOLT-4) are used in each of the two detector cells. Instrument response is evaluated immediately following calibration, and thereafter, following every 20 samples and at the end of each analytical run, by running two certified reference materials and a check blank. Instrument detection limit is approximately 0.050 ng. An acetone wash of the hair samples followed by a rinse with milli-Q water can be used to remove external contamination, such as hair products. Results of total mercury are then recorded for each sample in parts per million (ppm) and recorded in tables by location.

2.1.6. Assessment of results

The interpretation of sample results was based on the comparison of data generated from the field samples with a reference level of 1 ppm (parts per million), which equates approximately to the US EPA's reference dose for mercury in human hair[12]. Mercury concentrations above 1 ppm in hair have been related to neurological impairments in adults[13,14]. These data will help determine contaminant concentrations in participating human subjects and potentially identify regions that require more intensive investigation. In addition, recent advances in the study of mercury impacts on the developing fetus suggest that levels of mercury body burden for women of childbearing age, as measured in hair concentrations of total mercury (THg), above 0.58 ppm may have subtle but problematic impacts on the cognitive development of the unborn child[15]. For this reason, IPEN has applied the additional 'proposed' level of 0.58 ppm against the reported sampling results to assess relative levels of the groups studied. A number of scientists with expertise in this field have proposed that the USEPA threshold level of 1 ppm should be replaced with the 0.58 ppm level.

12 US EPA (1997) Mercury study report to Congress, Volume IV, An assessment of exposure to mercury in the United States. EPA-452/R-97-006

13 Yokoo, E.M., Valente, J.G., Grattan, L., Schmidt, S.L., Platt, I. and Silbergeld E.K. (2003) Low level methylmercury exposure affects neuropsychological function in adults. Environmental Health 2(1):8.

14 Karagas, M., Choi, A.L., Oken, E., Horvart, M., Schoeny, R., Kamai, E., Grandjean, P., and Korrick, S. (2012) Evidence on the human health effects of low-level methylmercury exposure. Environmental Health Perspectives, 120: 799-806

15 Grandjean P, Pichery C, Bellanger M, Budtz-Jørgensen E (2012) Calculation of Mercury's effect on Neurodevelopment. Environ Health Perspect. 2012 December; 120(12).

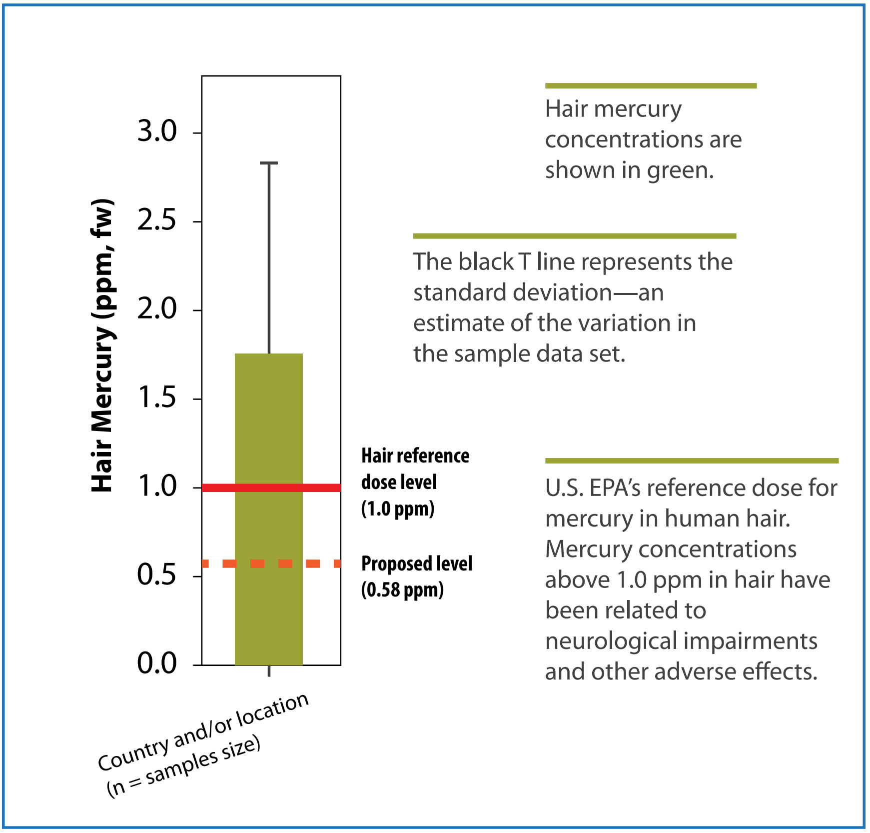


Figure 2. Interpretation of the mercury hair concentration chart.

3. SAMPLING LOCATIONS

The locations chosen to seek participants for mercury hair sampling in Latin America were based on advice from local IPEN POs and unaffiliated Civil Society Organisations who work in the area on community and women's health and/or sustainable development. In all four locations there were links between the participants and local ASGM activity. Somewhat exceptional was the location in Colombia, where miners and their families using more advanced mercury-free techniques for extracting gold had previously used mercury-based techniques. The data from this location was included to assess whether there are any health benefits or reduced mercury body burden involved/achieved in/associated with moving to mercury-free techniques. In Bolivia the women have no direct engagement with gold mining but are surrounded by wildcat miners including Chinese, Colombian and Brazilian nationals as well as Bolivian miners.[16]

3.1 BRAZIL – VILA NOVA, PORTO GRANDE, AMAPÁ STATE

Gold mining has taken place in the northern Brazilian Amapá state since the 1930s, initially by local prospectors and in recent decades by larger industrial gold mining companies. Cycles of conflict and cooperation between small-scale gold miners and industrial operations have taken place since the introduction of industrial mining in many areas. Artisanal mining is permitted under the Brazilian constitution and various statutes have governed the activity. Despite government licencing of the activity many illegal operations continue, some with the involvement of organised crime. In 2008, The Artisanal Mining Statute, Law 11.685 was enacted and extended the rights of artisanal miners to work with industrial tail-

16 https://www.noticiasfides.com/economia/armada-confisca-dragas-chinas-que-operaban-de-manera-irregular-en-cachuela-esperanza-393365
https://elpais.bo/nacional/20190620_armada-boliviana-secuestra-draga-colombiana-que-pretendia-operar-en-rio-beni.html

Figure 3. Vila Nova location

Source: Brazilian Geological Service (CPRM)

Figure 4. Illegal mining exists alongside legal mining in many Brazilian states.

ings, and to form cooperatives and other modes of employment (family groups, partnerships etc.).

Vila Nova in Amapá State is both the broad designation of a mineral-rich locality (the dark polygon in Fig. 4) and the name of a local village where gold is traded and provisions obtained by miners (the blue pointer in Fig. 3). The small village is about 20km in a direct line south from the main road "Perimetral Norte Road" also known as BR-210. The dirt road from the location meets BR-210 at another small village known as Cupixi, which also exists because of the ASGM site. The location is among dense tropical rainforest and includes narrow river valleys and swamps with low, dense forest.

Within the locality industrial gold mining, legal artisanal gold mining by cooperatives and illegal mining all take place, generating tension between the competing groups. Illegal miners are often quite distinct from traditional artisanal miners in that they are connected to or controlled by armed militia and/or organised crime groups. Illegal miners operate outside of the law, using banned practices (such as heavy machinery) and in protected areas. In the village of Vila Nova many artisanal miners, known as 'Garimpeiros' operate under the miners cooperative COOPGAVIN or Garimpo do Gaivota (Fig. 5), including female miners. Conflict with illegal miners is an operational hazard for many licenced artisanal miners yet they continue to mine and process gold. Gold is mined through shaft extraction, river dredging and some alluvial prospecting on riverbanks.

Mercury is used widely to amalgamate gold from concentrated ore and may potentially affect women engaged in artisanal mining and contaminate the local environment. In turn, women who are not engaged in mining may have elevated levels of mercury as a result of eating contaminated fish from the local tributaries of the Araguari River such as the Rio Amapari, which may be contaminated with mercury from mining. Environmental degradation is common in the heavily forested areas where mining takes place. Most miners use mercury to amalgamate gold using rudimentary techniques including sluices, panning and ball-mills and then blow torch the gold/mercury amalgam to extract the gold. Direct environmental contamination from the ASGM activity in Vila Nova combines with mercury contamination further upriver (from ASGM activity and some natural releases from erosion) to contaminate local fish species which are a staple protein for the miners and local residents.

A recently released study (Hacon *et al.* 2020) confirms that inland riverine fish in the Amapá state are more contaminated with mercury than coastal riverine fish and that carnivorous fish have the highest mercury levels. The study found that all 428 fish sampled had measurable levels of

Figure 5. Environmental impacts of illegal gold mining. Amapá State 2017.
Photo: Daniel Beltra/Greenpeace

Figure 6. Participant providing a hair sample for mercury analysis in Vila Nova

mercury and that 28.7% of them exceeded the WHO mercury threshold of 0.5 µg/g for human consumption. It was also reported that 77.6% of carnivorous fish, which are preferred by consumers in the Vila Nova region, exceeded the WHO threshold with an average concentration of 0.4 µg/g and a range of 0.008-2.1 µg/g.

The women from Vila Nova who volunteered hair samples for this study comprised residents who live along the river near the town, some from the village itself and others who live a subsistence lifestyle by extracting food from the forest and fish from the river.

All women in and around the Vila Nova village recorded a diet that included consumption of local fish at least once a week with around 10% of them eating fish every day. Elevated levels of mercury were reported in women with the higher fish consumption levels.

3.2 VENEZUELA – EL CALLAO, ESTADO BOLIVAR

The town of El Callao is located in the north-west of "Estado Bolivar" and is predominantly a gold mining town with industrial mining nearby as well as being a centre for gold trading for ASGM. The official population is around 20,000 but it has been reported that the population may increase by up to five-fold at different times due to the mining activity.

The small town is surrounded by mountainous green jungle and is located in one of the most mineral-rich areas in Latin America. Gold and cash are used to trade for food and provisions which are abundant and relatively inexpensive compared to other parts of the country. ASGM near El Callao often involves deep excavations and working in 1 metre high galleries with high humidity and poor ventilation. Reports of accidents are common.

The area is of strategic importance to the Venezuelan government who are looking to an alternative to slumping oil prices. They have designated the region *Arco Minero del Orinoco* (AMO) a national strategic development zone comprising 111,846 square kilometers, 12% of the country's surface, and it is estimated that it has some 7,000 tons of gold reserves. In 2018 alone it was reported that the Central Bank of Venezuela had received 9 tons of gold from the AMO. So important is the region that the government has delegated the military to regulate the area, which features military checkpoints on key access roads.

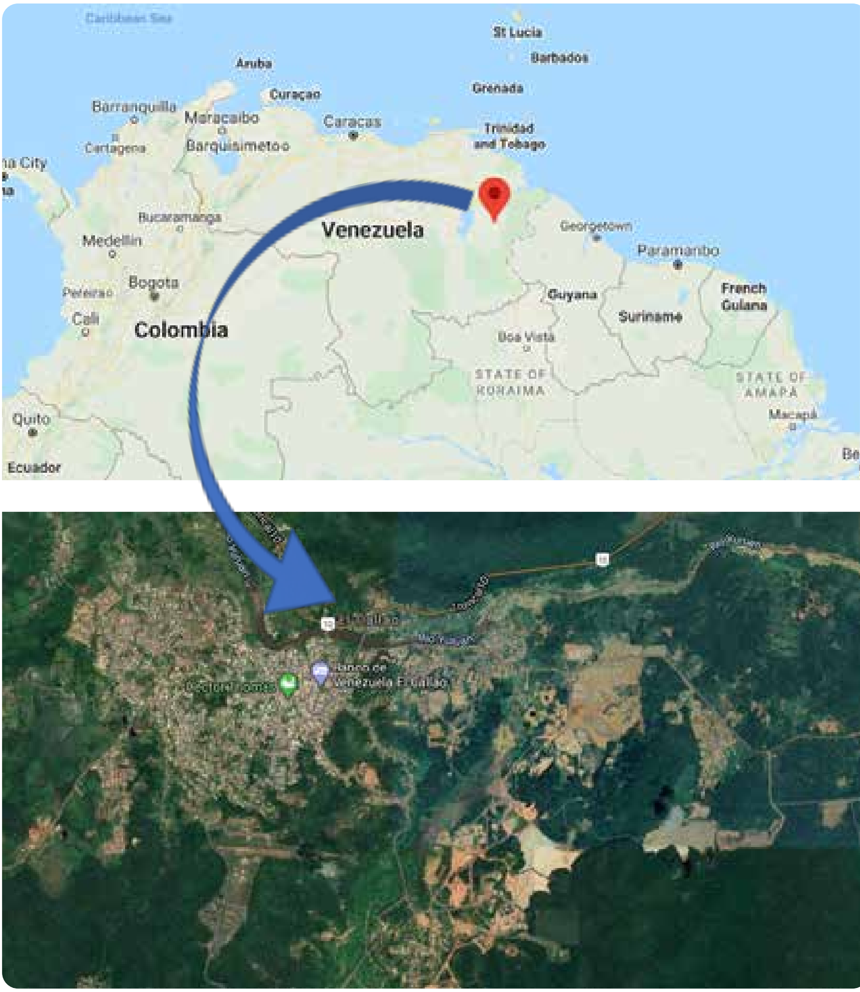
Socially and economically, the focus on gold in this area has generated conflict between armed gangs, the military and miners. Former guerrilla groups, including cross-border organizations, are also involved in gold activity and violence. The military of Venezuela is also alleged to be involved

Figure 7. Gold and mercury amalgam from extraction in El Callao.
Photo: Manu Quintero, BBC News

Figure 8. Miner in El Callao with gold ore from a shaft.
Photo: Manu Quintero, BBC News

Figure 9. ASGM mineshaft in El Callao. Source: Manu Quintero, BBC News

Figure 10. Military patrol in El Callao. Source: Manu Quintero, BBC News



in gold trading and control of miners in certain areas. The armed gangs known as 'Unions' or 'Syndicates' provide armed 'protection' for miners, but also demand payment for this service and as 'rental' fees for operating on various locations whether requested or not (International Crisis Group 2019). They are believed to control much of the ASGM activity and gold smuggling while oppressing local populations with violent attacks on those accused of theft or other offences (Marco 2018). Conflicts between the so-called miner 'Unions', miners and the military has cost many lives (International Crisis Group 2019) in a municipality where violence is common and which in 2017 and 2018 had the highest homicide rate in the country, according to the Venezuelan Observatory of Violence (OVV).

3.3 COLOMBIA – ÍQUIRA, HUILA PROVINCE

The town of Íquira in the Department of Huila, Colombia, has for decades been based around an economy dependent on coffee cultivation. However, in the early 2000s awareness was growing about local gold and silver deposits. Coffee farmers began to diverse out into artisanal mining to supplement their income. Even now, work on artisanal gold mining fluctuates seasonally to accommodate coffee growing and harvesting. Cooperatives such as Cooperativa Agrominera[17] established between gold miners in the area also manage agricultural businesses under the same structure to accommodate the dual mining and farming occupations of many people in the area.

In Colombia, the use of mercury in mining was prohibited on Monday, July 16, 2018, by the Colombian Government with the establishment of Law 1658 of 2013. However, it is likely that due to the high price of gold in the European and US markets, illegal mining and the use of mercury persists and may increase in some locations.

Prior to the prohibition of mercury in the gold mining area of Íquira (Huila), miners extracted hard rock ore material (quartz veins and sulfides with gold and silver content), processed it in small-scale mechanical plants by crushing, milling, concentrating, and mercury amalgamation followed by cyanidation. The ball mills used in this location are frequently referred to as 'cocos'. This gold extraction process is advanced above the rudimentary level and has some degree of mechanization and advanced processing to allow recovery of gold between 70% and 80%, but releases mercury into the environment in the form of tailings and contaminated water (Colombian Geological Service, 2018). Cyanidation of mercury-treated ore results in highly hazardous complexes of cyanide and mercury in tailings that are more dangerous to the environment and human health than mercury alone.

The mercury hair sampling conducted in Íquira, Colombia, was based on a different scenario to the ASGM mining in Brazil and Venezuela. The ASGM miners in Íquira had used mercury for many years to extract and amalgamate gold from ore. However, in 2013, the local miners recognized the harm to the environment and the health impacts of mercury use and decided to work toward alternative practices to extract gold from the ore. The local miners formed the Cooperativa Multiactiva Agrominera de Íquira with 40 shareholders including 6 women and 52 hired workers. The Cooperative pooled funds from mining to buy equipment and expert advice on how to extract gold and maximize the yield from the ore while significantly reducing or eliminating the use of mercury.

17 For more information see https://www.cmagrominera.com/nosotros

Figure 11. Ball mills in Íquira region known as 'cocos'.
Source: Colombian Geological Service.

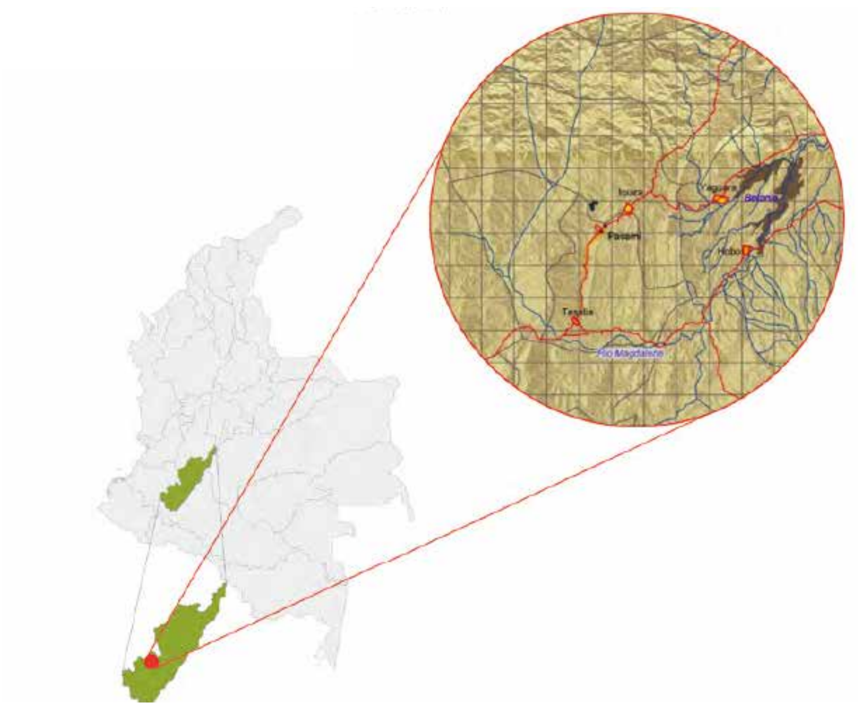


Figure 12. Geographical location of the mining area of Íquira (Huila) in Colombia.

Figure 13. Taking a sample of hair in Íquira.
Source: COLNODO

Within a year, the mining cooperative was able to reduce its mercury use by 80% and with further gradual reductions and investments they now have equipment that has allowed them to process gold ore without any use of mercury for several years. IPEN decided to conduct mercury hair testing to see if there was any significant mercury body burden in the women of Íquira as a result of previous mining practices using mercury or localized environmental contamination from historical use. The hair sampling results could then be compared to women from the ASGM locations where mercury is still being used in neighbouring countries. One important factor that emerged in the analysis of the test results and the questionnaires provided by the sampling participants was that not a single participant ate fish – the main dietary exposure source of mercury. The results of the sampling in Íquira are presented in the next section.

Figure 14. New mercury-free gold ore processing equipment purchased by the Cooperative at the Íquira mines. Source: Cooperativa Agrominera

3.4 BOLIVIA - THE EYIYO QUIBO AND PORTACHUELO INDIGENOUS COMMUNITIES: BENI RIVER BASIN

In Bolivia, ASGM gold mining has continued to expand in recent years. Indigenous communities are increasingly impacted by the pollution, social disturbances, and conflict associated with gold mining. The Eyiyo Quibo and Portachuelo people are nomadic members of the Esse Ejja ethnic group and rely heavily on the fish of the Beni river as their primary source of protein. The Portachuelo group of Esse Ejja live around 380 km north-east of the Eyiyo Quibo group. Both traditionally nomadic, they have each established semi-permanent settlements in recent decades. Both groups have become increasingly concerned that small scale gold mining is leading to the pollution of the river and contamination of the fish with mercury. IPEN participating organisation, Reacción Climatica, agreed to conduct hair sampling among the communities specifically collecting hair of women of child-bearing age. This sensitive sub-group of people are at risk of mercury intoxication from potentially contaminated river fish impacted by gold mining. The Eyiyo Quibo and Portachuelo people do not engage in gold mining or have direct contact with mercury, so their only identifiable mercury exposure is from their diet.

In the Beni River Basin there are a number settlements of the Esse Ejja ethnic group, who are periodically nomads and currently live in small towns on the banks of the river. The population does not generally reach more than 2000 people and their diet is based on fish. The Beni River

Figure 15. Home of the Eyiyo Quibo and Portachuelo indigenous people, Bolivia.

Cuadro 4: Principales especies según el número de individuos y el peso total			
Nombre común	**Nombre cientifico**	**Número de individuos (%)[8]**	**Peso total (%)[9]**
Simbao o Buchere	*Hoplosternum littorale*	15,45 %	-
Palometa	*Serrasalmus elongatus*	9,18 %	-
Pintado	*Pseudoplatystoma* sp.	7,9 %	-
Pacú	*Colossoma macropomum* y *Piaractus brachypomus*	6,36 %	6,56 %
Tachaca	*Pterodoras granulosus*	5,74 %	8,85 %
Pintado	*Pseudoplatystoma* sp.	-	16,76 %
Chanana	*Zungaro zungaro* [*Paulicea lutkeni*]	-	12,38 %
Piraiba	*Brachyplatystoma filamentosum*	-	11,69 %
Dorado	*Zungaro zungaro* [*Brychyplatystoma flavicans*]	-	10,75 %
General	*Phractocephalus hemiliopterus*	-	9 %
Fuente: Elaboración propia, en base a Copa, 2003: 7			

Figure 16. Main types of fish consumed in the region as percentage and by weight. Source FAO http://www.fao.org/3/i2446s/i2446s00.htm

currently suffers from uncontrolled gold exploitation by Chinese, Brazilian and Bolivian dredgers that move in the sector in an itinerant way, polluting the sector's water resources and fauna.

Fish is the staple protein diet of the Eyiyo Quibo and Portachuelo people and also accounts for a significant part of their internal economy and trade with the outside community in the Beni River region. Studies of the fish in the area had been conducted since the early 2000s and by 2017 consumption of fish from the Beni River and its lakes near Riberalta, were subject to consumption advisories due to mercury contamination from gold mining. It is recommended that an adult should not consume more than 250 grams of piranha per month, 750 grams / month of benton, or 500 grams / month of surubí. [18]

The two indigenous communities have become increasingly concerned about the effect of mining and the use of mercury for gold extraction along the Beni River and its impact on their health through the fish they eat. The results from the analysis of hair samples provided by the women of the each group have demonstrated that the community concern is justified. The levels of mercury body burden among women in the community are the highest found in this study (and most previous IPEN studies) and of serious concern. The fish they catch in the Beni River are their only source of exposure to mercury and this has caused significantly elevated mercury body burden for them. It can be logically assumed that other in-

18 Page Seven: National Independent Newspaper (2017) https://www.paginasiete.bo/ideas/2017/8/20/mercurio-amenaza-silenciosa-148753.html?fbclid=IwAR2Gse9l1uXccLStiazg3lDEImMuXA-MmWg-zaFW7Wu9LgkHau_qKwUvHXjA#!

digenous people in the region who are similarly reliant on fish in their diet may experience similar levels of mercury intoxication.

Figure 17. Eyiyo Quibo people with their catch from the Beni River.
Source: Carmen Capriles and Reacción Climatica

Figure 18. Fish are central to the diet of the Eyiyo Quibo.
Source: Carmen Capriles and Reacción Climatica

Figure 18a. Sampling hair in Eyiyo Quibo.
Source: Carmen Capriles and Reacción Climatica

4. RESULTS OF SAMPLING ANALYSIS

4.1 HAIR SAMPLE ANALYSIS

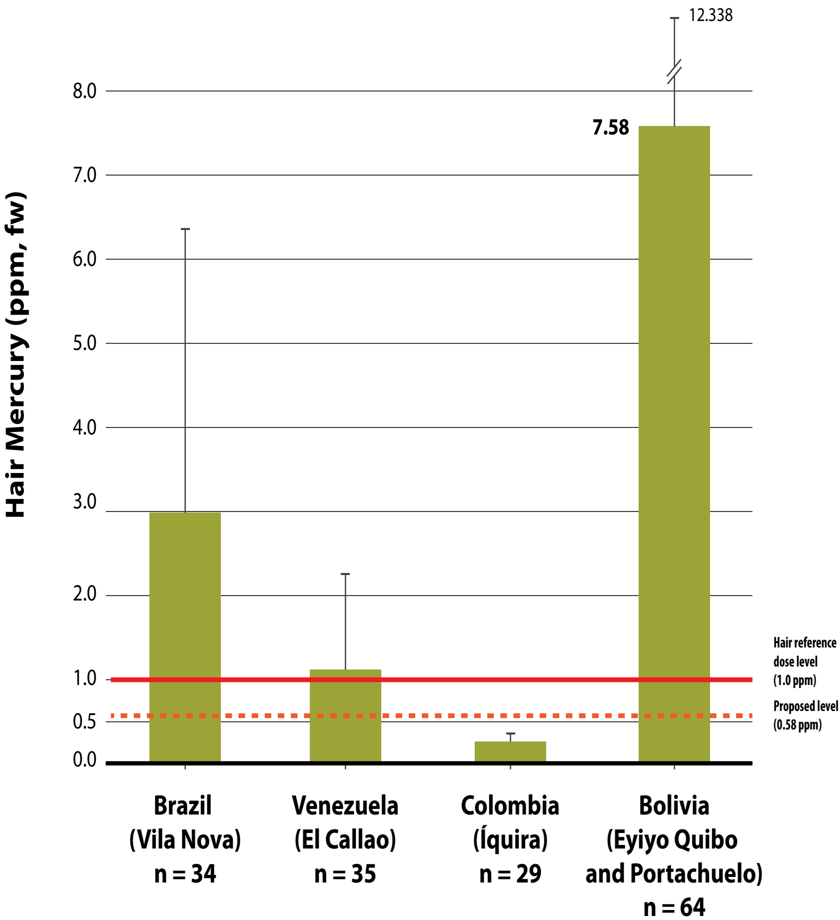
The total mercury (THg) concentrations detected in the hair of the participants from all countries where sampling occurred varied considerably and were influenced by diet, exposure scenarios, and exposure to mercury through gold amalgamation.

Table 1 below provides the analytical results for hair sampling, including the average mercury concentrations for each group, the standard deviation from the mean levels by group, the highest levels recorded by location, and the percentage of the sampled group that exceeded the 1 ppm (*unbroken red line*) threshold level and the 0.58 ppm proposed level (*dashed red line*).

TABLE 1. HAIR SAMPLING RESULTS BY LOCATION.

Location	No. of samples	Mean mercury (Hg) concentration (ppm) with standard deviation	No. of samples greater than 1 ppm	Percent greater than 1 ppm	Percent greater than 0.58 ppm	Highest mercury (Hg) level (ppm)
Brazil (Vila Nova)	34	2.98 ± 3.37	23	67.6	79.4	12.4
Venezuela (El Callao)	35	1.1 ± 1.09	13	37.1	60	5.5
Colombia (Íquira)	29	0.25 ± 0.15	0	0	3.4	0.7
Bolivia (Eyiyo Quibo and Portachuelo)	64	7.58 ± 4.758	60	93.7	93.7	32.4

Figure 19. Mean mercury levels of all participants by location.



5. ASSESSMENT AND DISCUSSION

Overall, the results indicate that exposure to mercury during gold extraction and through eating contaminated fish affected by mercury lost from gold extraction processes, resulted in elevated levels of mercury in the women who participated in the sampling. Of all the locations where sampling took place, the Bolivian indigenous women of the Eyiyo Quibo group and the Portachuelo group had, by far, the highest levels of all participants in this study with a mean total Hg level in hair of 7.58 ± 4.758 ppm (fw). Only 4 of the 64 women had levels below 1 ppm and most women had levels above 3 ppm up to 32 ppm. As they do not engage in gold mining and rely heavily on river fish for their diet, it is clear that they have a heavy mercury body burden as a result of fish contamination with methylmercury.

The village of Vila Nova in Brazil's northern province of Amapá had the second highest average levels with a mean total mercury hair concentration of 2.98 ± 3.37 ppm (fw). Women who self-identified as *extractavists* (women who live off fish and food products from the forests) had the highest levels in Vila Nova, while some women with other occupations also had elevated levels suggesting mercury-contamination of local fish.

In El Callao, Venezuela, the average level of mercury detected in participants hair just exceeded the 1 ppm threshold with a mean of 1.1 ± 1.09 ppm (fw). The 1 ppm threshold was exceeded by 37% of the women who participated, and the 0.58 ppm level was exceeded by 60% of participants. Of the women who participated in providing samples only one suggested they were directly involved in mining[19] and also had an elevated mercury level (2.1 ppm). The highest level recorded was 5.5 ppm by a participant who identified as a merchant.

Most participants in El Callao who exceeded the 1 ppm threshold had a mercury concentration in the 1-2 ppm range, indicating they were unlikely to be directly exposed to mercury in mining activities but more likely acquired their mercury body burden through diet. The women of El Callao all ate fish at least once per week from a range of 10 species. There were no clear patterns in participant age or fish consumption frequency or species to suggest why some participants had levels elevated above others,

19 Some women also identified as 'merchants' and indicated they were exposed to mercury. This may mean that they traded in mercury or mercury/gold amalgam and were exposed through that scenario.

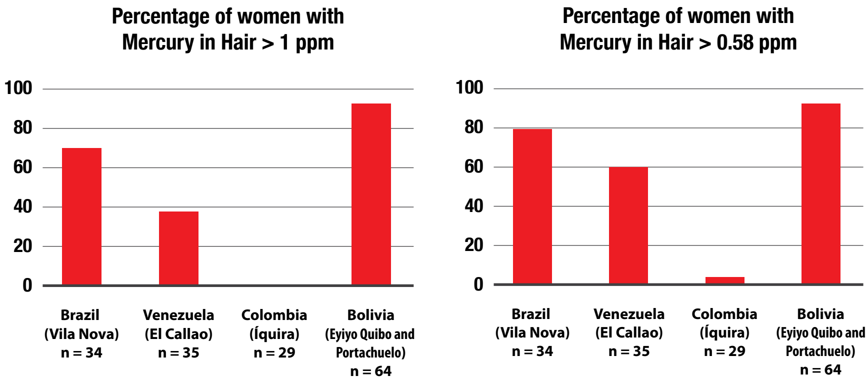


Figure 20. Percentage of participants over 1ppm and 0.58 ppm Hg in hair.

with the exception that participants who identified sardines as the only fish in their diet tended to have mercury levels lower than the threshold of 1 ppm. The fact that sardines are smaller fish with limited mercury accumulation could contribute to the lower dietary exposure.

In areas where no mercury is used for gold mining and where none of the participants eat fish the level of body burden of mercury is very low, as was the case in Íquira, Colombia. None of the women exceeded the 1 ppm threshold and only one exceeded the 0.58 ppm level. The women from Íquira had a mean level of total mercury of 0.25 ± 0.15 ppm (fw), as measured in hair samples provided by the volunteers. This is close to the lowest mean level recorded in all previous IPEN studies of mercury body burden of women of childbearing age. It also demonstrates the benefit to the health of miners of avoiding mercury use in gold extraction. However, the results from Íquira cannot be used to justify an absence of mercury contamination in the environment.

It is highly likely that previous use of mercury in artisanal gold mining in the locality has resulted in localized contamination of soil and some waterways which may have entered the local aquatic food chain. However, the complete absence of fish in the diet of the women of Íquira who participated in the study means that any contamination of local fish by mercury has no impact on this cohort. However, others in the community may be affected by dietary intake of mercury, as an exploratory study undertaken in 2013 demonstrated that mercury used commonly among miners historically in the Huila province (which includes Íquira) had leached into the Pacarní and Yaguará rivers, which supply water to the entire region via the Betania reservoir (Goretti, 2013). A separate study indicates that inland fish in the Huila province have the third highest levels of mercury

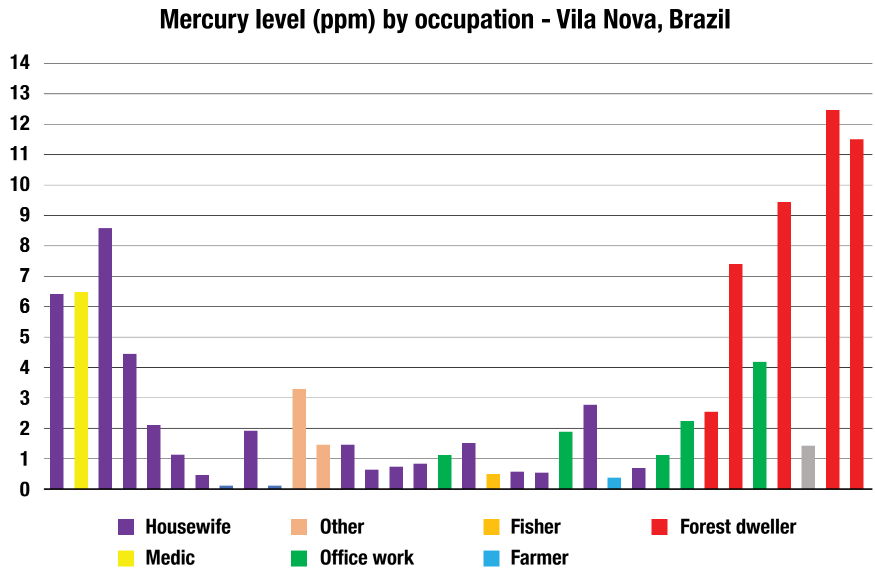


Figure 21. Mercury levels by occupation. Vila Nova, Brazil.

of all provinces in Colombia with a mean level of 0.63 ± 0.50 µg/g and that this is attributable to both gold mining and influences from coal mining (de Paula Gutierrez and Agudelo, 2020). Further research is required to assess if the broader population of Huila is affected by dietary intake of fish contaminated by mercury.

The situation in the village at Vila Nova, Brazil, is quite different. Some women had a highly elevated body burden of mercury with 67% of participants exceeding the 1 ppm threshold and close to 80% of participants exceeding the 0.58 ppm level. The mean level of mercury in hair was 2.98 ± 3.37 ppm (fw) which was the second highest recorded for any location in this study and significantly elevated above the 1 ppm threshold. In addition, 20% of respondents had mercury hair levels above 6 ppm and two women had levels exceeding 10 ppm.

In Vila Nova extraction of gold using mercury for amalgamation continues whether in illegal mining or in the organized cooperatives. The local river is a key source of fish for protein in the diet of both miners and local villagers. The questionnaire data provided by the participants at this location indicated that local fish are eaten by all women to varying degrees. Around 10% of the women ate fish twice a day, 20% ate fish every second day and the remaining 70% ate fish between 1 and 5 times in the 2 weeks prior to the survey. Clearly, fish are a significant source of protein for this remote inland community. Both the Amapari river and the Cupixi river are in close proximity to the village. A recent study (Hacon *et al.* 2020) has demonstrated that women of childbearing age are at significant risk of elevated dietary mercury intake from carnivorous fish in the Amapá province due to decades of mercury loss from gold mining activity to local waterways (with some influence from soil erosion). The study recommends that pregnant women should avoid consuming carnivorous fish and reduce the intake of omnivorous fish (which also had elevated mercury levels) during pregnancy.

In the questionnaire information provided, some women indicated they lived off forest products and fish (subsistence hunting and gathering). All of the these women had elevated levels of mercury including the two highest recorded levels of 11.4 ppm and 12.4 ppm. However, it was not only these women who reported elevated mercury body burden. Other occupations reported in the questionnaires also reported elevated mercury levels although no obvious exposure factors related to their occupation. High levels of mercury were recorded among housewives, nurses, office workers and sex workers , though not uniformly. The influencing factor for mercury exposure in these women may be the consumption of fish.

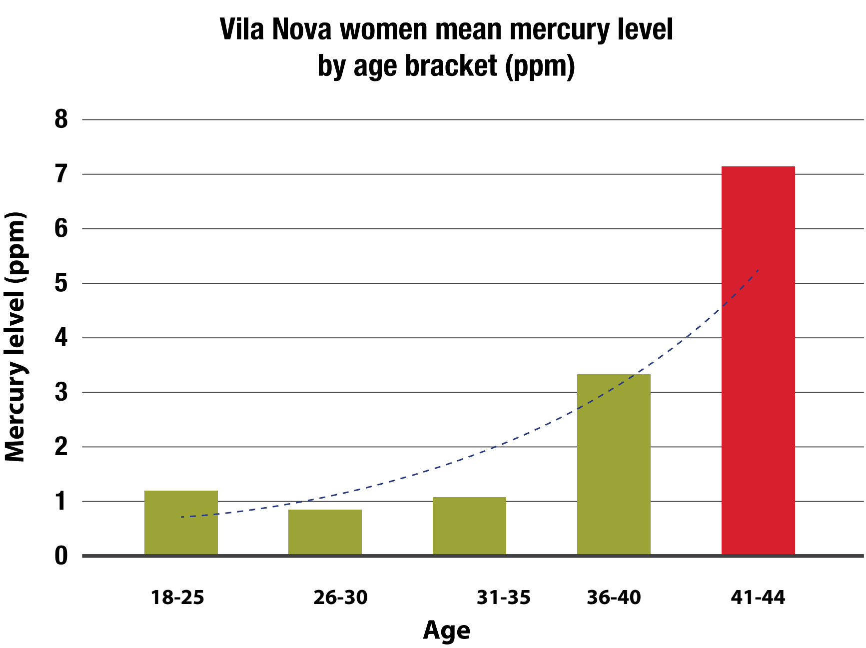


Figure 22. Trends in mean mercury level by age bracket Vila Nova

Women in Vila Nova who reported consuming fish more frequently tended to have higher mercury levels, but again not in a clear trend related to the number of fish consumed in previous weeks. As reported in recent studies (Hacon *et al.* 2020) carnivorous fish in the region had clearly elevated mercury levels and some women may consume more of these species or older fish with higher levels, than other women. The age of women may also be an influencing factor as the level of mercury body burden tended to trend upwards with age (Figure 22), which may be related to the amount of years that women have been consuming contaminated fish and well as the frequency of consumption. This hypothesis is supported further by the fact that nearly all women in the 41-44 age bracket (red bar in Figure 22) self-identified as *extractavists* of forest and river products. Most of the women who identified as housewives were in the 36-40 years old bracket and frequently consumed fish. Many in this group also had elevated mercury levels.

CONCLUSION

The results from this pilot sampling study confirm that women in localities where mercury-based ASGM is practised are exposed to mercury at levels of concern from two significant sources. For women who live in the community, or survive on fish, meat and plant food from the forest dietary mercury in the form of fish consumption is the principal means of exposure. There was some correlation between the amount of fish consumed and the concentration of mercury measured in hair, but there were other factors such as age and dietary accumulation over time as well as the type and size of fish consumed that may also have a significant influence on the mercury body burden of the participants.

In any event the primary source of mercury contamination of fish in the regions studied is mercury released in tailings from the ASGM amalgamation process. Whether primary or secondary exposure is considered, the key influence on mercury levels of participants can be traced back to the use of mercury in ASGM. In this study, Íquira, Colombia provided a useful comparison site in that the women are neither exposed directly to mercury through mining activity or through their diet (all participants indicated they did not eat any fish). This resulted in that cohort having some of the lowest levels of mercury recorded in all of IPEN's biomonitoring program. It also clearly demonstrates the health benefits of avoiding the use of mercury in an artisanal gold mining setting — not just for miners but for the broader community who consume fish as a key protein source.

For the women with elevated mercury levels in Vila Nova and El Callao it is important that they reduce their exposure to mercury from the more highly contaminated species of carnivorous fish in favour of smaller, younger or even canned fish if no alternative protein is available. They should also avoid fish consumption during pregnancy if protein substitutes are available or consider consuming canned fish as a substitute. The women of Vila Nova who identified as surviving on forest and river food had significantly higher mercury body burden than most other women of the community and should avoid carnivorous fish in favour of other species where available. The recent study of mercury levels in inland fish in Brazil (Hacon *et al.* 2020) provides some of the first relevant regional consumption advisories based on local fish species and consumption patterns and should be adopted and promoted by authorities to ensure women in the region are better able to control their exposure to mercury through fish.

The indigenous Eyiyo Quibo and Portachuelo women nearly all have a very high mercury body burden and action should be taken by authorities to intervene in this unacceptable mercury impact on these communities. Moreover the common use of the Beni river system by these two different groups indicate that mercury contamination of the aquatic food web across the entire region may be placing large populations at risk of mercury poisoning. Immediate action to curtail mercury use and provide alternate food sources is required. Health investigations and assistance should be prioritised for this group of women and their children.

In conclusion, the results of this study make it clear that women and their children in the regions of Latin American countries assessed in this study are at significant risk unless mercury use is prohibited and that the prohibition is enforced by authorities. The mercury that has entered the river systems is now a legacy for future generations and action must be taken to prevent further contamination. The example of gold mining in Iquira, Colombia demonstrates that new, mercury free methods for gold mining can be implemented that protect women from mercury exposure.

REFERENCES

Colombian Geological Service (2018) *Methodological guide for the productive improvement of the gold mill without the use of mercury*. Íquira (Huila) Ministry of Mines and Energy and the Colombian Geological Service. Bogotá, Colombia.

de Paula Gutiérrez, B.F., Agudelo, C.A.R. Fish as bioindicators: coal and mercury pollution in Colombia's ecosystems. Environ Sci Pollut Res 27, 27541–27562 (2020). https://doi.org/10.1007/s11356-020-09159-4

Feng, X., Li, P., Qiu, G., Wang, S., Li, G., Shang, L., Meng, B., Jiang, H., Bai, W., Li, Z. and Fu, X. (2008) Human Exposure To Methylmercury through Rice Intake in Mercury Mining Areas, Guizhou Province, China *Environmental Science & Technology* 2008 *42* (1), 326-332. DOI: 10.1021/es071948x

Grandjean P, Weise P, White RF, Debes F, Araki S, Yokoyama K, Murata K, Sorensen N, Dahl R, Jorgensen PJ (1997) Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicol Teratol 19:417-428.

Hacon, S. de S., Oliveira-da-Costa, M., Gama, C. de S., Ferreira, R., Basta, P. C., Schramm, A., & Yokota, D. (2020). Mercury Exposure through Fish Consumption in Traditional Communities in the Brazilian Northern Amazon. International Journal of Environmental Research and Public Health, 17(15), 5269. doi:10.3390/ijerph17155269

International Crisis Group (2019) *Gold and Grief in Venezuela's Violent South. Report no. 73 Latin America & Caribbean 28 February 2019*. https://www.crisisgroup.org/latin-america-caribbean/andes/venezuela/073-gold-and-grief-venezuelas-violent-south

Junaidi, M., Krisnayanti, B. D., Juharfa, & Anderson, C. (2019). Risk of Mercury Exposure from Fish Consumption at Artisanal Small-Scale Gold Mining Areas in West Nusa Tenggara, Indonesia. Journal of health & pollution, 9(21), 190302. https://doi.org/10.5696/2156-9614-9.21.190302

Murata, K., Weihe, P., Budtz-Jorgensen, E., Jorgensen PJ., Grandjean P., (2004) Delayed brainstem auditory evoked potential latencies in 14-year-old children exposed to methylmercury. J Pediatr 144(2):177-183.

Marco, D (2018) *Crisis in Venezuela: the distorted economy that gold creates in the richest (and most violent) place in the country*. BBC News Mundo, El Callao (Venezuela). 17 August 2018. https://www.bbc.com/mundo/noticias-america-latina-45204276

Steckling, N., Tobollik, M., Plass, D., Hornberg, C., Ericson, B., Fuller, R., and Bose-O'Reilly, S. (2017) Global Burden of Disease of Mercury Used in Artisanal Small-Scale Gold Mining, Annals of Global Health, Volume 83, Issue 2, 2017, Pages 234-247, ISSN 2214-9996, https://doi.org/10.1016/j.aogh.2016.12.005.

UNEP (2020). Artisanal and Small-Scale Gold Mining. Global Mercury Partnership. United Nations Environment Programme. https://web.unep.org/globalmercurypartnership/our-work/artisanal-and-small-scale-gold-mining-asgm.

UNEP (2018) Global Mercury Assessment 2018. United Nations Environment Programme. https://www.unenvironment.org/resources/publication/global-mercury-assessment-2018

ACKNOWLEDGMENTS

IPEN and BRI would like to acknowledge the hard work and dedication shown by the following environmental and civil society organisations who were directly involved in gathering hair samples in Latin America. The task was especially challenging due to the constraints imposed by the pandemic and difficult conditions in some of the locations. We would like to thank COLNODO (Colombia), Mapinguari (Brazil), Reacción Climatica (Bolivia) and Fundacion Aguaclara (Venezuela).

Additional thanks to: Raul Dorado, Alex Villca, Mirna Fernandez, Andrea Bedregal, Dr. Jorge Castillo, Dr. Jesús Olivero, Parkrangers Jose Luis Howards, Parkranger Marco Uzquiano, Sascha Gabizon, Carmen Capriles, Yuyun Ismawati, Community Esse Ejja of Eyiyo Quibo, Community Esse Ejja of Portachuelo, and Madidi National Park.

IPEN gratefully acknowledges the financial support provided by the Government of Sweden and other donors that made the production of this document possible.

The expressed views and interpretations herein shall not necessarily be taken to reflect the official opinion of any of the institutions providing financial support. Responsibility for the content lies entirely with IPEN.

Sweden
Sverige