GLOBAL REPORT

MERCURY IN WOMEN OF CHILD-BEARING AGE IN 25 COUNTRIES

BIODIVERSITY RESEARCH INSTITUTE
innovative wildlife science

IPEN
a toxics-free future

MERCURY IN WOMEN OF CHILD-BEARING AGE IN 25 COUNTRIES

September 2017

Lee Bell[2] *(Lead author)*

Contributing authors: ***David Evers***[1]***, Sarah Johnson***[1]***, Kevin Regan***[1]***, Joe DiGangi***[2]***, Jennifer Federico***[2]***, Jan Samanek***[3]

[1] *Biodiversity Research Institute (BRI), Maine, USA*
[2] *IPEN, Göteborg, Sweden*
[3] *Arnika Association, Prague, Czech Republic*

IPEN
a toxics-free future

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

bri
Biodiversity Research Institute
innovative wildlife science

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 a the leading international institute supporting the global mercury monitoring efforts for the Minamata Convention on Mercury.

www.briloon.org

Front cover photo: Mercury hair sampling in Nepal village. Ram Charitra Sah, CEPHED, Nepal

KEY FINDINGS

- 1044 women of child-bearing age from 25 countries participated in the study. 42% of them had mercury levels greater than 1 ppm — the level that approximately corresponds to the US EPA reference dose.* 55% of the women had mercury levels greater than 0.58 ppm mercury, a more recent, science-based threshold based on data indicating harmful effects at lower levels of exposure. Mercury is a health threat to women and the developing fetus.
- Women of the Pacific Islands have elevated mercury levels, likely due to a fish-rich diet. Distant air emissions of mercury from coal-fired power plants, cement kilns and other industries contaminate ocean fish that serve as a primary protein source for Pacific Islanders.
- Artisanal small-scale gold mining results in high mercury body burdens in women from Indonesia, Kenya, and Myanmar. Two likely mercury exposure sources are burning mercury amalgam and eating contaminated fish.
- Industrial mercury emissions contaminate local fish and elevate mercury levels in Thai women living nearby.
- Indigenous women in Alaska have mercury levels of concern due to their subsistence diet of sea mammals and fish. Consumption of seals may be a key source of mercury exposure.
- Women from locations in Albania, Chile, Nepal, Nigeria, Kazakhstan, and Ukraine have mercury levels of concern due to localised pollution of waterways and suspected fish contamination.
- Women using mercury to gold plate statues in Nepal have elevated mercury levels.

* This is the daily exposure that US EPA considers "likely to be without an appreciable risk of deleterious effects during a lifetime."

CONTENTS

Executive Summary **5**

1. Introduction **10**

2. Methodology **16**
2.1 Sampling Method 16
2.1.1 Target group 16
2.1.2 Participant selection 16
2.1.3. Ethics review and confidentiality of participants 17
2.1.4. Sample collection protocol 18
2.1.5. Sample analysis – mercury measurement 19
2.1.6. Assessment of results 19

3. Sampling locations **21**
3.1 Sampling location descriptions 21
3.1.1 Pacific countries: Tonga, Cook Islands, Kiribati, Marshall Islands, Tuvalu, Solomon Islands, Vanuatu 21
3.1.2 Southeast Asia: Indonesia, Myanmar, Thailand 24
3.1.3 South Asia: Nepal 27
3.1.4 The Middle East: Tunisia, Egypt 28
3.1.5 Latin America: Uruguay, Paraguay, Chile 29
3.1.6 Africa: Kenya, Nigeria 30
3.1.7 Central and Eastern Europe: Hungary, Albania 32
3.1.8 Eastern Europe, Caucasus, Central Asia: Russia, Kazakhstan, Tajikistan, Ukraine 33
3.1.9 North America: United States of America (Alaska) 35

4. Results of sample analysis **37**
4.1 Hair sample analysis 37

5. Assessment and discussion **42**

References **64**

Acknowledgements **68**

EXECUTIVE SUMMARY

OVERVIEW

Mercury is a potent neurotoxin, especially to the developing brain, and can affect the developing fetus months after the mother's exposure. The harmful effects that can be passed from the mother to the fetus when the mother's mercury levels exceed 1 ppm include neurological impairment, IQ loss, and damage to the kidneys and cardiovascular system. At high levels of mercury exposure this can lead to brain damage, mental retardation, blindness, seizures and the inability to speak. While researchers have studied mercury body burden in specific regions of the world, information in developing and transition countries is lacking. This comprehensive study focused on measuring the mercury body burden of 1044 women of child-bearing age in 25 developing and transition countries. The data indicates that there is a serious and substantial threat to women and children's health from mercury exposure.

METHODOLOGY

Sampling was undertaken across the globe during 2015 and 2016 by public interest Participating Organisations (POs) of IPEN—a global network operating in more than 100 countries. IPEN POs reached out to communities in areas with known mercury contamination hotspots as well as areas that may be susceptible to mercury contamination of food supplies such as fish, which can transfer their methylmercury body burden to humans when consumed. The study resulted in samples being taken from 1044 women in 37 locations across 25 countries. The methodology for the study required IPEN POs to identify groups of 30-35 women of child-bearing age (denoted as 18 - 44 years old) in one or two locations in each country. The women provided signed consent to participate in the study. Participants were required to provide a small sample of hair and to complete a questionnaire to assist with contextual analysis. The samples of hair were shipped to the laboratories of BRI in the United States for analysis.

Women in this age range were selected as they constitute part of the vulnerable sub-population groups at risk from mercury, a powerful neurotoxin that can affect both the health of the mother and impact on a range of developmental endpoints in the developing fetus with lifelong conse-

quences.[1] Sample results were assessed against the internationally recognised reference level of 1 ppm total mercury (THg), above which health effects to the developing fetus of pregnant mothers may occur.

The basis for the use of this reference level in this study is that it corresponds closely with the U.S. EPA's reference dose (RfD) of 0.1 µg/kg bw/day and a blood mercury concentration of 4 - 5 µg/L.[2] For some time, the scientific literature has suggested that adverse effects on the sampled individual begin to occur at or above the reference level of 1 ppm.[3,4] However, the latest scientific literature concludes that negative developmental effects may occur at even lower levels[5] and that a threshold level of 0.58 ppm should be adopted as the level below which impacts on the developing fetus are negligible.[6] For the purposes of this study we used the accepted threshold of 1 ppm to assess elevated mercury levels in participants. However, where appropriate we have also included references to the latest science-based threshold concentration of 0.58 ppm for comparison.

KEY FINDINGS

Mercury pollution poses a serious and substantial threat to the health of women and the developing fetus in many parts of the world. Of the 1044 women who participated in this study, 42% had a mercury body burden that exceeded the reference level of 1 ppm total mercury in hair. Locations where the mean (average) level for the group of women exceeded the 1 ppm reference level for mercury were the Cook Islands, Indonesia, Kenya, Kiribati, Marshall Islands, Myanmar, Nepal (location A), Nigeria, Solomon Islands, Thailand, Tonga, and Tuvalu. A second tier of women from Alaska, Albania, Chile, Kazakhstan (location B), Ukraine, and Vanuatu exceeded the 0.58 ppm mercury level as the mean for the group.[7]

1 Bose-O'Reilly, S., et al (2010) *Mercury exposure and children's health.* Curr Probl Pediatr Adolesc Health Care, 2010 Sep; 40(8):186-215.

2 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.

3 Trasande L, Landrigan PJ, Schecter C (2005) *Public health and economic consequences of Methyl Mercury Toxicity to the Developing Brain*, Environ Health Perspect 113:590-596.

4 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.

5 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.

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

7 Grandjean, P., et al (2010) *Adverse Effects of Methylmercury: Environmental Health Research Implications*. Environmental Health Perspectives, Vol 118. No.8. August 2010, 1137-1145.

The analysis suggests three specific factors resulted in elevated levels of mercury in mothers and potential mothers across different countries and continents: a fish-rich diet; the practice of artisanal and small-scale gold mining (ASGM); and proximity to industrial locations.

The data from the Pacific Islands illustrates the impact of a fish-rich diet. Women from Small Island Developing States (SIDS) in the Pacific were found to have very high levels of mercury body burden compared to most other locations except those engaged in ASGM. Of the 239 participants located in Pacific Island States, 209 (86%) exceeded the 1 ppm mercury threshold level. In Cook Islands, Kiribati, Marshall Islands, Tonga, and Tuvalu, 90% or more of each group exceeded 1 ppm mercury in hair. For Kiribati, 100% of women sampled exceeded the 1 ppm threshold level.

The high mercury levels in Pacific Island women are consistent with data from the study questionnaires and prior studies indicating that most of these women have a diet rich in seafood. Large predatory fish that feature in the diet of women in the Pacific SIDS are commonly cited in the literature[8] as having high methylmercury (MeHg) concentrations in their flesh. The absence of local industries with mercury emissions in the Pacific Islands and the remote distribution of the islands indicate mercury contamination of seafood as the primary factor in the elevated mercury body burden of these women. This points to a serious food chain contamination problem caused by global mercury deposition from industrial emissions to oceans. Subsequent bacterial methylation of mercury in oceans results in its magnification through the food chain, impacting on women reliant on fish as dietary protein such as Pacific Islanders.

The results from this study strongly suggest that the practice of artisanal and small-scale gold mining (ASGM) using mercury leads to elevated mercury levels for women engaged in this activity. In ASGM, elemental mercury is often used to amalgamate gold dust obtained by low technology mining (e.g. panning, sluicing and ball milling). The gold and mercury amalgam is 'roasted', often in domestic settings, to vaporise the mercury, leaving a small amount of gold. This leads to direct mercury exposure through handling and fume inhalation. Sampling results from women directly engaged in ASGM, or who had family members practicing ASGM with mercury in Indonesia, Kenya, and Myanmar, show significantly elevated mercury levels in their hair. In Indonesia, 100% of women sampled exceeded the 1 ppm threshold level. In Kenya and Myanmar, the percentage of women exceeding the 1 ppm threshold level was 44% - 93% respec-

8 Silbernagle, et al, (2011) *Recognizing and Preventing overexposure to Methylmercury from Fish and Seafood Consumption: Information for Physicians.* J Toxicology 2011;2011 983072.

tively. When compared to the 0.58 ppm threshold level, the percentage rose to 71% and 100% respectively.

Proximity to heavily industrialised areas or those areas with hotspots caused by historical industrial activities also led to high mercury body burden levels. This occurred in Thailand, where two locations featured mixed heavy industry facilities with known mercury releases adjoining waterways from which local people consumed fish. The percentage of women exceeding the 1 ppm threshold level in the two Thai locations ranged from 68% - 79%. When compared to the 0.58 ppm reference level, the percentage rose to 97% and 100% respectively for the two locations. The elevated mercury levels reported by these women were comparable with those of women from most of the Pacific Islands where sampling took place.

CONCLUSION

The data indicates that there is a serious and substantial threat to the health of women and the developing fetus in many parts of the world as a result of mercury pollution. Reducing or eliminating atmospheric mercury pollution and deposition to oceans from coal fired power plants and other industrial sources should be a priority for the international community. In addition, urgent action must be taken to reduce and eliminate mercury exposure of women involved in ASGM activity. An outright ban on mercury use in ASGM and the trade in mercury associated with it would have the most immediate beneficial health impacts for women.

The Minamata Convention on Mercury represents a global consensus that mercury pollution poses a serious threat to human health. However, the time frame for action in the Convention and the multiple exemptions for mercury use will limit its effectiveness in the medium term. National governments should take matters into their own hands by banning the import and export of mercury and introducing tough measures to eliminate domestic sources of mercury pollution as soon as possible. Hotspot contamination from industrial sources such as those in Thailand must be much more strictly controlled and mercury emissions heavily restricted or, preferably, eliminated, to protect the women and children in those localities.

An immediate step that should be taken to reduce impacts of mercury pollution in all the locations studied is to intensify and expand monitoring of women's body burden and food sources (especially fish and marine mammals). This should lead to locally relevant food advisories that should be rapidly developed to inform women of the safest types of fish and marine

mammals to consume where alternative protein sources are unavailable. In the absence of urgent action, generations of women and their offspring will bear the brunt of mercury contamination, while others will profit from ongoing mercury pollution.

1. INTRODUCTION

The Minamata Convention on Mercury 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 as a global threat to human health, livelihoods, and the environment, and is 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. To support this effort, IPEN has conducted a range of mercury treaty-related enabling activities, released publications and developed awareness-raising campaigns that included mercury monitoring and biomonitoring.

This study was undertaken to answer questions that arose from previous smaller-scale sampling studies conducted by IPEN, BRI and UN Environment. A number of these studies suggested that there may be significant mercury contamination issues affecting women in the Pacific Islands, women engaged in small-scale gold mining, and women near industrial mercury pollution sources. In particular, we wanted to answer the question of whether all Pacific Islands are impacted to a similar degree by mercury deposition to oceans and subsequent fish contamination or whether it was a localised issue for one or two island nations.

BIOMONITORING

Mercury biomonitoring is an essential element of any effective strategy to assess and reduce global mercury pollution. Recognising this need, 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 that is a leader in ecological research related to mercury toxicology. This study represents one of IPEN and BRI's largest partnership programmes to date, with hair sampling of women of child-bearing age taking place across the globe in all UN regions. At their laboratory in the state of Maine, U.S., BRI processed over one thousand hair samples for this study,

which were provided by women concerned about their mercury body burden and the potential impacts on the fetus. Hair samples were collected by IPEN Participating Organisations in cooperation with local communities.

This form of mercury monitoring can act as an impetus for countries to ratify 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 which can 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 programme 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) 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[9] 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 particular emphasis on Pacific Small Island Developing States (SIDs).

9 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. 20 pages.

Expanding recent hair monitoring studies

In a 2015/16 study[10] (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 SIDs and two non-Pacific countries. Data from that report for the countries of Cook Islands, Marshall Islands, Kiribati, Tuvalu, Nepal and Tajikistan have been combined with the broader database of this report, as they used identical methodologies and sampling protocols to provide a more complete picture of the Pacific Island situation.

The mercury monitoring results from the 2015/16 study were significantly elevated for 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 Pacific Islanders studied face a serious problem with mercury contamination of fish that comprise a major part of their diet. The problem may have significant ramifications for all Pacific Islanders, as nearly all of those assessed exceeded the 1 ppm threshold level for mercury contamination of their hair. The addition of 3 Pacific Islands in this study expanded that database with similar results, suggesting a widespread contamination issue may be having population-level effects, which requires additional monitoring. The mode by which Pacific Island women are exposed can be explained by the deposition and methylation of mercury in the ocean.

Global mercury deposition to oceans contaminates the food chain

Methylation of mercury in the ocean results from atmospheric deposition from known mercury sources such as coal fired power plants, cement kilns, metal processing smelters, chlor-alkali plants, vinyl monomer production facilities in China, and gold production. The primary source is identified as coal fired power stations. Following atmospheric deposition, naturally occurring bacteria convert elemental mercury and other mercury compounds into methylmercury, which is far more bioavailable than other forms of mercury and which accumulates through the food chain, resulting in high concentrations in top feeding predatory fish such as swordfish, shark and king mackerel.[11] Mercury also accumulates in fish further down the predatory chain.

10 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 the International POPs Elimination Network. April 2017. Berkeley California.

11 Kim et al (2006) *The Effect of Fish Consumption on Blood Mercury Levels of Pregnant Women*. Yonsei Med J. 2006 Oct 31; 47(5): 626–633.

Coal fired power plants contribute a high proportion of mercury deposition to oceans, as coal contains small amounts of mercury but is released in significant quantities to the atmosphere due to the vast amounts of coal that are burned to produce electricity globally.

Large, predatory fish build a high mercury body burden due to mercury biomagnification in the food chain. When consumed by humans, these fish pass their mercury body burden to humans. For women who have a diet rich in fish, there is a significant risk that their body burden of mercury will be elevated and they may pass on some of this mercury to their unborn children with potential neurological impacts. Some studies have indicated that umbilical cord blood has higher concentrations of methylmercury than the blood of the mother.[12] Combined with the ability of mercury to pass both the blood/brain barrier and the placental barrier, this represents a greater risk to the development of the fetus than exposure after birth.[13]

High levels of mercury among Pacific Islanders

The concerns raised by the IPEN/BRI UN E 2017 study prompted IPEN to expand its Pacific sampling program to include the Kingdom of Tonga, the Solomon Islands and Vanuatu. The sampling results from these countries mirrored the elevated mercury levels found in the hair of women from earlier sampling in the Cook Islands, Kiribati, The Marshall Islands and Tuvalu, with the exception of Vanuatu, which had significantly lower levels. The reason for this result is discussed in Section 5 of this report and strengthens the assertion that food chain contamination is responsible for the high mercury body burden among Pacific Island women.

IPEN, in collaboration with BRI, developed a detailed methodology for the sampling activity, which included a background brief on the project to orient IPEN Participating Organisations that implemented the sampling. The methodology also included templates of key documents such as consent forms, questionnaires and data log sheets. A detailed sampling protocol was provided, and demonstrated how to take the samples safely, avoid cross contamination, and prepare the samples for shipment to the laboratory with tracking documentation. This same protocol was employed in all sampling to ensure comparability of results. The methodology documentation also included a fact sheet to provide contextualised feedback to the participants on the results of their sample analysis, implications for

12 Grandjean et al (1997) *Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury*. Neurotoxicol Teratol. 1997;19:417–428.

13 Davidson et al. (1998) Effects of prenatal and postnatal methylmercury exposure form fish consumption on neurodevelopment: outcomes at 66 months of age in the Seychelles Child Development Study. JAMA. 1998;280:701–707.

their health, and potential mitigation measures they may take to avoid or reduce further mercury exposure.

Distribution of sampling location types for this study were not narrowly defined, but had sufficient scope to allow for sampling that reflects typical urban settings that may result in industrialised society exposures, as well as remote locations such as Pacific Islands, which are more likely to reflect diffuse global mercury pollution that impacts on marine food webs. In some cases, known mercury hotspots such as industrial facilities or contaminated sites were in proximity to the communities where women provided samples. One particular setting type that was studied focused on communities that were engaged in small-scale gold mining using mercury for gold extraction and processing.

Small-scale gold mining poisoning communities

The results from selected ASGM communities in Indonesia, Myanmar and Kenya all reported elevated mercury levels, including some of the highest mean cohort levels recorded. A small number of samples from these locations had extremely high mercury hair concentrations which were well beyond the range of other community members. IPEN and BRI believe these may be due to surface contamination of the hair with elemental mercury, which is handled by some individuals as part of the gold processing activity. If this is the case, it does not reflect the actual body burden of those individuals. In order to determine if surface hair contamination is the cause of the very high sampling results, IPEN and BRI will employ a more complex analysis of the hair samples to determine methylmercury (MeHg) levels, which will provide an accurate body burden level for those individuals concerned. In some cases, these high results have increased the cohort mean concentrations for some locations, but this is made clear in the standard deviation results in section 4 and in the discussion at section 5. Further details on the locations for sampling are discussed under section 3 of this report.

Economic impacts of elevated mercury body burden

While the health impacts of elevated mercury levels in the human body are well documented, a recent ground-breaking study[14] 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

14 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 http://www.ncbi.nlm.nih.gov/pubmed/27594689

study analysed 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 lost productivity was developed. This data was used to estimate increases in intellectual disability and lost Disability-Adjusted Life Years (DALY). A total of $77.4 million in lost economic productivity was estimated assuming a 1 ppm reference level, and $130 million if no reference level was used.

For many of the 25 countries identified in this report, the human health issues revealed through the sampling process are critical to address, but the Trasande 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.

Sampling Results

The wide variety of contexts in which sampling was conducted is reflected in the disparity of the sampling results, which range from low levels in some locations to highly elevated levels in others. More detailed information on sampling locations, results, and interpretations of the findings are provided in section 5.

2. METHODOLOGY

In preparation for the implementation of this project, IPEN and BRI developed a methodology based on the framework for hair sampling previously utilised by IPEN/BRI in their 2014 global study of mercury in fish and hair.[15] 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 by the University of Southern Maine in Portland, U.S. The methodology covers sampling method, collection of data, and mercury measurements, as well as assessment and evaluation of the results.

2.1 SAMPLING METHOD

2.1.1 Target group

The focus of this project is the vulnerable sub-population group of women of child-bearing age. The definition of child-bearing age differs to some degree between various institutions. Studies undertaken by United States researchers use the age range of 18 - 44 years due to federal government limitations on sampling of biological material from minors. For this project, the target group for sampling is women of child-bearing age from 18 to 44 years, as it would allow comparison with other studies using this range while meeting legal requirements.

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 Organisations identified and convened participants at each location to administer the consent forms and questionnaire, and conduct hair sampling according to the specified protocols. The Participating Organisations gathered samples in a scientifically sound manner that is consistent with recognized standards for sample collection of human hair for mercury monitoring.[16]

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) p. 18.

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

Locations where sampling took place were based on advice from IPEN Participating Organisations, which considered issues of access, cultural sensitivities, timing and cooperative approaches with local communities and civil society organisations 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 U.S. 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 participant by the IPEN Participating Organisation representative, supported by a local, native language-speaking volunteer to ensure that the process was understood by 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 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 does 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 IPEN organisation 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 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 IPEN POs tasked with coordinating the collection of samples were provided with detailed sample collection, packaging and shipping protocols to ensure minimisation 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

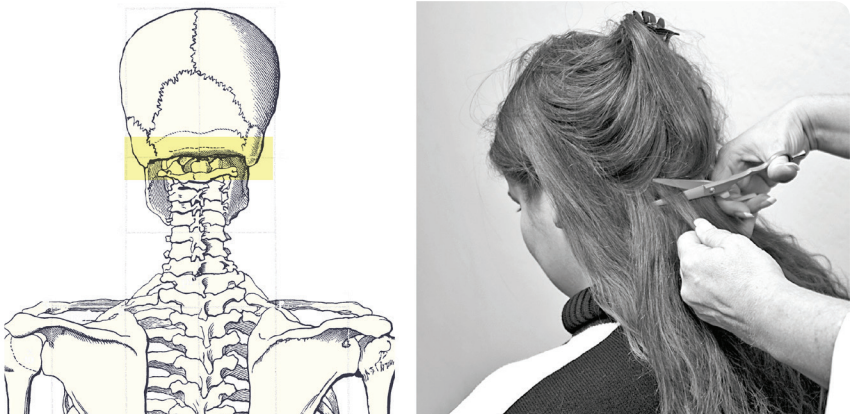


Figure 1. Occipital region: Target sample area.

Figure 2. Correct labelling and storage of sample.

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 U.S., the hair samples were analysed 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. In a small number of samples the levels of Hg reported were well beyond the range for the rest of the group from that location. In nearly all cases this occurred among groups engaged in small-scale gold mining (ASGM). It appears likely that this small number (< 0.1%) of highly elevated samples may be due to gross surface contamination of the hair with elemental mercury caused by repeated handling of mercury in the gold production setting. As a follow-up to this study this small number of samples will be reprocessed using laboratory analysis for methylmercury content to assess if contamination of the hair surface with elemental mercury is responsible for the extremely high sampling results.

2.1.6. Assessment of results

The interpretation of sample results will be 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 U.S. EPA's refer-

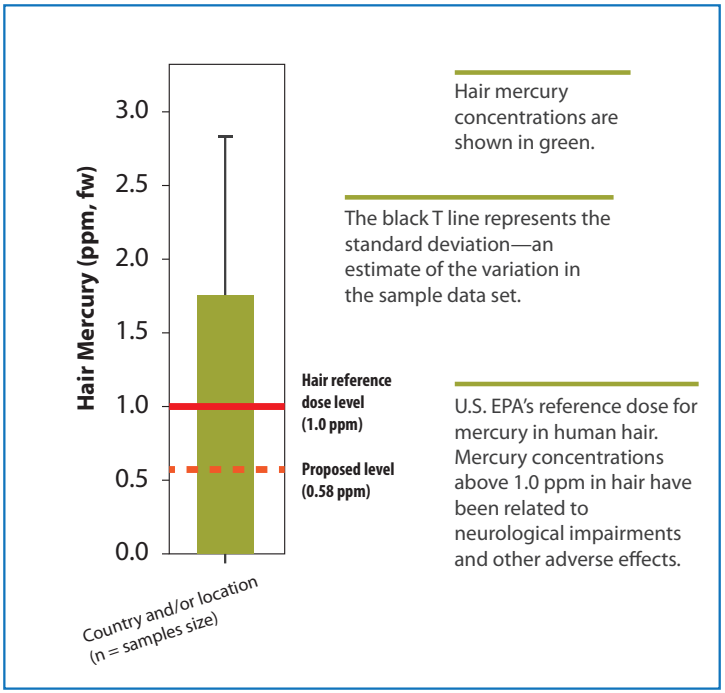


Figure 3. Interpreting the hair mercury concentration chart.

ence dose for mercury in human hair.[17] Mercury concentrations above 1.0 ppm in hair have been related to neurological impairments in adults.[18,19] 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.[20] For this reason, IPEN has applied the additional threshold of 0.58 ppm against the reported sampling results to assess relative levels of the groups studied.

17 United States Environmental Protection Agency [USEPA]. 2000. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1: Fish Sampling and Analysis* (3rd edition). US EPA, Office of Water. EPA 823-B-00-007. Washington, DC. 485 pp.

18 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.

19 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.

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

3. SAMPLING LOCATIONS

In this section, further details are provided on selected locations where sampling has been conducted. A particular focus is provided on those locations where mercury levels in samples were elevated, such as the Pacific Islands, communities where small-scale gold mining is practiced, and some sites where industrial pollution may influence the elevated results.

3.1 SAMPLING LOCATION DESCRIPTIONS

3.1.1 Pacific countries: Tonga, Cook Islands, Kiribati, Marshall Islands, Tuvalu, Solomon Islands, Vanuatu

Data collected from hair sampling in this study builds upon sampling conducted in the Pacific Islands by IPEN and analyzed by BRI in 2016 and published in 2017 as the result of a joint IPEN/BRI/UN Environment study focused on hair sampling for mercury among women of childbear-

Figure 4. Map of Pacific including Small Island Developing States.

ing age in six countries.[21] The four pacific island countries included in the May 2017 report were the Cook Islands, Marshall Islands, Kiribati and Tuvalu. In this study, directly comparable data has been added from the Kingdom of Tonga, the Solomon Islands and Vanuatu.

It is notable that, in the case of all Pacific Islands where sampling took place, no major industrial facilities that are known as a source of mercury pollution exist. Some islands have small landfills that would contain some discarded mercury-added products and subsequent leachate, but there appears to be no significant sources of mercury emissions and releases on any of the populated islands that would contribute to the elevated levels reported by women of childbearing age in all but one Pacific Island. This phenomenon is discussed further in section 5.

The Kingdom of Tonga

The Kingdom of Tonga is a Polynesian archipelago which consists of a group of 169 islands with a population of 103,252 people.[22] Only 39 of the islands are inhabited. The surface area of the islands is around 750 square kilometers, but they are dispersed across 700,000 square kilometers in an 800 km line north to south. Participants that provided samples came from various locations, including Kolofo'ou, Ma'ufanga, Kolomotu'a, Halafo'ou, Vaololao and Halafo'ou.

Cook Islands

The nation of Cook Islands is a remote group of 15 South Pacific islands spread over 2.2 million square kilometres. Sampling was conducted in two locations in the Cook Islands group.

Location A: Rarotonga – village-based participants

Sampling was conducted in Rarotonga among women who were originally from other villages in Rarotonga or islands in the Cook Island group.

Location B: Rarotonga – urban participants.

The second location for sampling in Cook Islands was among office workers based in Rarotonga.

---

21 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 the International POPs Elimination Network. April 2017. Berkeley California. Available: http://www.mercuryconvention.org/Portals/11/documents/News/Mercury%20Monitoring%20Women%20Asia%20Pacific%20April%2011%20Raw%20data.pdf

22 Tongan Department of Statistics http://tonga.prism.spc.int/#population-statistics-including-administrative-information-and-statistical-tabulation-of-the-2011

Tuvalu

Tuvalu is a nation of nine islands in the southwest Pacific Ocean formerly known as the Ellice Islands. They have a combined land mass of 27 square kilometres. Around 94% of the ethnic Tuvaluan population are Polynesian. Those on the island of Nui are of Micronesian origin. Sampling was conducted in Funafuti Island, the administrative capital of Tuvalu. Women who participated were from a range of Tuvaluan islands.

The Republic of Kiribati

The Kiribati islands consist of three main groups separated by long distances in the southwest Pacific Ocean. The three groups are the Gilbert group on the equator, the Phoenix Islands in the east, and the Line Islands further east. The total land mass is 811 square kilometres. Participants in the sampling project were from the Betio district of the capital island Tarawa.

The Republic of Marshall Islands

The Marshall Islands are a nation of 29 coral atolls and 1,156 islands and islets in the Pacific Ocean located close to the equator just west of the international date line. Sampling was conducted in the capital of Majuro, which has a population of around 27,800 people who are predominantly Micronesian.

The Solomon Islands

The Solomon Islands are a group of six major islands and over 900 smaller islands with a population of 635,027 people and a land mass of 28,400 square kilometers. The island group lies east of Papua New Guinea and northwest of Vanuatu. Sampling was conducted in Honiara, which is the capital of the Solomon Islands and is based on the island of Guadalcanal.

The Republic of Vanuatu

Vanuatu is a Melanesian society consisting of 80 islands in the South Pacific Ocean distributed across 1300 kilometres with a population of 234,023 The surface area of the islands is approximately 12,200 km^2. Its capital, Port Vila, is situated on the island of Efate. Sampling was conducted with participants from Port Vila.

3.1.2 Southeast Asia: Indonesia, Myanmar, Thailand

Sampling in Indonesia and Myanmar was conducted among women who engaged in artisanal small-scale gold mining (ASGM) or who were part of community where this practice was common. In most cases the women also had a significant fish-based diet, which may have provided the link between the economic activity of mercury-based gold production and elevated levels of hair mercury. This is due to local waterway and fish contamination caused by dumping of mining waste contaminated with mercury. In Thailand, the samples were taken from women who lived adjacent to waterways with significant heavy industrial plants. The waterways were used for a variety of purposes, including fishing for local consumption. More detailed descriptions of these locations are provided below.

The Republic of Indonesia

Indonesia is a heavily populated country in southeast Asia with more than 260 million inhabitants spread across 17,000 islands with a surface area of 1,904,569 km^2. The island of Java is occupied by nearly half the population of Indonesia. The practice of ASGM is carried out in many locations in Indonesia, with Kalimantan being the best-known location. For this study two ASGM-related sites were chosen: Pongkor and Sekotong.

Location A: Sekotong, West Java province

The Sekotong ASGM hotspot area in West Java Province is a relatively recent gold mining site, having been established around 2012. The Sekotong ASGM site overlaps with a joint venture gold mining company, PT Indotan Lombok Barat Bangkit—owned by the Local Government of West Lombok. Many gold processing activities involving mercury are located between houses in the village at Sekotong. Mercury/gold amalgam burning activities take place in the kitchen and inside the house where pregnant women, babies and children are present.

Location B: Pongkor, West Java province

Pongkor is one of the oldest ASGM sites in Indonesia and is located in West Java Province, about 5 hours from Jakarta. In the last 15 years, miners have been encroaching on the concession mining areas of the state-owned gold mining company, PT Aneka Tambang (Antam) Persero Tbk (public listed company). Until early 2017, PT Antam and local authorities burned down community ball-mill huts (used for processing gold ore) and shut down all the small-scale gold mining operations. Many publications covered the dynamic of ASGM in Pongkor but only a few studies covered the health impact of mercury use in the Pongkor area. Due to the high gold deposit potential, Pongkor ASGM areas are protected or guarded by

an informal group of security to screen the number and type of visitors entering Pongkor.

The Republic of the Union of Myanmar (formerly Burma)

Myanmar has a population of around 60 million people and is bordered by India and Bangladesh to its west, China to the north, and Laos and Thailand to the east, and covers 676,578 km^2. Myanmar features over 100 separate ethnic groups and, since independence from Britain in 1948, has been subject to periods of intense civil war. Ongoing conflict has limited opportunities to research environmental issues in recent decades and the hair sampling for mercury conducted as part of this study is unique. There are numerous areas in Myanmar that are suspected of having mercury contamination as a result of gold mining activity. Suspected mercury-impacted areas include communities along the Ayeyawady river, Chindwin river, and Tanintharyi river, which are the largest rivers of the country. The communities along these rivers rely on them as the primary sources of water for drinking and household use.

The area for the collection of hair samples for this study was along the Tanintharyi river. The Karen ethnic people who have been impacted by decades-long civil war are now affected by increased extractive industries, including gold mining using mercury in the post-conflict area following the ceasefire. The communities along the Tanintharyi River rely on it as their main water resource as well as for fishing and transportation. Mercury levels in this location were significantly elevated.

Thailand

Location A: Map Ta Phut industrial complex in Rayong province

The Map Ta Phut complex along the eastern coast of Thailand is the world's 8th largest petrochemical production hub and is Thailand's largest industrial complex, consisting of more than 150 factories located in 5 industrial estates. The total population is over 300,000 people, and about one-third are poor migrant workers from northeast Thailand. The industrial complex energy supply is via 4 coal fired power plants, with a combined output of 3160 MW. Wastewater from two of these plants is discharged to the Bang Berd Canal. The other two plants discharge to the Chak Mark canal, which flows into Ta Kuan/Pradue Bay, adjacent to the BLCP coal power plant.

Levels of mercury in the hair of women who provided samples around this location were generally elevated at significant levels.

Figure 5. Map Ta Phut Petrochemical complex. *Pattaya News*

Location B: Tha Tum, Prachinburi, eastern Thailand

The Tha Tum location has some heavy industrial development alongside residential areas and canal waterways. The industry includes two coal-burning power plants (adjacent facilities) that together produce 326 MW of electricity and use 700,000 - 800,000 tons/year of bituminous coal. The power station provides electricity for a paper and pulp production complex and at least 130 other factories in 304 Industrial Park. Coal ash from the power plants is mixed with biomass power plant ash and sewage sludge and used as "fertilizer" in over 9,000 acres of eucalyptus plantations nearby. More sewage sludge is stored along with treated wastewater in the common wastewater aeration pond for 304 Industrial Park. This pond holds 15 million cubic meters, and is usually filled to near-maximum capacity. Shalongwaeng Canal provides the main food resource for the local population of at least 20,000 people. Tha Tum is fast growing from a rural village into an industrial city. Local residents and migrant factory workers catch fish in Shalongwaeng Canal, for daily household consumption and to sell in nearby markets for income. The canal is the breeding ground for fish and links to Prachinburi River, which is another major food source, especially for commercial breeding of fish for market. In addition, the 304 Industrial Park Wastewater Aeration Pond is a food source for poorer residents to collect vegetables and fish to sell in nearby markets. There is some household consumption as well, but most people avoid

consuming fish from this site because they have noticed irregularities in the fish.

3.1.3 South Asia: Nepal

Nepal

Sampling in Nepal was conducted in two locations. The first location was among the Jalari community of fisherfolk in the Begnas Lake area of Pokhara, Nepal. The second location was an urban area in the Lalitpur District of the Kathmandu Valley where workers are engaged in 'fire gilding' of religious idols, a gold plating method using mercury.

Location A: Women of the Jalari community near Begnas Lake

The Begnas Lake is the second largest lake in Pokhara city, Nepal, and is subject to pollution via urban and agricultural drainage as well as waste from health care centres (including dental clinics that may contain mercury). The Jalari community are a genuine fisherfolk community who live nearby and are dependent on this lake for fishing for their livelihood. They consume those fish least preferred by customers; in particular a species called Tilapia (a predatory fish) with the least commercial value.

Figure 6. Woman of the Jalari community fishing on Lake Begnas (left) and the daily catch. *CEPHED, Nepal*

Location 2: Idol gilders in Lalitpur District of the Kathmandu Valley

This is an urban area similar to many in major cities in Nepal. Women who participated in sampling are engaged in religious idol manufacture (including a process of mercury-based gold plating known as "mercury gilding" or "fire gilding"), domestic tasks and associated urban activity. Men also take part in the gilding process. The gold plating process has

been practised in Europe and Japan for over 2000 years[23] and involves mixing metallic mercury and gold particles to form a paste which is applied to the idols. The mercury is then burned off with a blow torch (in the modern era), leaving a gold coating. This activity results in mercury vapor exposure of workers that are engaged in this process. Some workers may also directly handle mercury. The levels of total mercury measured in the hair of some of these workers is at similar elevated levels to Tanzanian small-scale gold miners that are directly engaged in burning mercury gold amalgam for extended periods.[24] The occupational exposure of mercury gilders to mercury vapor has not been extensively studied; however, one recent study[25] concluded that acute mercury intoxication arose among a group of gilders using this technique to gold plate a shrine. Those exposure results suggest this metal plating technique is a plausible exposure route leading to elevated hair mercury concentrations among the workers sampled in Nepal. For more information on this group and the gilding process see Section 5.

3.1.4 The Middle East: Tunisia, Egypt

Tunisia

The regional location selected for sampling was the city of Kasserine, which is in west-central Tunisia on the frontier with Algeria. Hair sampling was conducted in two locations: Olympique City and El Kadhra City, both within the locality of Kasserine. Sampling was conducted among women of the local populations to assess if there was any immediate influence from mercury contamination left at the site of the National Society of Cellulose and Paper Alpha facility, a paper pulp production plant formerly using the Kraft chlorine method of paper pulp production and generating its own chlorine from a mercury cell chlor-alkali plant on-site. The mercury cell plant has been replaced with a non-mercury based alternative. The results indicate that most women had mercury hair levels below 1 ppm (with one exception). This is likely related to the lack of waterways and fish-based diet as an exposure pathway. Ongoing exposure to vapor or dust inhalation from the industrial site should be investigated further and action taken to ensure that mercury contamination from that site cannot impact on local communities.

23 Giumlia-Mair et al (2014) *Mercury Gilding in Today's Japan: An Amalgam of Old and New*. ISIJ International Vol. 54 (2014) No. 5 p. 1106-1110.

24 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.

25 Vahabzadeh M, Balali-Mood M. (2016) Occupational metallic mercury poisoning in gilders. Int J. Occup Environ Med 2016: 7-122.

Figure 7. Women of Sohag use Nile water for domestic purposes.
Kenana NGO for Sustainable Development, Egypt

Egypt

The locations selected for sampling in Egypt were villages near the City of Sohag (upper Egypt), which is located on the western bank of the Nile river among fertile river plains. The main water source for this community is the Nile river, and people use it for all purposes—especially women.

Previous studies have demonstrated that Nile crocodiles (Crocodylus niloticus) had shown elevated mercury concentrations as had some species of Nile fish such as Clarius gariepinus, Oreochromis andersoni, Serranochromis angusticeps and juvenile Tilapia.[26] Levels of mercury in hair were relatively low from this location, with only one individual exceeding the 1 ppm reference level.

3.1.5 Latin America: Uruguay, Paraguay, Chile

Uruguay

Sampling was conducted in two small rural villages situated 25 km southwest from the capital city, Montevideo, near the mouth of the Rio Santa Lucia. The villagers of Villa River and Villa San Fernando in the province of San Jose provided hair samples which, like Tajikistan and Russian locations, reported low mercury hair concentrations, due in part to low fish diets.

26 Smith, A.C., Mackay A.W., Shacks, V.A. (2014) *Mercury contamination of the Nile Crocodile (Crocodylus niloticus) in the Okavango Delta, Botswana: A Baseline for the Assessment of Future Threats*. Final report to the Rufford Small Grants Foundation (May 2014).

Paraguay

The location of mercury sampling was the Municipality of Paso Yobai, 250 km from the capital, Asuncion. The 2 communities ("Compañías") selected were Coronel Cubas (location A) and Vega Cue (location B) in the Guaira Department of the Eastern Region of Paraguay. Mercury contamination occurs very close to waterways where gold mining is conducted. Gold is extracted by milling near a stream called Gasory in the community of San Antonio from the Municipality of Paso Yobáid, Dept. of Guairá. The Gasory stream flows into a major river called Tebicuary, spanning several departments (Guairá, Caaguazú and Misiones), and in turn emptying into the Paraguay River. Tebicuary is a tributary of Rio Paraguay Rivers and many fish are taken from it for human consumption. Mercury levels in hair among participants in location A were low, with no participants exceeding the 1 ppm threshold, while several participants from location B slightly exceeded the threshold of 1 ppm. The ASGM miners in these areas had a very low fish diet compared to other areas, with many individuals not eating fish at all, and those who did averaging around 2 - 4 fish meals per month. The main fish consumed are small Tilapia, which have relatively low mercury levels. When compared to the threshold level of 0.58 ppm, up to 18% of those providing samples exceeded the threshold despite low fish consumption.

Chile

Sampling was conducted in the Huasco Bay area, which has a high concentration of industrial activity including known mercury emissions sources such as coal fired power plants and an iron pellet plant powered by coal fired energy production. According to local estimates, more than 80 million tonnes of coal is burned each year for iron pellet production, and waste waters are discharged to the bay where marine biota have been impacted by pollution and overfishing. Several respondents had elevated mercury hair levels from this location, with 17% of the group exceeding the 1 ppm reference level. This is most likely attributable to their consumption of fish from the bay.

3.1.6 Africa: Kenya, Nigeria

Kenya

In Kenya sampling was conducted in 3 locations where ASGM activity occurs in the western part of the country in all the counties in the Lake Victoria Basin. Specifically, the county of Migori in the gold mining villages of Osiri and Mikei of Nyatike Sub County and Masara in Suna West

Sub County. Lake Victoria Basin is located in the upper reaches of the Nile Basin and occupies an area of about 251,000 square kilometers, of which 69,000 sq. km is the lake itself. The lake is shared among Kenya, Uganda and Tanzania. Lake Victoria is the largest fresh water lake in Africa and second largest in the world. Local populations in the basin depend on the lake for several livelihood activities, including fishing, farming, mining, bee keeping, trading activities, and quarrying.

Artisanal miners in the Migori-Transmara region, as well as the other gold mining areas in Kenya, use mercury in gold recovery processes. During small-scale gold mining, mercury is released to the environment while mixing mercury with finely crushed ore, squeezing the mercury amalgam into a piece of fabric, and burning the amalgam to drive off mercury and recover the gold.

A significant number of the hair samples from women at these three locations had elevated concentrations of mercury. More women from the Osiri/Mikei locations had elevated levels of mercury than in the Masara location; however, all locations reported significant elevated levels.

Nigeria

Lagos State has 22.5% of Nigeria's coastline and occupies an area of 3,577 square kilometers, with 786.94 square kilometers or 22% of the total comprising lagoons and creeks in Lagos, Ikorodu, Badagry and Epe local government areas. Lagos Lagoon empties into the Atlantic via Lagos Harbor, a main channel through the heart of the city, 0.5 km to 1 km wide and 10 km long. The Lagos Lagoon is under consistent and sometimes severe pressure from diverse forms of human activities emanating from the surrounding city centers. It is known that about 80 - 85% of industries in Nigeria are concentrated in Lagos, and the Lagos lagoon is the ultimate recipient of their municipal and industrial waste effluents. The Lagoon receives wastewater from an estimated 2000 major and small industrial users, including industrial and commercial establishments, and domestic sources from both Lagos and Ogun states. On the basis of the available data, the Lagoon is subject to an industrial wastewater pollution load of 6.2 Mt of pollutant per sq. km per annum. Fishing communities in Lagos Lagoon are usually located near water bodies, where most families in the community engage in fishing activities. These fishermen live in communities on the water's edge, their homes on pilings and boats docked beside them. The coastline is dotted with many fishing villages of variable size, according to the number of fishing canoes and number of fishermen. The two locations sampled were fishing communities with high frequency fish diets.

Ilaje fishing community, Bariga, Lagos

Ajido fishing community, Badagry, Lagos (comprising of women from Ajido Fish Sellers Association and Epe-Moba fish traders)

The mean mercury hair concentration for women who provided hair samples from these locations slightly exceeded the 1 ppm threshold at 1.053 ppm ± 0.652 ppm (fw). This is likely to indicate that there is contamination of local fish from Lagos Lagoon. Further research is required to identify which species may have higher body burdens and can therefore be avoided for consumption by the fishing community.

3.1.7 Central and Eastern Europe: Hungary, Albania

Hungary

The city of Kazincbarcika is surrounded by small villages, including some with high population concentrations of disadvantaged Roma. One of the nearby villages is called Sajószentpéter, where Borsches chlor-alkali plant uses sites for waste disposal. Many of those providing hair samples were from the Roma population of Sajószentpéter.

In the past, local NGOs have highlighted that people experience high cancer rates in that area, especially those in the Roma community. The hazardous waste sites are not separated from the village, so children play in the area. Sample results from this location were all below the 1 ppm threshold.

Albania

The community where sampling was conducted is located close to the coast in an area called Vlora Bay, in Vlora city in Albania. The community lives close to the site of a former chemical manufacturing complex of SODA-PVC, including a chlor-alkali plant. It is situated five kilometers north of Vlora city and about 4 km from Narta Lagoon.

Vlora Bay is part of the Adriatic Sea and is located in the southwestern part of Albania. The former chlor-alkali and PVC plant in Vlora is the most significant source of mercury contamination in Vlora Bay.

The plant was closed on 1992, and its buildings have been completely destroyed since that time. During its operation (1976 - 1992), liquid wastes of about 500 m^3/hr containing 1.1 mg/L mercury were discharged directly without any treatment into the sea, and polluted sludge was deposited on an open damp land (25 ha) very near the seashore. The amount of mer-

cury discharged in the environment during 1977 - 1983 was estimated at about 65 tons. Fish and plants from Vlora Bay and surrounding areas have been analyzed and found to have elevated mercury levels attributed to the discharge of the former SODA-PVC plant. Of those women sampled, 23% exceeded the 1 ppm reference level, with one individual exceeding 4.5 ppm. The mean for the entire group exceeded the proposed 0.58 ppm level at a mean level of 0.668 ppm ± 0.865 ppm (fw).

3.1.8 Eastern Europe, Caucasus, Central Asia: Russia, Kazakhstan, Tajikistan, Ukraine

Ukraine

Shostka is a town in Sumy Region located in the northeastern part of Ukraine with a population of 77,800. The town is based in the basin of the Shostka River, a tributary of the Desna river, after which the city was named. Shostka is an important center of chemical industry and includes large coal burning power plants and, until recently, an explosives manufacturing plant converting mercury into an explosive for use in detonators known as mercury fulminate ($C_2N_2O_2Hg$).

The Shostka river belongs to the basin of the Dnieper River. It flows through Yampolsky and Shostka districts of the Sumy Region and its length is 56 km. The river is the home for 12 species of fish, though the number of species is decreasing, as well as the overall fish population. Local people catch fish for their own use and buy it at the local markets. However, fish is not the main food source for people in the city. Hair samples were collected from fishing family members and from those who purchase local fish from the food market. Although the majority of those sampled did not exceed the 1 ppm threshold, a significant number of those sampled had elevated levels, with 20% of the group exceeding the 1 ppm reference level. While 30% of those who participated do not eat fish at all, those that exceeded the 1 ppm reference level ate around 2 fish meals a week. A single exception was an individual who recorded a hair mercury level of 1.89 ppm (the highest in the group), despite not eating fish. When compared to the 0.58 ppm threshold, 50% of those sampled exceeded this level.

Russia

Sampling took place in three locations in Russia, including:

Volgograd city (Volgograd region) – samples were collected in communities of Svetly Yar, Bolshie Chapurniki and Malie Chapurniki.

Krasnodar region – samples were collected in communities of Kholmskaya, Sinegorsk, and Akhtirski.

Klin city communities (near Moscow).

Samples from all three locations in Russia had exceptionally low mercury hair concentrations.

Kazakhstan

Two locations were chosen for sampling in Kazakhstan: Pavlodar (Location A) and Karaganda (Location B).

Location A: Pavlodar

The northern part of Pavlodar city is an industrialized area that included the former Khimprom chemical facility. Khimprom used to be a chlor-alkali production facility using mercury. During its 17 years of operation, about 1200 tonnes of mercury were released. Currently, there are numerous waste disposal ponds and dump sites containing former waste from the chlor-alkali plant, as well as waste and ash from current industrial facilities such as thermal power plants and petrochemical facilities. Pavlodar village is within 4 kilometers of these sites and fish consumption is relatively low. Hair mercury concentrations did not exceed the 1 ppm threshold among any of this cohort, most likely due to low fish consumption. The threshold level of 0.58 ppm was exceeded by 13% of this group.

Location B: Karaganda

In Karaganda oblast (province), citizens of the nearby coastal villages of Chkalovo, Gagarinskoe, Molodetskoe, Rostovka and Berezniaki (tens of thousands of people in total) use Nura River water for irrigation, and engage in fishing in the contaminated river. These communities were selected for sampling based on their elevated fish diet, which is less common in this region.

During the period 1950 - 1997 a large facility for the production of synthetic rubber in Temirtau city discharged significant amounts of mercury into the Nura River and the surrounding area. Mercury-containing waste water was discharged into the Zhaur swamp, which was also used as a dumping site for the bottom ash from the coal power plant. Wastewater was also discharged through the main sewer. Contaminated river sediments were transferred over to the lower parts of the Nura River and over the flood plain.

Every year during the spring, flooding causes mercury contaminated silt on the bottom of the river to be deposited onto low lying meadows on

which local residents graze their livestock and grow crops. Citizens of the nearby coastal villages of Chkalovo, Gagarinskoe, Molodetskoe, Rostovka and Berezniaki are exposed. Multiple exposure pathways for mercury are present for residents along the Nura River who graze animals and consume local fish. Mercury levels were elevated among some residents who took part in sampling, with 19% exceeding the 1 ppm reference level and 31% exceeding the 0.58 ppm level. Widespread contamination of the river and its surroundings are likely responsible for the elevated levels among some residents of this location.

Tajikistan

Sampling was conducted in Somoni District, an urban area of Dushanbe, which is the capital city of Tajikistan. Participants live close to the Varzob River, where some catch fish for personal consumption. There are sources of mercury pollution in the area such as the Dushanbe Thermal Power Plant (TPP), which was commissioned in 2013. The facility uses coal from the Ziddi coal field located in the upper stream of the Varzob River. The old cement production plant is located near the TPP and consumes coal from the same coal mining field. Fish is not a popular part of the diet in Tajikistan and the results of hair sampling did not exceed the 1 ppm threshold among any of the participants.

3.1.9 North America: United States of America (Alaska)

Alaska

Hair sampling in Alaska took place at two locations on St Lawrence Island, which is located in the northern Bering Sea off the northwest coast of Alaska. It is only 40 miles from the Chukotkan Peninsula of Russia. This location was selected because the Arctic has become a hemispheric sink for persistent chemicals that travel hundreds of miles into the region, through a process known as global distillation, and accumulate in the bodies of wildlife and people. This region of the Arctic may also be a deposition zone for mercury and the hair sampling may provide some initial indication as to whether this is occurring via dietary indicators.

St. Lawrence Island is approximately 100 miles long and 20 miles wide at the widest point. It is comprised of volcanic mountains (inactive) as well as wetlands and streams. There are approximately 1600 people who live on the island in two communities—Gambell and Savoonga. They are Yupik people who have relied on traditional foods, including fish and marine mammals, for centuries for their physical, spiritual, and cultural sustenance.

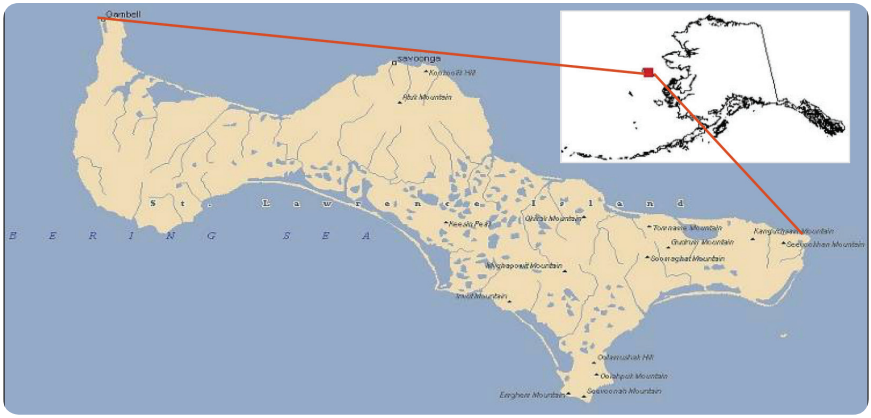


Figure 8. Map of St Lawrence Island noting sampling locations at Gambell and Savoonga.

According to the questionnaire data obtained at the time of sampling, the diet of the women who provided hair samples is dominated by walrus and seal meat (and to a lesser extent, whale meat and blubber). The marine mammals include Pacific walrus (Odobenus rosmarus divergens), ringed seal (Pusa hispida), bearded seal (Erignathus barbatus), spotted seal (Phoca largha), ribbon seal (Histriophoca fasciata), and bowhead whale (Balaena mysticetus). A variety of fish species and marine invertebrates are also eaten, including sockeye salmon (Oncorhynchus nerka), chum salmon (Oncorhynchus keta) and halibut (Hippoglossus stenolepis). In addition, crustacea are also eaten, including clams, tunicates and crab. A significant number of women among the sample cohort exceeded the 1 ppm threshold level (30%) and the 0.58 ppm level (70%). This is discussed in more detail in section 5 due to the unusual influence of marine mammals in the local diet.

4. RESULTS OF SAMPLE ANALYSIS

4.1 HAIR SAMPLE ANALYSIS

The total mercury (THg) concentrations detected in the hair of the participants from around the world varied considerably and were affected by diet, exposure scenarios and engagement in activities such as ASGM or other occupations where mercury vapor exposure is common.

Table 1 below provides the analytical results for hair sampling, including the average for each group, the highest levels recorded, and the percentage of the sampled group that exceeded the 1 ppm reference level and the 0.58 ppm level.

TABLE 1. HAIR SAMPLING RESULTS FOR TOTAL MERCURY (Hg) CONCENTRATION BY LOCATION.

Location	Number of samples	Mean Hg Concentration (ppm)	Number of samples greater than 1 ppm[a]	Percent greater than 1 ppm	Percent greater than 0.58 ppm[b]	Highest Hg level (ppm)
Albania	30	0.668 ± 0.865	7	23	40	4.55
Chile	34	0.687 ± 0.437	6	18	53	2.15
Cook Islands A	30	3.607 ± 1.613	28	93	93	6.96
Cook Islands B	30	3.669 ± 2.197	29	97	100	8.54
Egypt	23	0.294 ± 0.439	1	4	4	2.25
Hungary	35	0.058 ± 0.063	0	0	0	0.37
Indonesia A Sekotong	32	9.405 ± 18.87	30	94	100	90.84

Location	Number of samples	Mean Hg Concentration (ppm)	Number of samples greater than 1 ppm[a]	Percent greater than 1 ppm	Percent greater than 0.58 ppm[b]	Highest Hg level (ppm)
Indonesia B Pongkor, Bogor	35	2.996 ± 1.128	35	100	100	6.18
Kazakhstan A Pavlodar	30	0.33 ± 0.209	0	0	13	0.82
Kazakhstan B Karaganda	32	0.841 ± 1.486	6	19	31	8.21
Kenya A Masara	25	1.274 ± 1.437	11	44	56	6.28
Kenya B Osiri/ Mikei	31	5.26 ± 15.663	20	64	84	81.12
Kiribati	30	3.427 ± 1.272	30	100	100	6.24
Marshall Islands	30	3.258 ± 2.219	29	97	97	11.31
Myanmar	30	2.264 ± 0.993	28	93	100	5.46
Nepal A Jalari fisherfolk	33	0.67 ± 0.243	3	9	61	1.18
Nepal B Kathmandu gilders	20	3.62 ± 12.382	15	75	80	28.46
Nigeria	21	1.053 ± 0.652	9	43	76	2.79
Paraguay A	36	0.31 ± 0.212	0	0	14	0.82
Paraguay B	34	0.346 ± 0.377	3	9	18	1.46
Russia A Volgograd	30	0.014 ± 0.076	0	0	0	0.42
Russia B Krasnodar	30	0.0028 ± 0.011	0	0	0	0.05

Location	Number of samples	Mean Hg Concentration (ppm)	Number of samples greater than 1 ppm[a]	Percent greater than 1 ppm	Percent greater than 0.58 ppm[b]	Highest Hg level (ppm)
Russia C Moscow/Klin	30	0.0028 ± 0.010	0	0	0	0.04
Solomon Islands	29	1.634 ± 0.579	26	90	97	3.12
Tajikistan	31	0.068 ± 0.123	0	0	3	0.70
Thailand A Map Ta Phut	34	4.339 ± 7.608	23	68	97	35.29
Thailand B Tha Tum	34	1.814 ± 1.720	27	79	100	10.09
Tonga	30	3.677 ± 2.573	29	97	97	14.74
Tunisia A Ain el Khadra City	17	0.205 ± 0.155	0	0	6	0.73
Tunisia B Olympic City	20	0.427 ± 0.366	1	5	20	1.70
Tuvalu	30	2 ± 0.649	28	93	97	3.40
Ukraine	35	0.708 ± 0.442	7	20	51	1.91
United States Alaska	33	0.824 ± 0.450	10	30	70	1.90
Uruguay	30	0.117 ± 0.199	1	3	3	1.13
Vanuatu	30	0.717 ± 0.611	6	20	50	2.97

[a] 1 ppm corresponds closely with the U.S. EPA's reference dose (RfD) of 0.1 μg/kg bw/day and a blood mercury concentration of 4 - 5 μg/L

[b] Recent studies conclude that negative developmental effects may occur at even lower levels and that a threshold level of 0.58 ppm should be adopted as the level below which impacts on the developing fetus are negligible.

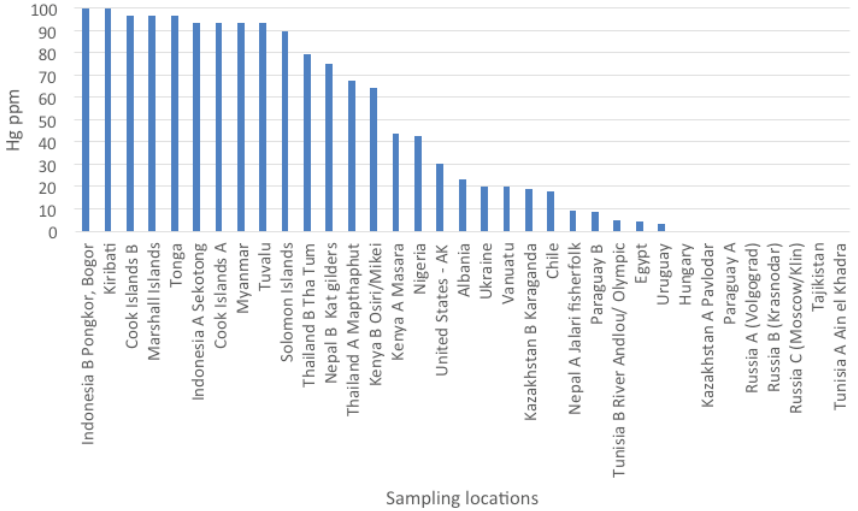


Figure 9. Percentage of global mercury (Hg) hair samples over reference level (1 ppm).

In some cases, several unusually high levels were recorded which may have increased the mean concentrations for the cohort beyond expected levels. This was a particular issue for Indonesia, Thailand and Kenya, and is discussed further in section 5. To illustrate the range of results in each location, the following chart (Figure 10) provides the mean for each location with a single standard deviation. In the case of Indonesia and Kenya, a few extremely high mercury analysis results prevented the standard deviation from being represented graphically on the error bar for standard deviation and have been superimposed on the chart as numbers above the relevant bar.

The broken red horizontal line represents the 1 ppm total mercury (THg) reference level that should not be exceeded by women of childbearing age.

In addition, the broken blue horizontal line (below the red line) indicates the 0.58 ppm total mercury (THg) level suggested by Grandjean et al 2012, as a new threshold level that women of childbearing age should aim to remain below to avoid subtle developmental and cognitive impacts on unborn children. Locations are arranged from left to right in order of descending average concentrations.

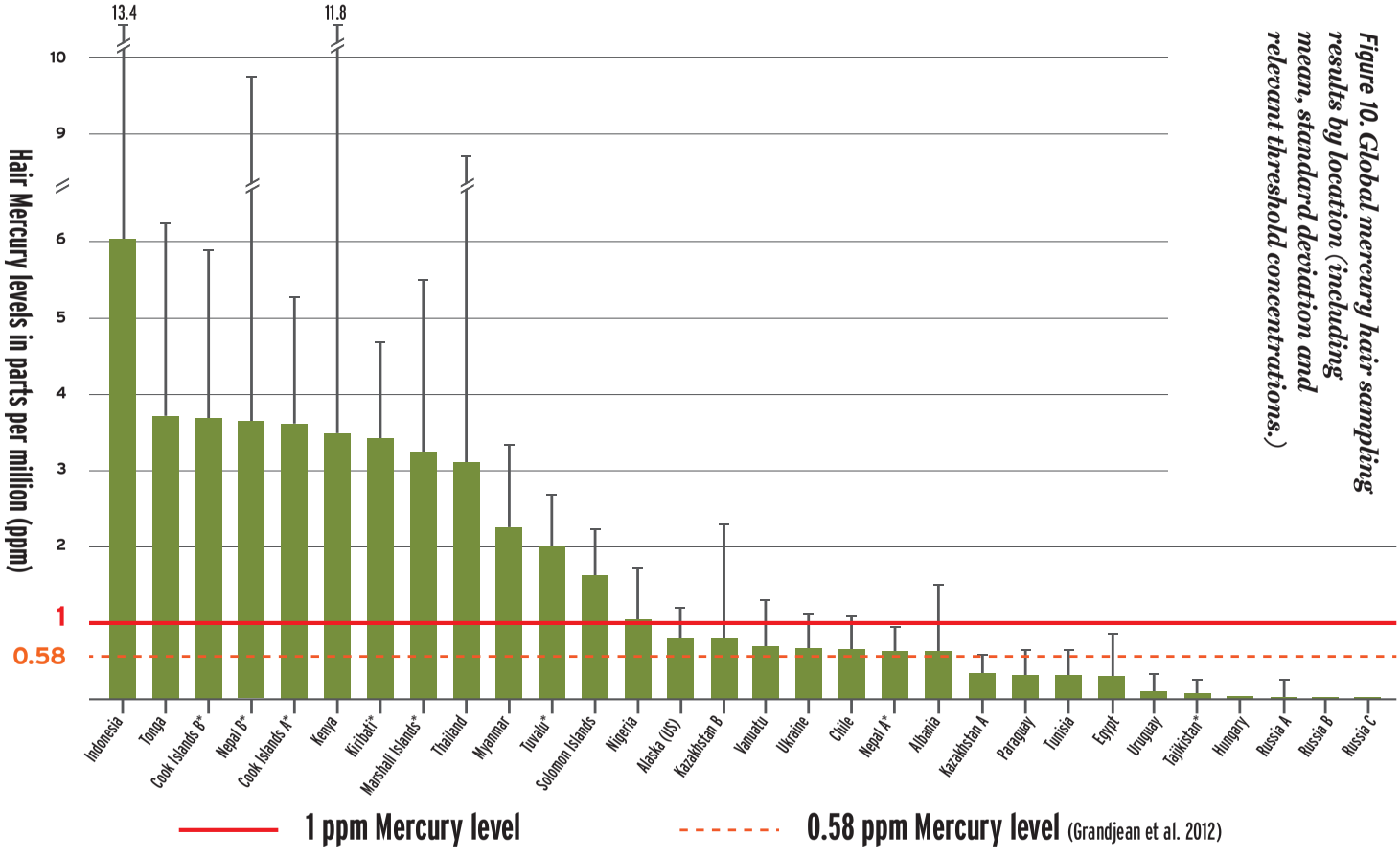


Figure 10. Global mercury hair sampling results by location (including mean, standard deviation and relevant threshold concentrations.)

* Data source: 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.

5. ASSESSMENT AND DISCUSSION

An analysis of the hair sampling results provides indicators to a number of trends and elements of causation for body burden in specific locations, while at the same time raising many additional questions about factors affecting the mercury body burden of women of childbearing age around the globe. Two clear scenarios that are causing an impact on the populations selected for sampling are, firstly, global deposition of mercury to oceans contaminating fish and the humans who eat them, and, secondly, mercury exposure through small-scale gold mining. In the first scenario, which is most relevant to Pacific Islanders, there are no obvious industrial mercury sources that would impact on these populations, but sufficient evidence that their high seafood-based diet is contaminated by methylmercury.

This is a most pronounced trend in the Pacific Islands, but also appears to impact to some degree upon Alaska, where some fish such as pike and large halibut exceed regulatory consumption levels,[27] while the commonly consumed Pacific salmon had very low levels of mercury. However, the two locations in Alaska were unique among all groups sampled in that their diet consisted primarily of marine mammals such as walrus, seal and bowhead whale as well as a variety of fish species and marine invertebrates. Fish such as sockeye salmon and (to a lesser extent) halibut were also eaten, but, according to the questionnaire data, generally only in summer and at a much lower frequency than mammal consumption. Dried fish are eaten by members of the community throughout the year, though the frequency is not available from the questionnaires. The implications are discussed further below.

A second scenario which is a major influence on mercury hair concentrations among women sampled is their involvement in the practice of small-scale gold mining. The exposure is either directly through handling mercury and roasting amalgam or from living in proximity to ball mills (small rotating drums used to finely crush gold bearing ore in combination with elemental mercury to develop amalgam). Very high levels of mercury in hair were found in the sampled groups of women that are associated with small-scale gold mining from Indonesia, Kenya and Myanmar. A small group of samples were so high in mercury, and so far beyond the mean for the group, that it may be the result of direct contamination

27 Jewett, S., and Duffy L., (2007) *Mercury in fishes of Alaska, with emphasis on subsistence species*. Science of the Total Environment 387 (2007) 3–27.

of the outside surface of the hair with elemental mercury from handling the metal during gold production. IPEN and partners BRI will reprocess this small group of samples using more complex analysis to determine if the levels of total mercury reported in the hair of these individuals are an accurate measure of their methylmercury body burden. Nearly all of the very high results were from communities where small-scale gold mining is practiced (with two exceptions from a location in Thailand, which is discussed further below).

In what seems a confirmatory scenario for elevated levels of mercury in the hair of small-scale gold mining workers, a group of women in Nepal also recorded very elevated levels. They are not engaged in small-scale gold mining, but are employed in the gold plating of religious idols for temples and festivals. The technical process of gold plating creates a very similar exposure scenario for the women as for those engaged in small-scale gold mining. The women involved in this activity had significantly elevated mercury levels at an early age. More details on the gold plating process are discussed below.

The two locations in Thailand where sampling occurred raise a number of questions that will require further research and dedicated resources from the government to address a significant health issue. Both sites are impacted by heavy industry known to emit and release mercury. However, other sites sampled also had similar heavy industry in proximity to their communities, but average mercury concentrations were much lower. The reason for the elevated levels may be associated with the canal system and bays around these sites and the consumption of fish from these waterways where mercury methylation is taking place.

What is happening in the Pacific Islands?

A number of distinct trends can be observed in the data from hair sampling for mercury concentrations in women of childbearing age. The most striking result is for the Pacific Island nations, where 90% or more of the women who provided samples had mercury levels elevated above the 1 ppm threshold. For people who are occupationally exposed to mercury such as small-scale gold mining workers or mercury amalgam gold platers, elevated levels are easier to explain due to inhalation of vapors, dermal contact and food contamination with mercury. Pacific Island women have no such exposure to mercury from occupational sources. There are also very few manufacturing or industrial facilities in these countries and certainly no heavy industry that would be associated with mercury emissions such as chlor-alkali plants, coal fired power stations or large cement kilns. However, an examination of the diet of Pacific Island women

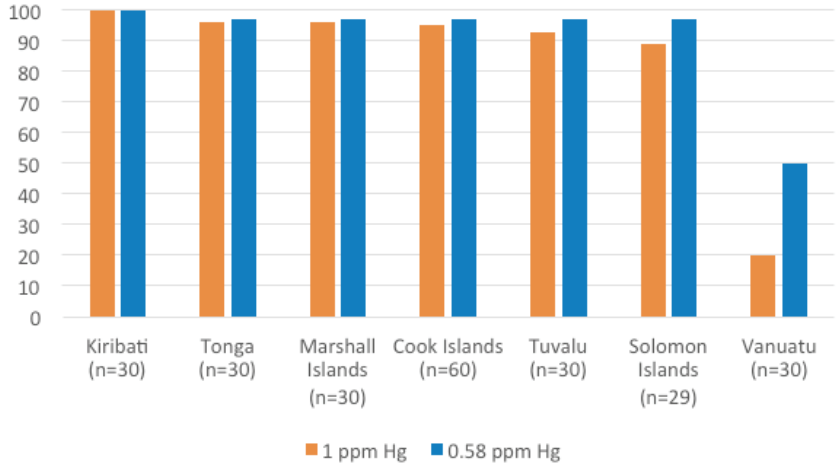


Figure 11. Percentage of Pacific Islander hair samples exceeding the mercury (Hg) 1 ppm reference level and the 0.58ppm level.

provides the strongest link to their mercury body burden. Almost without exception, Pacific Island women have a diet rich in seafood, and particularly predatory fish. Analysis of the questionnaires provided by the women in the Pacific who provided samples confirms a high frequency fish diet and often the species consumed are those high in methylmercury such as swordfish, tuna and shark.

For the Cook Islands, both locations generated results showing 95% of women exceeded the 1 ppm threshold, irrespective of age. For Kiribati, the figure rose even higher, and 100% of the women who provided samples exceeded the 1 ppm threshold. The mean concentration of mercury in hair for Tonga, Cook Islands, Kiribati and Marshall Islands were within a very narrow range, from 3.26 ppm to 3.66 ppm, with Tuvalu and the Solomon Islands somewhat lower at 2 ppm ± 0.65 ppm (fw) and 1.63 ppm ± 0.58 ppm (fw) respectively. The only Pacific nation with markedly different results was Vanuatu, where 20% of participants exceeded the 1 ppm threshold level with a mean of 0.72 ppm ± 0.61 ppm (fw). The lower results appear to be related entirely to the diet of women from Vanuatu who, like other Pacific Island women, have a diet high in fish. The difference between the diet in this country compared to the women from other Pacific Islands is that those from Vanuatu eat mostly canned fish and not wild-caught fish. While the results for Vanuatu are still of great concern, the difference in diet provides an interesting element for comparison with other Pacific Islands.

A study based on commonly consumed fish in Fiji[28] provides more insight into this phenomenon. The study clearly shows a significant difference in the concentration of methylmercury in wild-caught local fish species and locally available canned fish of several varieties.

TABLE 2. MERCURY (Hg) LEVELS (RANGE AND AVERAGE) IN DIFFERENT FRESH FISH AND SHELLFISH FROM THE FIJI ISLANDS WITH LENGTH AND WEIGHT DATA WHERE AVAILABLE.

Seafood Sample	N	Average Length (cm)	Average Weight (kg)	Range [Hg] (mg/kg)	Average [Hg] (mg/kg) ± SD
Albacore Tuna	31	72.7	21.3	0.03 - 1.01	0.34 ± 0.22
Yellowfin Tuna	24	71.3	15.2	< 0.02 - 0.40	0.11 ± 0.11
Skipjack Tuna	12	45.7	2.4	< 0.02 - 0.16	0.06 ± 0.04
Bigeye Tuna	3	103.3	28.3	0.28 - 0.80	0.53 ± 0.21
Marlin	5	167.6	67.4	0.45 - 5.60	1.76 ± 1.94
Reef fish	5	17.2	0.09	< 0.02 - 0.04	0.04 ± 0.01
Barracuda	4	61.25	1.32	0.18 - 0.38	0.26 ± 0.07
Mussels	3	-	-	< 0.02 - 0.04	0.03 ± 0.01
Shellfish	3	-	-	< 0.02 - 0.05	0.03 ± 0.01
Crab meat	3	13.3	-	0.03 - 0.07	0.05 ± 0.02
Parrot fish	2	31 - 35	0.75	< 0.02	< 0.02
Wahoo	1	92	6	0.17	0.17
Goatfish	1	28	0.31	0.03	0.03
Rabbit fish	1	32	0.5	0.15	0.15
Peacock cod	1	33	0.62	< 0.02	< 0.02
Unicorn fish	1	39	1.07	< 0.02	< 0.02
Opah	1	111	65	0.27	0.27

Source Kumar et al. 2004

When compared to the values for canned fish available in Fiji (Table 3), the fresh caught fish are generally significantly higher in methylmercury (Table 2). This is likely due to the fact that smaller fish are used for can-

28 Kumar, M., Aalbersberg, W. G., & Mosley, L. (2004). *Mercury levels in Fijian seafoods and potential health implications*. University of South Pacific. Report prepared for the World Health Organisation.

ning and have not accumulated as high a body burden of mercury as some larger predatory species which are wild-caught and sold at local markets. Notably, the women of Vanuatu that were interviewed ate predominantly canned Skipjack, which has some of the lowest levels of mercury among the species sampled for the Fijian fish study.

TABLE 3. MERCURY (Hg) LEVELS IN CANNED FISH SOLD IN THE FIJI ISLANDS.

Canned Fish Type	N	[Hg] Range (mg/kg)	[Hg] Average mg/kg) ± SD
Canned Albacore	6	0.16 - 0.27	0.20 ± 0.03
Canned Skipjack	9	0.06 - 0.11	0.08 ± 0.02
Canned Tuna in Oil	3	0.05 - 0.16	0.09 ± 0.05
Canned Mackerel	6	0.18 - 0.22	0.21 ± 0.01
Canned Salmon Style Mackerel	6	0.17 - 0.29	0.23 ± 0.05

Source Kumar et al. 2004

The species of fish eaten is one of many dietary factors that may influence mercury body burden among those women sampled. In addition, the age and size of the fish are relevant (older, larger fish accumulate more mercury than smaller, younger ones in most cases), as well as the frequency of fish meals. There are indications from the Pacific Island countries where we sampled that the frequency of consumption of fish meals varies considerably, as does the species consumed. The chart below describes the type of fish eaten and the first and second preference fish of consumers interviewed.

The women of Kiribati, who all exceeded the 1 ppm threshold, also eat a significant amount of canned Skipjack compared to other fish (as do the women of Vanuatu); however, according to the questionnaire data obtained, they also consume an average of 50 fish meals a month, with a greater diversity of wild-caught fish than those consumed in Kiribati. The women of Vanuatu eat fish 18.5 times a month (less than half that of Kiribati), indicating that both the type of fish and frequency of consumption may be factors in the much lower mercury levels among Vanuatu women in this sampling study.

There is clearly a need for further investigation into influence of fish diet on mercury body burden among women of the Pacific Islands. As the primary protein source in many Pacific Island nations, fish are a central

part of local diets. It is important to be able to give advice to Pacific Island women as to which type of fish they should eat and at what frequency to reduce their exposure to methylmercury. Ultimately, the level of mercury in fish may decline with control measures to reduce the trade, use and release of mercury incorporated in global legal instruments such as the Minamata Convention on Mercury, which entered into force in August 2017. However, such reductions will take time, possibly many decades, and the women of the Pacific Islands require urgent mitigation measures now to reduce their mercury body burden.

Unlike many other countries, Pacific Island countries do not have the ability to exert direct control over the mercury sources that are contaminating their food supply. Most Pacific Island nations do not have the coal fired power plants, metallurgy plants, large waste incinerators or small-scale gold mining activity that contribute large volumes of mercury to the atmosphere and then to oceans where it is methylated and bioaccumulates in fish. They must rely on the international community to act for the long term, but must take mitigation measures in the short term to protect their communities and future generations. That is why there is a clear need for detailed, locally relevant dietary information about seafood and mercury risks to be developed and distributed as soon as possible among Pacific Island nations.

Small-scale gold mining: creating localized mercury poisoning while posing a global threat

The second notable feature of the hair sampling results was the elevated levels among small-scale gold mining workers and their immediate families. Due to the nature of the gold processing, mercury amalgam may often be roasted with blow torches to drive off the mercury in vapor form close to households or even in the kitchen. This has the potential to cause mercury intoxication by vapor inhalation among the workers (which may be male or female), their spouses and children. In locations where sampling was conducted in Indonesia, there have been numerous reports of birth defects and people displaying symptoms of mercury intoxication similar to that of Minamata Disease,[29] which emerged in Japan in the 1950s as a result of mercury waste dumping by the Chisso Corporation in Minamata Bay.

Congenital defects and developmental problems associated with mercury in the offspring of intoxicated adults has also been observed. Mercury contaminated waste from processing of gold bearing ore is often dumped

29 Harada, M., (1995) *Minamata disease: methylmercury poisoning in Japan caused by environmental pollution*. Crit Rev Toxicol. 1995;25(1):1-24.

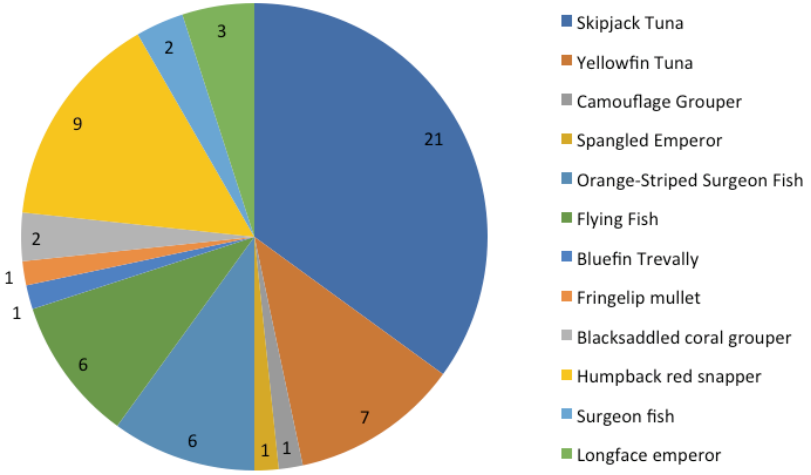


Figure 12. First and second preference fish consumed by participants in Kiribati (50 meals per month).

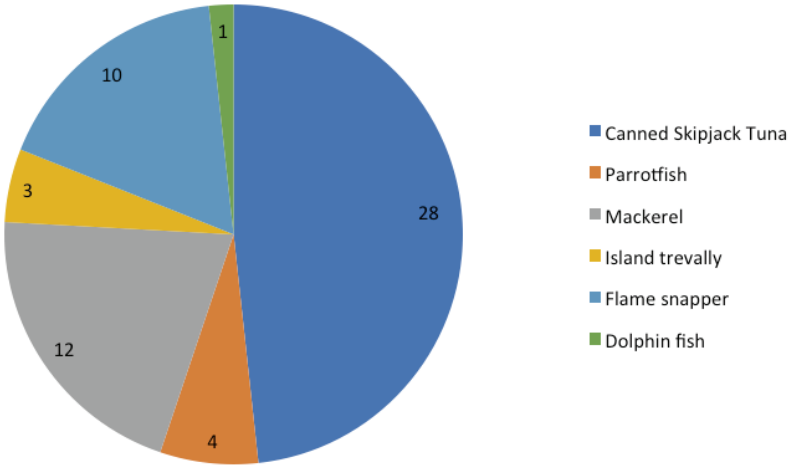


Figure 13. Species of fish consumed among Vanuatu sampling group (18.5 meals per month).

Figure 14. Baby and children with birth defects in gold mining communities in Indonesia. *(top) Larry C. Price/Pulitzer Centre on Crisis Reporting / (bottom): BaliFokus, Indonesia*

near or in waterways that contribute to local food production—especially fish but also rice paddies. Recent studies have indicated that rice can also be contaminated by mercury.[30] This localised contamination continues the cycle of contamination, causing impacts both from vapor inhalation

30 Rothenberg, S., Windham-Myers, L., Creswell, J., (2014) *Rice methylmercury exposure and mitigation: A comprehensive review*, Environmental Research Volume 133, August 2014, Pages 407-423.

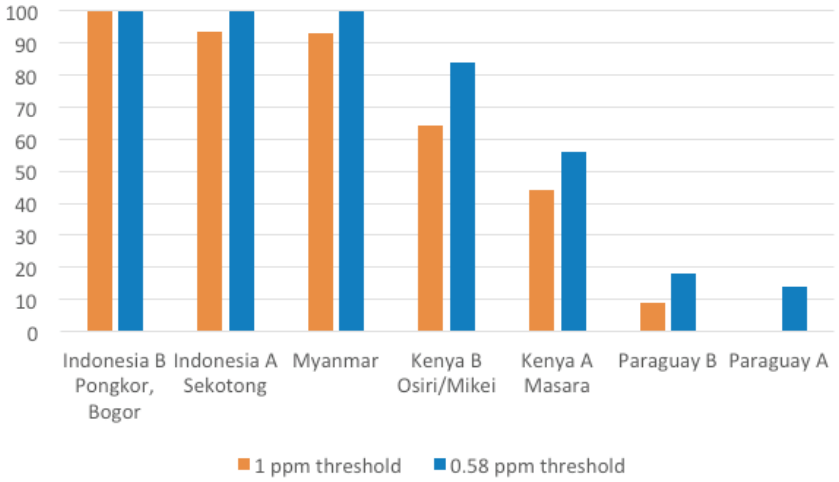


Figure 15. Percentage of small-scale gold mining related hair samples exceeding the mercury (Hg) reference level of 1ppm and the 0.58 ppm level.

and, in cases where local fish are consumed, also through methylmercury transfer via fish, creating a double impact on small-scale gold miners and their families.

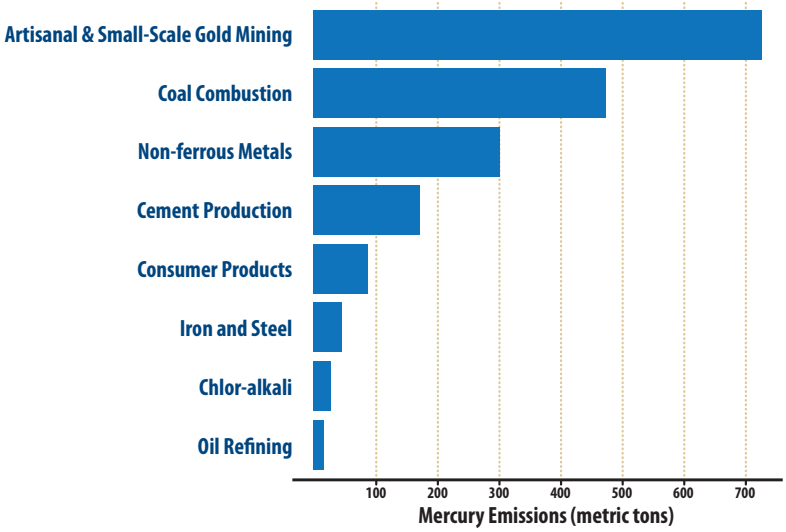
Small-scale gold mining activity is particularly intense in some parts of Southeast Asia, Latin America and Africa, with up to 20 million people worldwide engaged in this activity in some form or other. There was significant variability among the results from different small-scale gold mining locations; however, in most cases there were significant numbers of women who exceeded the reference level. Paraguay was an exception in this case.

The frequently communal practices used in small-scale gold mining result in exposure of both children and adults to mercury. Awareness of its toxicity varies considerably, resulting in many workers handling mercury without any form of protection.

The widespread use of mercury in small-scale gold mining contributes a similar atmospheric load to atmosphere as industrial sources such as coal fired power stations. As the use of mercury in gold production is reduced by mercury treaty obligations, the contribution of coal fired power stations will emerge as the most significant airborne source of mercury pollution globally (see Figure 17 below).

Figure 16. In many parts of the world babies and young children remain close to mothers throughout the day. Here women use mercury in an ASGM site in Kenya. *CEJAD, Kenya*

Figure 17. Global sources of mercury emissions to air.



Paraguay – low but significant mercury levels despite small-scale gold mining

Of all the sites where participants in the hair sampling were engaged in small-scale gold mining, Paraguay showed the lowest levels of mercury contamination in women's hair. In the two locations where sampling occurred, Paso Yobai – Coronel Cubas and Paso Yobai – Vega Cue, only a small number of participants exceeded the 1 ppm Hg threshold and these were in the Coronel Cubas location. Unlike other locations where ASGM was practiced (Indonesia, Myanmar and Kenya), the levels of fish eaten in Paraguay were very low.

In the Vega Cue location, the majority of participants did not eat fish at all, while in Coronel Cubas the average monthly fish consumption was around 4 meals. More information is required about the processing of gold ore in these locations to assess whether work practices such as only men processing amalgam or remote amalgam processing takes place. This may reduce the exposure of these women to metallic mercury vapor inhalation, resulting in lower mercury hair levels than other small-scale gold mining locations. While the levels were low compared to other small-scale gold mining locations, there was still a significant detection of mercury, with up to 18% of participants exceeding the 0.58 ppm level.

Fire gilding in Nepal – a severe occupational hazard

This ancient process of "fire gilding"—used as early as 2000 years ago—was used to impart a thin gold plating to lower-value metals by mixing a blend of gold powder with elemental mercury and applying the paste to the object. The object would then be "fired" by placing it in a fire or extremely hot oven or kiln where the mercury vaporized, leaving a bright gold plating on the object. Very few accounts of modern day practice of this technique exist, and even fewer describe the health impacts.[31] In any event, the use of flame or ovens to drive off the mercury in a vapor form creates a similar scenario to that of small-scale gold mining workers burning mercury off the amalgam to leave a gold residue and creating inhalable mercury vapor.

The exposure to workers is primarily metallic vapor inhalation, but perhaps also dermal absorption through direct handling of mercury in the workplace. It should also be acknowledged that exposed elemental mercury releases vapor at room temperature without additional heat sources, so those involved with handling mercury may not necessarily have to make contact with it to inhale hazardous volumes of mercury vapor. Urgent in-

31 Vahabzadeh M, Balali-Mood M. (2016) *Occupational metallic mercury poisoning in gilders*. Int J. Occup Environ Med 2016: 7-122.

Figure 18. Gold plating worker mixes mercury and gold dust. *CEPHED, Nepal*

Figure 19. Fire gilder drives off mercury from coating paste to leave gold plate. *CEPHED, Nepal*

tervention is required to ensure that safe workplace standards for fire gilders are implemented and that emissions to air and releases to water are characterized and eliminated. The location where this work is conducted

should also be subject to investigation as a suspected contaminated site. The workers involved in this sampling study and their colleagues in this workplace should be assessed by health professionals and offered treatment.

Industry/ mixed sources

Thailand: Tha Tum and Map Ta Phut

The results from hair samples of women in the two locations in Thailand—Tha Tum and Map Ta Phut—are significantly elevated. The results varied widely within both groups, as is shown on the standard deviation for both groups in Figure 10. Some very high results for a few individuals in Map Ta Phut (>35 ppm) and Tha Tum (>10 ppm) elevated the cohort mean to some extent (4.34 ppm ± 7.6 ppm (fw) and 1.81 ppm ± 1.72 ppm (fw) respectively); however, in both locations the majority of participants exceeded the 1 ppm threshold. In Tha Tum 79% of participants had mercury hair levels above 1 ppm and in Map Ta Phut 67% exceeded the threshold, irrespective of the few individuals with very high results. When compared to the 0.58 ppm level, 97% of Map Tha Phut women and 100% from Tha Tum exceeded the level.

This raises some questions as to the source of the mercury exposure and the exposure pathway(s). Where sampling occurred in the Pacific Islands, the absence of local mercury pollution sources, a high fish diet, and numerous studies reporting elevated methylmercury in those preferred fish species for consumption creates a strong case for food chain contamination as the most significant contributor to elevated levels in the Pacific Island women. Similarly, the elevated levels of mercury in women engaged in small-scale gold mining activity (and the fire gilders of Nepal) appear to be consistent with inhalation of mercury vapor and secondary impacts from contamination of local fish supplies in some cases. However, for both Thailand locations the exposure pathways may be more complex, with multiple potential mercury pollution sources to atmosphere, land and waterways. This is further complicated by the consumption of fish in these locations. According to data from the questionnaires administered to participants, local people in Tha Tum and Map Ta Phut communities have a diet rich in fish and with a great deal of diversity. Figures 20 and 23 indicate the type of fish eaten by local women and the number of women who chose each species as their first and second preference for consumption.

In Map Ta Phut the levels of mercury among all the species of fish consumed are not available, however there is some data that indicates that

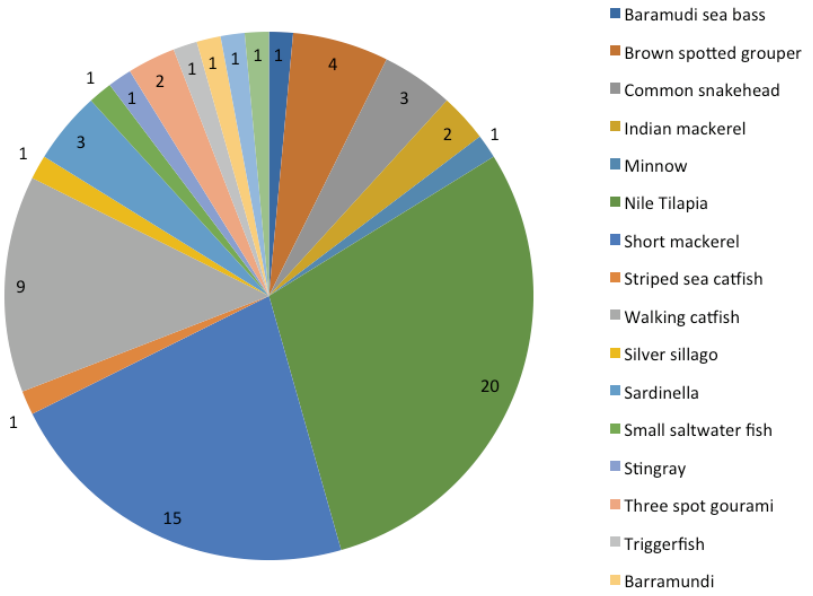


Figure 20. Map Ta Phut first and second preference fish species for consumption, average 6 fish meals per month.

mercury levels are elevated in the sediments around the gas production platforms near Map Ta Phut petro-chemical complex[32] (mercury levels in the water average roughly 60 parts per trillion (ppt), which is less than the Thai standard of 100 ppt but well over the world average of 10 ppt for mercury in coastal water). Other studies note that significant quantities of mercury had been discharged by industry into the coastal zone around Map Ta Phut during the mid-1990s.[33]

Mercury levels in sediment around Map Ta Phut were also relatively high compared to other coastal areas of Thailand (<0.005 - 0.134 µg-1 dry weight mercury). Thongra-ar and Parkpian (2002) concluded that mercury contamination of sediment in the upper Thai gulf areas such as Map Ta Phut are due to "discharges from industries, natural gas platforms, agriculture and untreated domestic sewage," yet concluded that they were still within 'safe' levels despite some fish exceeding Thai standards for consumption. Fish, crabs and mollusc have been sampled close to Map Ta

32 Chongprasith P and Wilairatanadilok W. (1999) *Are Thai waters really contaminated with mercury?* Thailand Pollution Control Department 1998.

33 Thongra-ar, W., and Parkpian, P (2002) *Total Mercury Concentrations in Coastal Areas of Thailand: A Review*. ScienceAsia 28 (2002) : 301-312.

Phut and the range of mercury spanned 0.029 - 1.04 ppm mercury.[34] According to the US EPA Fish Consumption Guidelines, eating some of the fish around Map Ta Phut should be restricted to weekly or monthly consumption and those exceeding 0.95 ppm mercury concentrations should not be eaten at all.

TABLE 4. FISH CONSUMPTION GUIDELINES FOR METHYLMERCURY BASED ON THE U.S. EPA REFERENCE DOSE

Fish Methylmercury Concentrations (ppm/ww)	Recommended Consumption
< 0.05	Unrestricted
> 0.05 - 0.11	2 meals/week
> 0.11 - 0.22	1 meals/week
> 0.22 - 0.95	1 meals/week
> 0.95	No consumption

In addition to environmental and biota sampling, a recent study that took blood samples of schoolchildren in coastal areas of Thailand near industrial estates found that most children had levels of mercury within acceptable thresholds.[35] However, the study authors noted that, "67 subjects exceeding the lowest standard were observed in this study. The two sites close to the industrial zone of MTPIE (Map Ta Phut Industrial Estate) showed highest total Hg-B concentrations in schoolchildren." The combination of mercury contaminated sediment, seawater, and elevated levels of mercury in some fish combined with the significant and diverse fish diet of locals suggest that elevated mercury in women around Map Ta Phut is mainly due to food chain contamination from local industrial sources.

Tha Thum

The women who participated in sampling in the second Thai location are residents around the Prachinburi Province's largest industrial complex, located 120 km to the East-northeast from Bangkok, and 5.5 km south from the Prachinburi River. The complex includes large coal fired power stations and a pulp and paper mill. Coal fired power stations are known to emit particulate bound mercury while pulp mills use phenyl mercury

34 Chongprasith P and Wilairatanadilok W. (1999) Are Thai waters really contaminated with mercury? Thailand Pollution Control Department 1998

35 Teeyapant P, Leudang S, Parnmen S. A cross-sectional study of exposure to mercury in schoolchildren living near the eastern seaboard industrial estate of Thailand. WHO South-East Asia J Public Health 2015; 4(1): 45–53.

Figure 21. Fishing in the Shalongwaeng Canal. *EARTH, Thailand*

Figure 22. Tha Tum coal fired power plant *(below left)* ***and wastewater treatment pond for the paper and pulp mill*** *(below right)****.*** *EARTH, Thailand*

acetate as an anti-fungal agent, which may then contaminate plant wastewaters[36] that are discharged to the canals and holding ponds in the area. Many local people fish from the canals as an essential contribution to their diet, and fish consumption is relatively high among a diversity of species as can be seen in Figure 23.

36 Beim, A. M. and E. I. Grosheva (1992). "Ecological chemistry of mercury contained in bleached kraft pulp mill effluents." Water, Air, & Soil Pollution 65(1): 135-141.

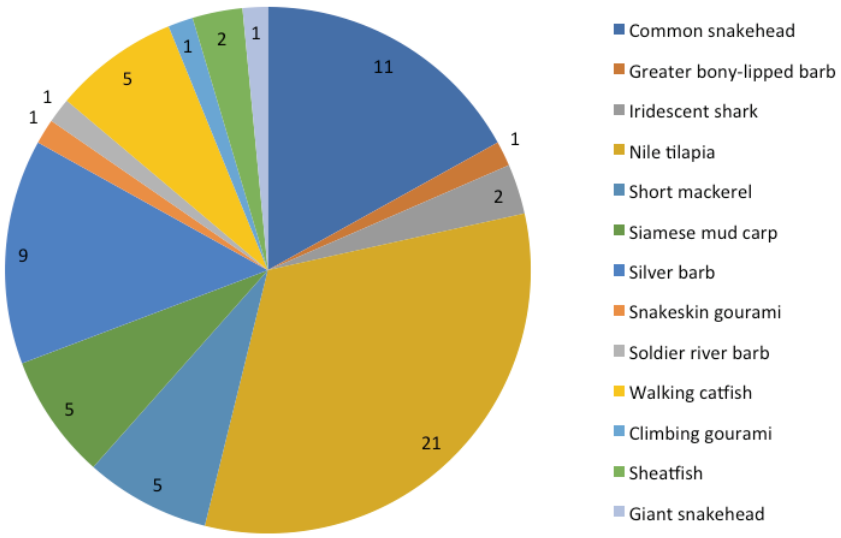


Figure 23. Tha Tum first and second preference fish species for consumption Average 4.5 fish meals per month.

Previous sampling of fish by IPEN[37] around the Tha Tum locality revealed that 85% of the common snakehead fish (Channa striata) sampled exceeded the reference dose of 0.22 ppm.[38] As can be seen in Figure 20, snakehead fish make up a significant fraction of the fish consumed locally. The 2013 IPEN study also sampled hair of some local community members and the average concentration was 4.5 times higher than the U.S. EPA reference level of 1 ppm. Mercury levels tended to be higher among people who were older (due to accumulation), and also among those who consumed higher levels of fish. There is clearly a need to conduct sampling of other fish species in this location to ascertain if the diverse fish-based diet of local residents is contributing to elevated mercury levels in hair. In addition, such research may help provide these communities with better advice as to which fish should be avoided due to high mercury levels or to the levels at which they may be consumed without harm.

37 IPEN (2013) Coal-fired power plant and pulp and paper mill site: Tha Tum Mercury Hot Spot in Thailand, Prepared by Ecological Alert and Recovery Thailand – EARTH (Thailand), Arnika Association (Czech Republic) and the IPEN Heavy Metals Working Group.

38 Figure derived from the reference dose used as U.S. EPA consumption guidelines for fish (0.2 mg.kg-1 methylmercury) based on the presumption that methylmercury counts for 90% of THg levels, limit value used by Canada is similar. Japan and/or UK use 0.3 ppm as a reference dose. Source: US EPA (2001). Water Quality Criterion for the Protection of Human Health: Methylmercury. Final. EPA-823-R-01-001, Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency Washington, DC: 303.

Figure 24. Alaskan Walrus. *Anderson, Santa Barbara City College, USA*

In the current study, the group mean for mercury in hair was 1.81 ppm ± 1.72 ppm (fw) and more than 96% of those providing samples exceeded the 1 ppm reference level. The highest level recorded was just over 10 ppm. The lower mean does not necessarily suggest environmental contamination has fallen since the 2013 sampling activity, but may be associated with local knowledge that the fish are contaminated and the community is hence reducing their consumption of them where possible. Notably, the participant with the highest mercury concentration in the 2013 sampling was not the oldest, but a person eating the common snakehead fish very often. It was also observed that the size of snakefish did not correlate with their mercury contamination levels, making it impossible to advise local people to consume smaller fish (which generally have lower mercury levels) rather than larger fish of the same species.

There clearly remains a significant mercury contamination problem in the waterways around Tha Tum that is leading to contamination of the aquatic food chain and resulting in elevated mercury levels in the hair of local women. Industrial sources of mercury pollution such as coal fired power plants and pulp production should be assessed for their contribution to this mercury hotspot and regulated in such a way as to prevent further contamination from occurring.

Alaska: Savoonga and Gambell

The results of hair sampling from the communities of Savoonga and Gambell in St Lawrence Island, Alaska revealed that consumption of sea mam-

mals—specifically seals—may be a significant source of dietary mercury. While the mean level of mercury in hair for the group was below 1 ppm (0.82 ppm ± 0.45 ppm (fw), 30% of the women who provided samples exceeded the 1 ppm reference level and 70% exceeded the proposed threshold of 0.58 ppm. This is of particular interest due to the diet of these women. Fish are eaten, but, for those women who provided questionnaire data, generally only during the three summer months, although some dried and fresh fish is also consumed throughout the year. In addition, the sockeye salmon and other commonly eaten Alaskan fish species are reported to have low levels of mercury.[39] Large halibut can have excessive mercury levels and Alaskan government fish advisories[40] indicate elevated levels of mercury in halibut exceeding 40 pounds. When fish are eaten by the women who participated in this study, the frequency of fish meals is much less than that of marine mammals, which make up the bulk of the local diet. It appears that the low frequency of the fish diet in non-summer months, dominated by fish of low mercury concentrations, is unlikely to account for the elevated mercury levels in women's hair.

The marine mammals commonly consumed are primarily pacific walrus (Odobenus rosmarus divergens), a variety of seals and Bowhead whale (Balaena mysticetus) meat or blubber. The bowhead whale has particular spiritual and cultural significance to the Yupik people of St Lawrence Island and it is possible that one or more species of these mammals may be a source of dietary mercury contamination.

While studies have been conducted to assess the levels of mercury in marine mammals in Arctic waters, walrus does not feature as a species of concern. However, many seal species have been found to exhibit relatively high mercury concentrations in their meat. This includes the species commonly eaten by the women of St Lawrence Island. The mean concentration of mercury in these seal species exceeds the U.S. EPA mercury consumption guideline of 0.3 ppm Hg/wet weight[41] (see Figure 25 below).

Taking into account the low mercury levels in commonly eaten fish species and walrus, the elevated mercury levels in seals are most likely to be the source of elevated mercury levels among some women in the St Lawrence Island communities. Organ tissues such as liver and kidney tissues

39 State of Alaska (SOA). Bulletin No. 6, June 15, 2001. Mercury and National Fish Advisories Statement from Alaska Division of Public Health: Recommendations for Fish Consumption in Alaska.

40 Hamade, A. (2014) *A Risk Management Strategy to Optimize the Public's Health*. Alaska Scientific Advisory Committee for Fish Consumption Section of Epidemiology. Division of Public Health Department of Health and Social Services. State of Alaska.

41 Evers, D.C., Buck, D.G., Dalton, A.K., Johnson, S.M. 2016. *Mercury in the Global Environment: Marine Mammals*. Biodiversity Research Institute. Portland, Maine. BRI Science Communications Series 2016-03. 8 pages.

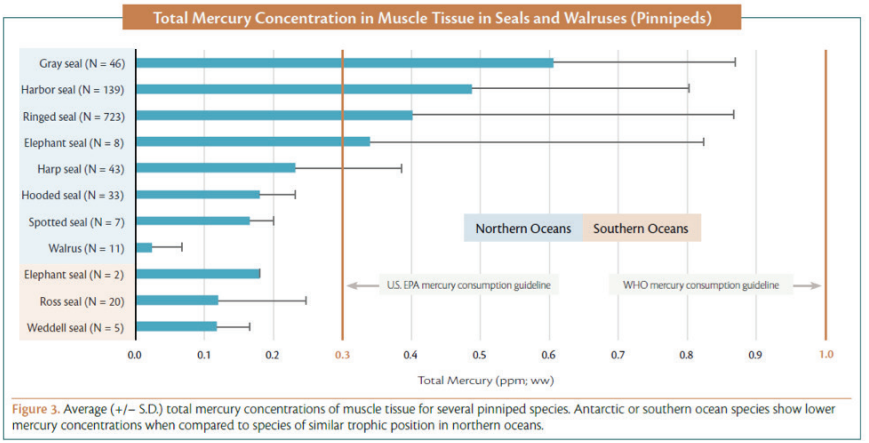


Figure 25. Mercury concentrations in Pinnipeds of the polar regions. *Evers et al. 2016*

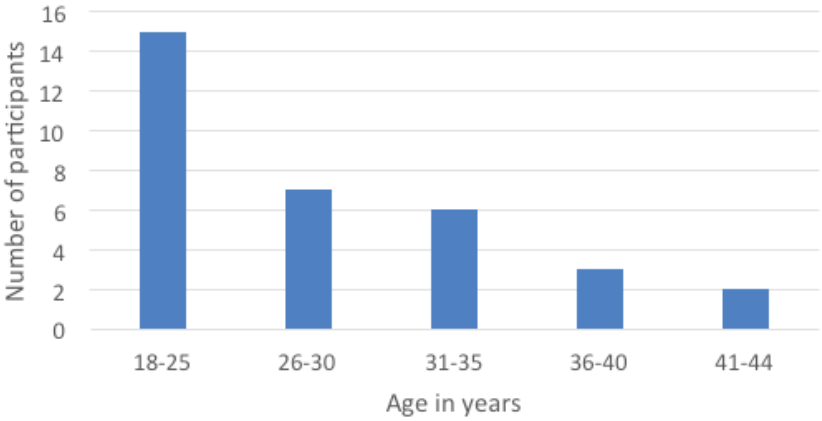


Figure 26. Female Alaskan sampling participants by age group (n-33).

may contain higher levels of mercury than muscle tissue,[42] and should be analysed in detail to determine if they contribute mercury to the diet of the Yupik people and, if so, to what extent. Further research should be conducted on the specific marine mammals consumed by the St Lawrence

42 Welfinger-Smith, G., Minholz, J., Byrne, S., Waghiyi, V., Gologergen, J., Kava, J., Apatiki, M., Ungott, E., Miller, P., Arnason, J., and Carpenter, D., (2011) *Organochlorine and Metal Contaminants in traditional Foods from St. Lawrence Island, Alaska*, Journal of Toxicology and Environmental Health, Part A. 74:18, 1195-1214.

Island communities to confirm if seals may be the major source of dietary mercury in this location.

An opportunistic analysis of the age-related data for women sampled in Alaska also points to mercury accumulation trending upward with age, suggesting that long term exposure to contaminated food sources is resulting in increased body burden over time. However, there was no attempt made to balance the sampling cohort according to age ranges (e.g. there were 15 women in the 18 - 25 age bracket and only 2 in the 40 - 44 age bracket), so the results are indicative only and would require a much larger study with balanced groupings to confirm this trend.

When the mean concentrations of mercury by age bracket are assessed, there is a strong indication of increasing levels as the participants age. However, this may be affected by the frequency of consumption of mercury-impacted mammals and fish by an individual. The questionnaires showed that the frequency of marine mammal consumption was very similar between all women in Savoonga and Gambell. This is not unusual given that the community shares the catch of walrus, seal, whale or fish (arising from traditional hunting activity), and other food sources are limited in availability.

To conclude, more research is required to determine which elements of the food sources of inhabitants of St Lawrence Island are impacted by mercury and to what degree. This may require specific sampling of those seal species that are eaten on St Lawrence Island as well as other marine mammals consumed to determine if specific organs that are consumed

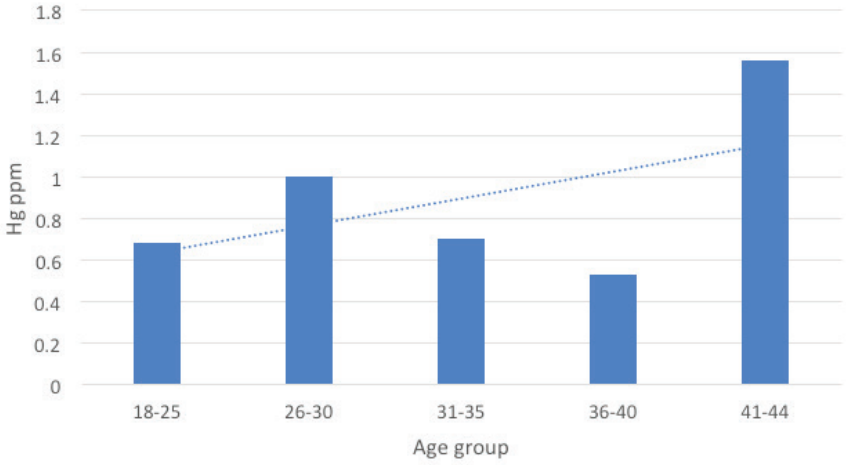


Figure 27. Hair mercury (Hg) trends by age bracket: Alaska (mean).

(liver, kidneys, etc.) contain elevated mercury levels and may be contributing to mercury exposure. While many respondents from St Lawrence island indicated that they only ate fish in summer, other information suggests that dried fish may be consumed by many members of the community throughout the year and this should also be assessed for mercury concentrations and exposure contribution.

REFERENCES

Beim, A. M. and E. I. Grosheva (1992). "Ecological chemistry of mercury contained in bleached kraft pulp mill effluents." Water, Air, & Soil Pollution 65(1): 135-141.

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 the International POPs Elimination Network. April 2017. Berkeley California.

Bose-O'Reilly, S., et al (2010) *Mercury exposure and children's health*. Curr Probl Pediatr Adolesc Health Care, 2010 Sep; 40(8):186-215.

Burger, J., and Gochfeld, M. (2004) *Mercury in canned tuna: white versus light and temporal variation*. Environ Res. 2004 Nov;96(3):239-49.

Chen, C.Y., Driscoll, C.T., Lambert, K.F., Mason, R.P., Rardin, L.R., Schmitt, C.V., Serrel, N.S. and Sunderland, E.M. 2012. *Sources to Seafood: Mercury pollution in the marine environment*. Hanover, NH: Toxic Metals Superfund Research Program, Dartmouth College.

Chongprasith P and Wilairatanadilok W (1999) *Are Thai waters really contaminated with mercury?* In: ASEAN Marine Environmental Management: Towards Sustainable Development and Integrated Management of the Marine Environment in ASEAN. Proceedings of the Fourth ASEAN-Canada Technical Conference on Marine Science (26-30 October 1998), Langkawi, Malaysia (Edited by Watson I, Vigers G, Ong KS, McPherson C, Millson N, Tang A and Gass D), pp 11-26. EVS Environment Consultants, North Vancouver and Department of Fisheries, Malaysia

Davidson PW, Myers GJ, Cox C, Axtell C, Shamlaye C, Sloane-Reeves J, (1998) *Effects of prenatal and postnatal methylmercury exposure form fish consumption on neurodevelopment: outcomes at 66 months of age in the Seychelles Child Development Study*. JAMA. 1998; 280:701-707. [PubMed])

Euy Hyuk Kim, In Kyu Kim, Ja Young Kwon, Sang Wun Kim, and Yong Won Park (2006) *The Effect of Fish Consumption on Blood Mercury Levels of Pregnant Women*. Yonsei Med J. 2006 Oct 31; 47(5): 626-6330

Evers, D.C., Mason, R.P., Kamman, N.C., Chen, C.Y., Bogomolni, A.L., Taylor, D.H., Hammerschmidt, C.R., Jones, S.H., Burgess, N.M., Munney, K. and Parsons, K.C. (2008). *An integrated mercury monitoring program for temperate estuarine and marine ecosystems on the North American Atlantic Coast*. EcoHealth 5:426-441.

Evers, D.C., Turnquist, M.A. and Buck, D.G. (2012) *Patterns of global seafood mercury concentrations and their relationship with human health*. Biodiversity Research Institute. Gorham, Maine. BRI Science Communications Series 2012-45. 16 pages.

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. 20 pages.

Evers, D.C., Buck, D.G., Dalton, A.K., Johnson, S.M. (2016) *Mercury in the Global Environment: Marine Mammals*. Biodiversity Research Institute. Portland, Maine. BRI Science Communications Series 2016-03. 8 pages.

Giumlia-Mair et al (2014) *Mercury Gilding in Today's Japan: An Amalgam of Old and New*. ISIJ International Vol. 54(2014)No. 5p. 1106-1110

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

Grandjean, P., et al (2010) *Adverse Effects of Methylmercury: Environmental Health Research Implications*. Environmental Health Perspectives, Vol 118. No.8. August 2010, 1137-1145

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

Hamade, A. (2014) *A Risk Management Strategy To Optimize the Public's Health*. Alaska Scientific Advisory Committee for Fish Consumption Section of Epidemiology. Division of Public Health Department of Health and Social Services. State of Alaska.

Harada, M., (1995) *Minamata disease: methylmercury poisoning in Japan caused by environmental pollution*. Crit Rev Toxicol. 1995;25(1):1-24.

IPEN (2013) *Coal-fired power plant and pulp and paper mill site: Tha Tum Mercury Hot Spot in Thailand*, Prepared by Ecological Alert and Recovery Thailand – EARTH (Thailand), Arnika Association (Czech Republic) and the IPEN Heavy Metals Working Group

Jewett, S., and Duffy L., (2007) *Mercury in fishes of Alaska, with emphasis on subsistence species*. Science of the Total Environment 387 (2007) 3-27

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.

Karimi, R., Fitzgerald, T.P. and Fisher, N.S. (2012). *A quantitative synthesis of mercury in commercial seafood and implications for exposure in the U.S.* Environ. Health Perspectives. http://dx.doi.org/10.1289/ehp.1205122.

Kim, J.H., Park, J.M., Lee, S.B., Pudasainee, D. and Seo, Y.C. (2010). *Anthropogenic mercury emission inventory with emission factors and total emission in Korea*. Atmospheric Environment 44:2714-2721.

Kumar, M., Aalbersberg, W. G., & Mosley, L. (2004). *Mercury levels in Fijian seafoods and potential health implications*. University of South Pacific. Report prepared for the World Health Organisation.

Lambert, K.F., Evers, D.C., Warner, K.A., King, S.L. and Selin, S.E. (2012). *Integrating mercury science and policy in the marine context: Challenges and opportunities*. Environmental Research, http://dx.doi.org/10.1016/j.envres.2012.06.002.

Mankolli, H., Proko, V. and Lika, M. (2008). *Evaluation of mercury in the Vlora Gulf Albania and impacts on the environment*. J. Int. Environmental Application Science 3:258-264.

Mason, R.P., Choi, A.L., Fitzgerald, W.F., Hammerschmidt, C.R., Lamborg, H., Soerensen, A.L. and Sunderland, E.M. (2012). *Mercury biogeochemical cycling in the ocean and policy implications*. Environmental Research 119:101-117.

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.

Pacyna, E.G., Pacyna, J.M., Sundseth, K., Munthe, J., Kindblom, K., Wilson, S., Steenhuisen, F. and Maxon, P. (2010). *Global emissions of mercury to the atmosphere from anthropogenic sources in 2005 and projections to 2020*. Atmospheric Environment 44:2487-2499.

Rothenberg, S., Windham-Myers, L., Creswell, J., (2014) *Rice methylmercury exposure and mitigation: A comprehensive review*. Environmental Research Volume 133, August 2014, Pages 407-423.

Serikawa Y., Inoue T., Kawakami T., Cyio B., Nur I. and Elvince R. (2011). *Emission and dispersion of gaseous mercury from artisanal and small-scale gold mining plants in the Poboya Area of Palu City, Central Sulawesi, Indonesia*. Toyama Prefectural University.

Silbernagle, et al, (2011) *Recognizing and Preventing overexposure to Methylmercury from Fish and Seafood Consumption: Information for Physicians*. J Toxicology 2011;2011 983072.

Smith, A.C., Mackay A.W., Shacks, V.A. (2014) *Mercury contamination of the Nile Crocodile (Crocodylus niloticus) in the Okavango Delta, Botswana: A Baseline for the Assessment of Future Threats*. Final report to the Rufford Small Grants Foundation (May 2014).

Soerensen, A.L., Sunderland, E.M., Holmes, C.D., Jacob, D.J., Yantosca, R.M., Skov, H., Christensen, J.H., Strode, S.A. and Mason, R.P. (2010). *An improved global model for air-sea exchange of mercury: High concentrations over the North Atlantic*. Environmental Science & Technology 44:8574-8580.

State of Alaska (SOA). Bulletin No. 6, June 15, 2001. Mercury and National Fish Advisories Statement from Alaska Division of Public Health: Recommendations for Fish Consumption in Alaska.

Sunderland, E.M., Krabbenhoft, D.P., Moreau, J.W., Strode, S.A. and Landing, W.M. (2009). *Mercury sources, distribution, and bioavailability in the North Pacific Ocean: Insights from data and models*. Global Biogeochemical Cycles 23: GB2010. 14 pp.

Teeyapant P, Leudang S, Parnmen S. (2015) *A cross-sectional study of exposure to mercury in schoolchildren living near the eastern seaboard industrial estate of Thailand*. WHO South-East Asia J Public Health 2015; 4(1): 45-53.

Thongra-ar, W., and Parkpian, P (2002) *Total Mercury Concentrations in Coastal Areas of Thailand: A Review*. ScienceAsia 28 (2002): 301-312.

Trasande L, Landrigan PJ, Schecter C (2005) *Public health and economic consequences of Methyl Mercury Toxicity to the Developing Brain*, Environ Health Perspect 113:590-596

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

United Nations Environment Programme [UNEP] and World Health Organization [WHO]. (2008). Guidance for identifying populations at risk from mercury exposure. UNEP Chemicals Branch and WHO Department of Food Safety, Zoonoses and Foodborne Diseases. Geneva, Switzerland 176 pp.

United States Environmental Protection Agency [USEPA]. 2000. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1: Fish Sampling and Analysis (3rd edition)*. US EPA, Office of Water. EPA 823-B-00-007. Washington, DC. 485 pp.

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.

Vahabzadeh M, Balali-Mood M. (2016) *Occupational metallic mercury poisoning in gilders*. Int J. Occup Environ Med 2016: 7-122.

Welfinger-Smith, G., Minholz, J., Byrne, S., Waghiyi, V., Gologergen, J., Kava, J., Apatiki, M., Ungott, E., Miller, P., Arnason, J., and Carpenter, D., (2011) *Organochlorine and Metal Contaminants in traditional Foods from St. Lawrence Island, Alaska*, Journal of Toxicology and Environmental Health, Part A. 74:18, 1195-1214

Yess N.J., (1993) *U.S. Food and Drug Administration survey of methyl mercury in canned tuna*. Journ. AOAC Int. 1993 Jan-Feb;76(1):36-8.

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.

DOWNLOAD THE REPORT

MERCURY IN WOMEN OF CHILD-BEARING AGE IN 25 COUNTRIES

http://ipen.org/mercury-and-women

ACKNOWLEDGEMENTS

IPEN and Biodiversity Research Institute (BRI) would like to acknowledge the participation of 1044 women in 37 communities across 25 countries who contributed hair samples for this study. In addition, we would like to recognize the contributions from the following IPEN Participating Organizations (listed below) that conducted research and prepared reports characterizing the participating community locations; collected samples for mercury analysis; and communicated the results of this study to the participants, their governments, media, and other public health and civil society groups:

- Island Sustainability Alliance Cook Islands Inc. (ISACI), Cook Islands;
- Centre for Public Health and Environmental Development (CEPHED), Nepal;
- Foundation to Support Civil Initiatives (FSCI) Dastgirie-Center, Tajikistan;
- Centre for Environmental Justice and Development (CEJAD), Kenya;
- Sustainable Research and Action for Environmental Development (SRAdev), Nigeria;
- Observatorio Latinoamericano de Conflictos Ambientales (OLCA), Chile;
- La Red de Acción en Plaguicidas y sus Alternativas para América Latina (RAPAL), Uruguay;
- Alter Vida, Paraguay;
- The Environmental Development, Education and Networking Center (EDEN), Albania;
- Ecomuseum, Karaganda, Kazakhstan;
- Public Association EKOM, Kazakhstan;
- Szubjektiv Értékek Alapítvány (Subjective Values Foundation), Hungary;
- Kenana NGO for Sustainable Development, Egypt;
- Association d'Education Environnementale pour la Future Génération (AEEFG), Tunisia;
- Dawei Development Association (DDA), Myanmar;
- Alaska Community Action on Toxics (ACAT), USA;
- BaliFokus, Indonesia;
- Ecological Alert and Recovery Thailand (EARTH), Thailand;
- NGO Rozbudova, Ukraine; and
- Volgograd-Ecopress Information Centre, Russia.

IPEN would also like to acknowledge the contributions from Biodiversity Research Institute (BRI), for assisting in developing the methodology and protocols, and thereafter organizing the international shipments of materials and samples and conducting sample analysis.

IPEN gratefully acknowledges the financial support provided by the:

- Government of Germany;
- Government of Sweden;
- Government of Switzerland;
- 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.

Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

SWEDEN

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

www.briloon.org

www.ipen.org