



# Global Mercury Hotspots

New Evidence Reveals Mercury Contamination Regularly Exceeds Health Advisory Levels in Humans and Fish Worldwide



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# The Global Fish and Community Mercury Monitoring Project

Mercury is a well-known neurotoxin that damages the kidneys and many body systems including the nervous, cardiovascular, respiratory, gastrointestinal, hematologic, immune, and reproductive systems (UNEP/WHO 2008).

IPEN and Biodiversity Research Institute (BRI) are collaborating to conduct a global mercury study in response to strong public interest and governmental negotiation of a mercury treaty—the first global treaty on the environment in well over a decade by the United Nations Environment Programme (UNEP). The IPEN-BRI collaboration provides a rare opportunity to compile new and standardized mercury concentrations on a global basis.

The *Global Fish and Community Mercury Monitoring Project* is the first of its kind to identify, in one collaborative effort, global biological mercury hotspots. These hotspots are of particular concern to human populations and the ecosystems on which they depend.

Mercury is present in different forms, but the organic form of mercury, methylmercury, is especially toxic to humans and wildlife because it is readily absorbed by the body and can accumulate in places such as the brain.

People become exposed to methylmercury primarily through the consumption of fish. Many national and international health organizations recognize mercury in fish as a threat to human health, livelihoods, and the environment. However, these same organizations, particularly in developing and transitioning countries, have limited or no information about the mercury levels in fish and other food items of risk. The IPEN-BRI collaboration begins to bridge these data gaps.

The study generated new data on mercury concentrations in samples from fish and people to accomplish the following goals:

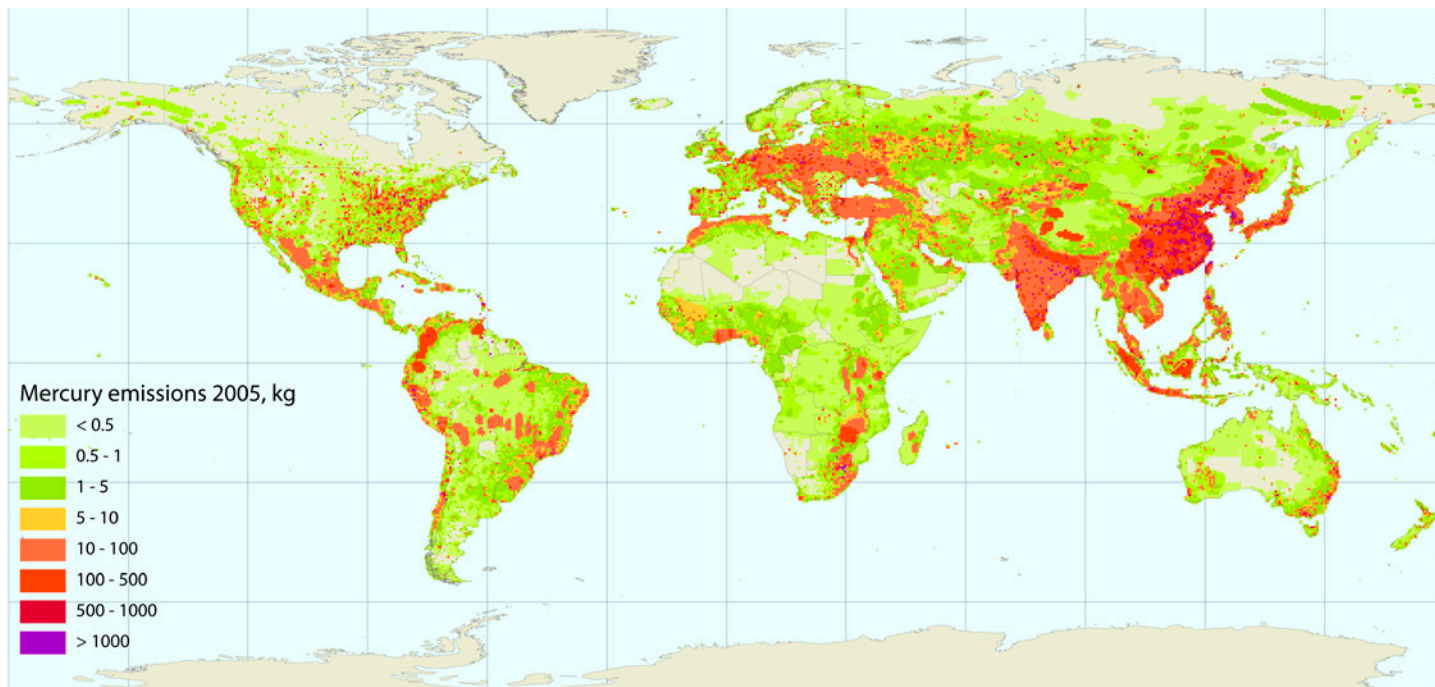
1. Raise awareness about global mercury pollution among the general public, policymakers, and the human health assessment community
2. Identify and characterize biological mercury hotspots around the world
3. Explore how the proposed treaty might affect mercury pollution at these hotspots

## Major Findings

- The extent of significant mercury contamination is ubiquitous in marine and freshwater ecosystems around the world.
- Biological mercury hotspots are globally common and can be related to human-generated mercury releases to air, land, and water from multiple point and nonpoint source types.
- Fish samples from around the world regularly demonstrate mercury concentrations exceeding human health advisory guidelines based on the U.S. Environmental Protection Agency (EPA) reference dose. This translates to 84 percent of total samples were above the level at which one meal per month is recommended.
- Hair samples from around the world regularly demonstrate mercury concentrations exceeding fish consumption advisory levels based on the U.S. EPA reference dose, which translates to 82 percent above the guidelines.

*For an explanation of the graphs used throughout this report, turn to the Appendix on page 18.*





**Figure 1.** Global distribution of human-generated atmospheric emissions of mercury for 2005 (Pacyna et al. 2010).

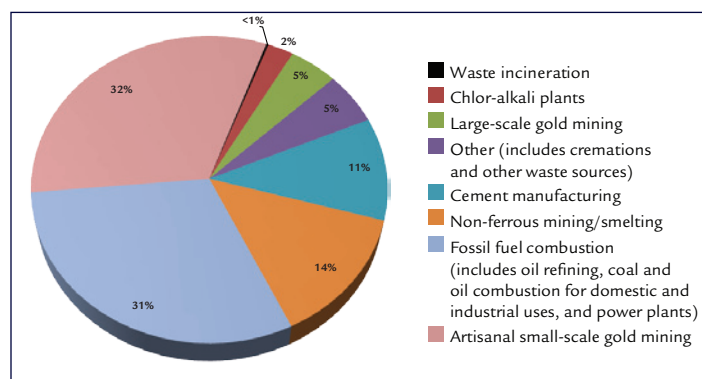
## Global Sources and Trends of Mercury

Concentrations of mercury in the global environment have increased approximately three-fold as a result of human activities. While industrial emissions have declined in North America and Europe during the past two decades, emissions have more than doubled in East Asia and India over a similar time period (Figure 1; Pacyna et al. 2010; Wilson et al. 2012).

The United Nations Environment Programme (UNEP) and the Arctic Monitoring and Assessment Program (AMAP) estimate global mercury emissions to air from human-generated sources for 2010 total approximately 2063 metric tons (Figure 2; Wilson et al. 2012).

Fossil fuel combustion and small-scale gold mining account for more than two-thirds of the 2010 mercury emissions to air (Figure 2; Wilson et al. 2012). Note that since there appear to be no available data on mercury air emissions from vinyl chloride monomer (VCM) production, emissions from this source are counted as zero. However, more mercury is used in VCM production than in most other intentional sources (UNEP/AMAP 2008).

Finally, some mercury sources release large quantities of mercury to soils, water, and wastes. Mercury that is released to media other than air will frequently contaminate aquatic ecosystems and contribute to the total global mercury pollution (Figure 3). In addition, much of this mercury will volatilize and enter the air at a later time.



**Figure 2.** Global mercury emissions to air from human-generated sources for 2010. Value represents an average emissions estimate from each sector. Data obtained from the UNEP/AMAP global assessment of mercury emissions into the atmosphere (Wilson et al. 2012).

## United Nations Environment Programme (UNEP) Global Treaty on Mercury

In 2010, an intergovernmental treaty negotiations process began to develop a global treaty to control mercury. UNEP is leading this effort with the aim to adopt a treaty in 2013. IPEN's global network of public health and environmental organizations brings a public interest perspective to the negotiations. BRI is a member of the UNEP Mercury Air Transport and Fate Research Partnership and is contributing with new research related to global mercury monitoring.



United States - Alaska	
Specific Location	Anchorage
Sample Type	Fish (43%)*
NGO Participant	Alaska Community Action on Toxics
Potential Hg Source	Global Deposition
Associated Pages	14-15

Italy	
Specific Location	Messina
Sample Type	Fish (100%)*
NGO Participant	Arnika - Toxics and Waste Programme
Potential Hg Source	Global Deposition
Associated Pages	14-15

Albania	
Specific Location	Vlora Bay
Sample Type	Fish (50%)*
NGO Participant	EDEN Center
Potential Hg Source	Contaminated Site
Associated Page	8

Portugal - Azores	
Specific Location	Ponta Delgada, Sao Miguel
Sample Type	Fish (100%)*
NGO Participant	Arnika - Toxics and Waste Programme
Potential Hg Source	Global Deposition
Associated Pages	14-15

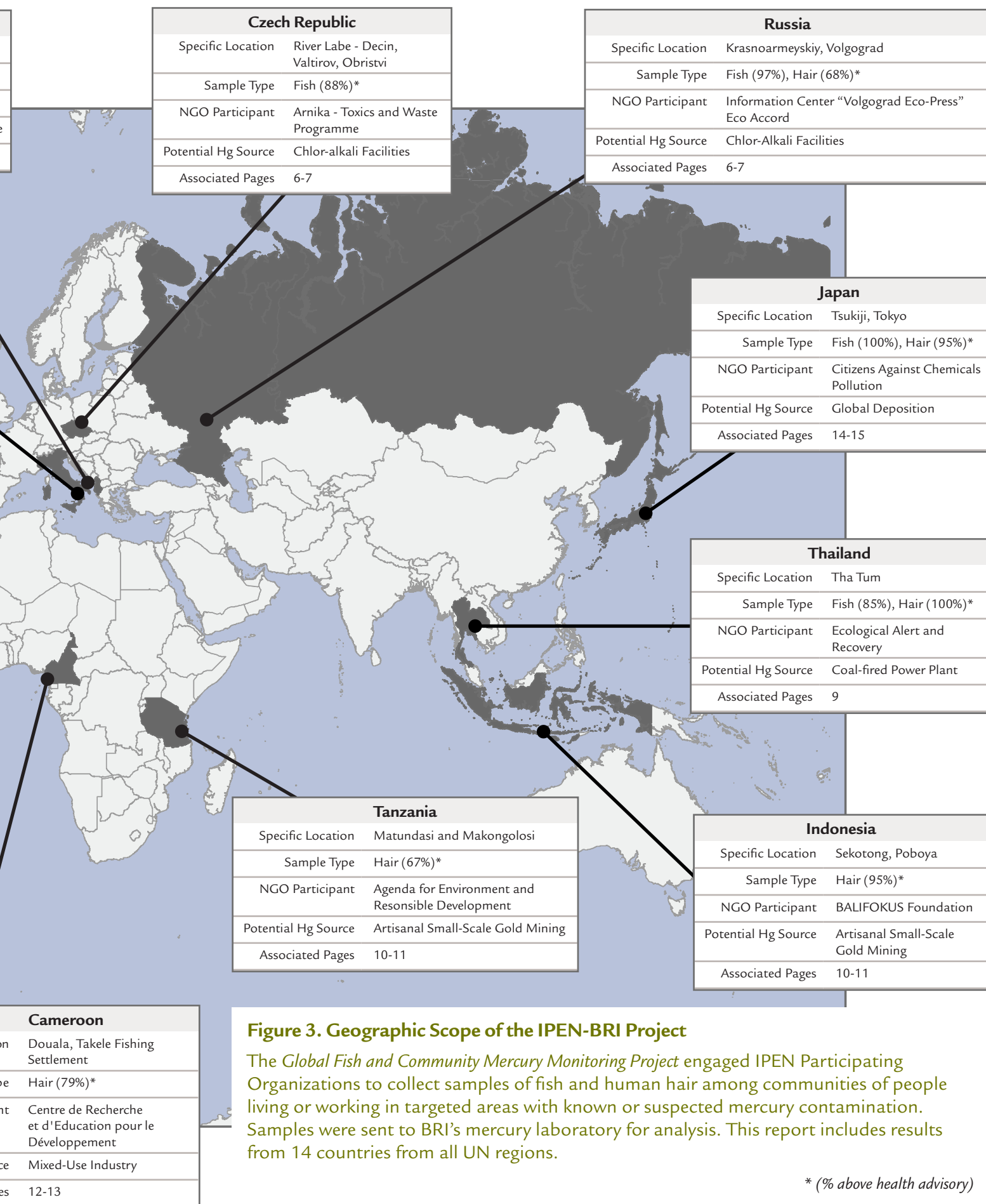
Mexico	
Specific Location	Coatzacoalcos
Sample Type	Hair (73%)*
NGO Participant	Centro de Análisis y Acción en Tóxicos y sus Alternativas Ecología y Desarrollo Sostenible en Coatzacoalcos
Potential Hg Source	Mixed Use Chemical Industry
Associated Pages	12-13

Cook Islands	
Specific Location	Muri
Sample Type	Hair (89%)*
NGO Participant	Island Sustainability Alliance CIS Inc.
Potential Hg Source	Global Deposition
Associated Pages	14-15

Uruguay	
Specific Location	Montevideo
Sample Type	Fish (100%)*
NGO Participant	Red de Acción en Plaguicidas y sus Alternativas para América Latina
Potential Hg Source	Global Deposition
Associated Pages	14-15

Specific Location	
Sample Type	
NGO Participant	
Potential Hg Source	
Associated Pages	





## Mercury Source: Chlor-Alkali Facilities

### Hotspots in Czech Republic and Russia

From the 1890s through the mid-20th century, mercury-cell technology was the main commercial process used for the production of chlorine and sodium hydroxide—two of the most commonly used chemicals worldwide. The process, still used today, involves large quantities of mercury and is a major source of mercury pollution. Each mercury-cell plant facility may contain hundreds of tons of elemental mercury (see Box 1).

### Spolana in Neratovice and Spolchemie in Ústí nad Labem, Czech Republic

Two plants using mercury-cell processes in the Czech Republic, Spolana in Neratovice and Spolchemie in Ústí nad Labem, are located close to the River Labe, which flows to Germany and into the North Sea. Government reporting data by the plants in 2011 shows releases of mercury to air (125 kg) and water (10 kg), and transfers to wastewater (19 kg) and wastes (>2000 kg).

### Volgograd, Russia

The JSC “Kaustik” chlor-alkali plant in Volgograd is close to the Volga River. The plant uses mercury cell and diaphragm processes, which release mercury directly into the air. A waste water disposal system releases almost 400 kg of mercury per year into local waterways. Mercury contamination is also found at waste sites where large drums are stored on the bare ground without protective covers.

### Results of Mercury Exposure—Czech Republic

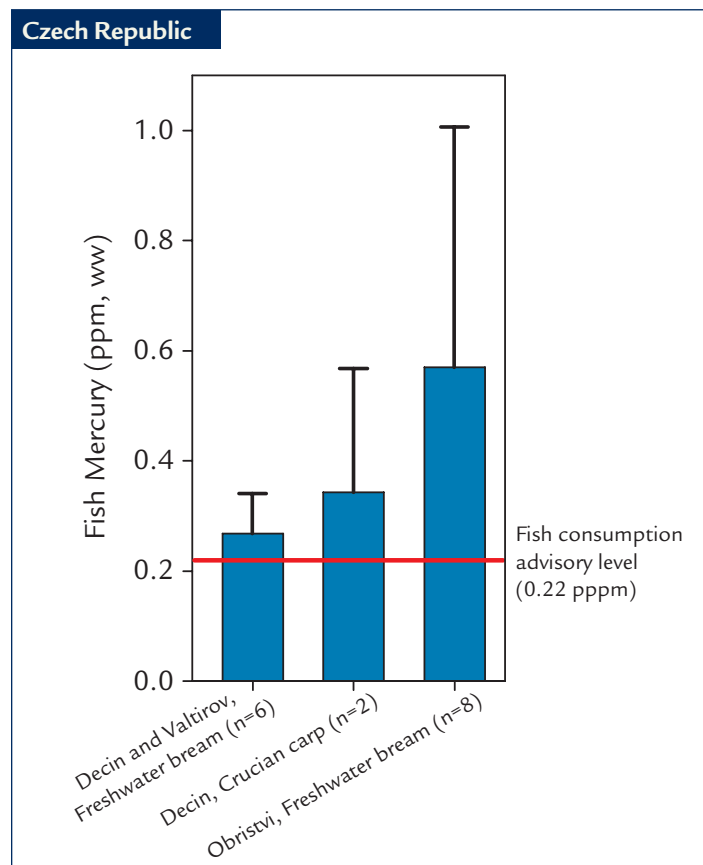
Eighty-three percent of the freshwater bream and 50 percent of the crucian carp sampled downstream from the plants in the Czech Republic exceeded the fish consumption advisory level of 0.22 ppm (Figure 4). Three of the eight freshwater bream from Obristvi near Neratovice also exceeded the EU limit for mercury in fish (0.5 ppm). The highest mercury levels in the Czech Republic samples were more than seven times greater (1.58 ppm) than the monthly fish consumption advisory level.

### Relevance to the Global Mercury Treaty

Current treaty text proposes elimination of mercury in chlor-alkali production in either 2020 or 2025. However, no agreement exists on whether countries must identify and characterize mercury use at chlor-alkali facilities or whether to allow new mercury-cell chlor-alkali facilities under certain circumstances in the future.



The chlor-alkali plant Spolana in Neratovice lies on the River Labe.

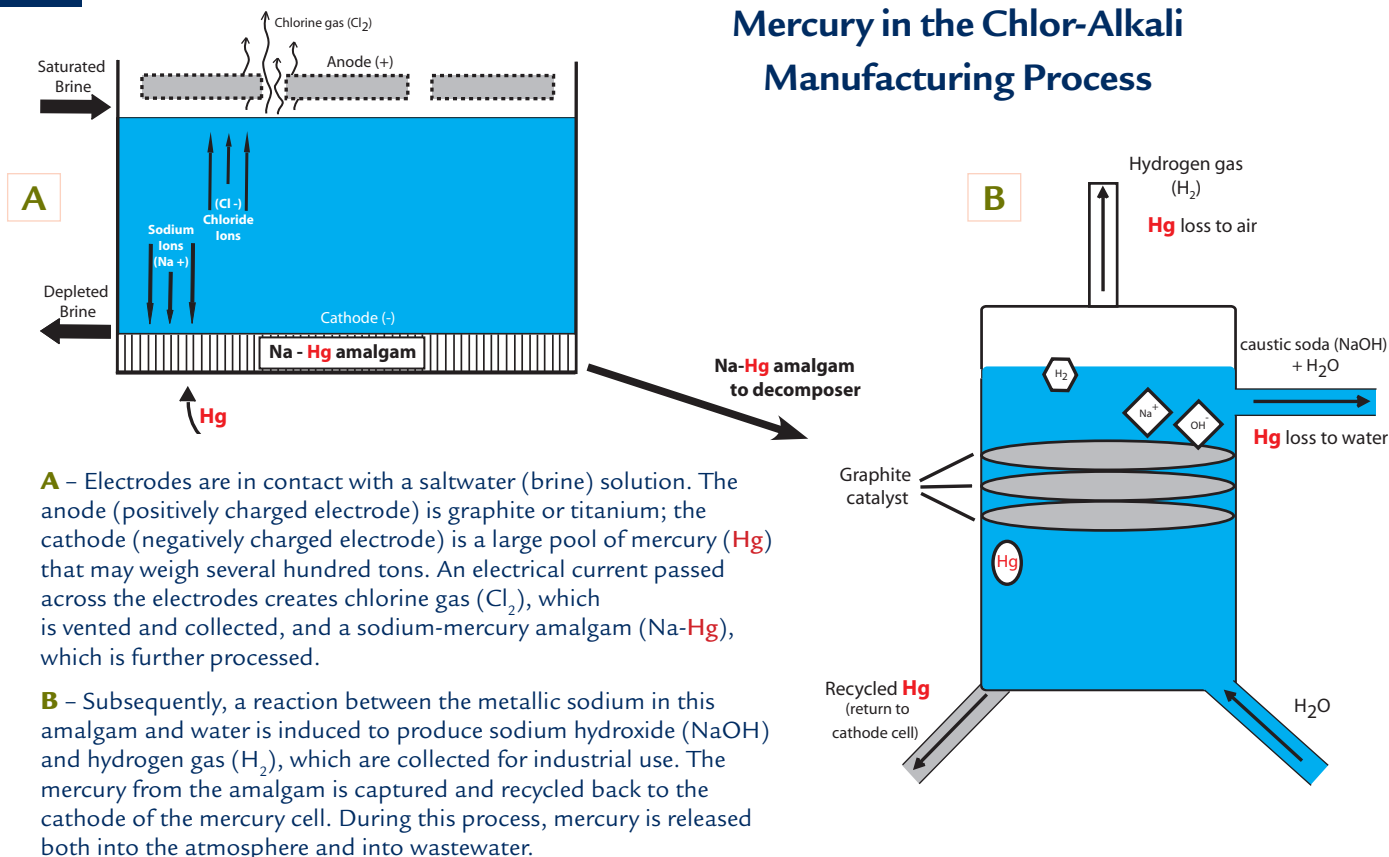


**Figure 4.** Mercury content of fish sampled from the River Labe, Czech Republic.

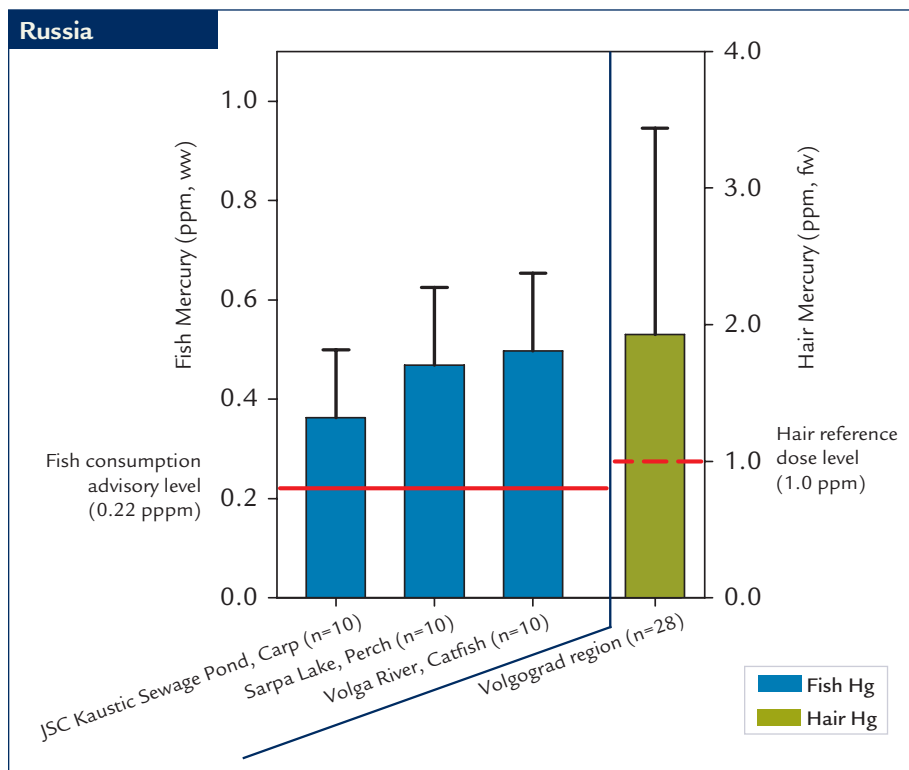


## Box 1

# Mercury in the Chlor-Alkali Manufacturing Process



## Russia



**Figure 5.** Fish samples were collected from three different locations in Russia including a sewage pond adjacent to the plant along the Volga River and Sarpa Lake, further downstream from where the Volga River drains.

## Results of Mercury Exposure—Russia

Mercury levels in fish from the surface waters in Volgograd, Russia exceeded the fish consumption advisory level of 0.22 ppm, the U.S. EPA reference dose limit for all three species (Figure 5). The highest mercury levels in these samples were nearly four times greater than the fish consumption advisory level. Nine of 10 carp samples (90 percent) from the sewage pond and all of the fish sampled in the Volga River and Sarpa Lake were above the fish consumption advisory level.

Hair samples collected from two communities near the facility had a mean mercury concentration of  $1.93 \pm 1.50$  ppm, with 67 percent of the samples being above the U.S. EPA reference dose level of 1.0 ppm (Figure 5).

# Mercury Source: Contaminated Sites

## Hotspot in Albania

Contaminated sites contribute to remobilization and re-emissions of mercury, a significant source and pathway of mercury air emissions.

### Vlora Bay, Albania

The former chlor-alkali and PVC plant in Vlora used a mercury-cell process, discharged its waste directly into Vlora Bay, and dumped polluted sludge near the seashore where it remains today. The plant operated from 1967–1992; its buildings have been completely destroyed since then. No precautions have been taken to prevent further contamination of the bay or nearby residents. In 2002, an identification mission of UNEP/MAP (GEF Project GF/ME6030-00-08) identified this area as a hotspot after a soil sample showed mercury levels greater than 10,000 ppm in the area of the former plant—1000 times greater than typical EU thresholds. Vlora Bay is an important fishing area; fish from the area are distributed to all cities in Albania.

### Results of Mercury Exposure

European hake and surmullet (or red mullet) were collected from Vlora Bay. Four of the eleven hake (36 percent) contained mercury concentrations above the fish consumption advisory level of 0.22 ppm (Figure 6).



Representatives of a local public interest organization visit an abandoned PVC plant in Albania, the site where waste products from the working plant (including mercury chloride) were dumped. There are no restrictions for public exposure to this site.

All surmullet (100 percent) were above the fish consumption guideline with a mean concentration of  $0.62 \pm 0.31$  ppm (ww). Other studies in Vlora Bay have also documented high mercury levels in fish and plants in this area (Storelli et al. 1998; Mankolli et al. 2008 ).

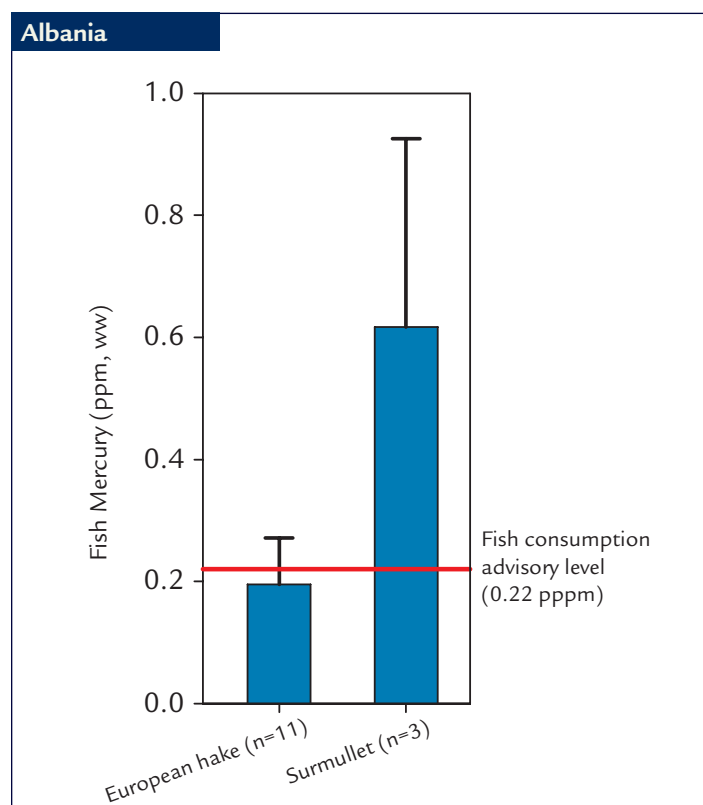


Figure 6. Mercury content of fish sampled in Vlora Bay, Albania.

## Relevance to the Global Mercury Treaty

The current treaty text does not require the identification and cleanup of contaminated sites. In addition, the current treaty text provides no guidance on a health-protective value that defines waste as hazardous nor does it require the minimization and prevention of generating mercury-containing waste.

Finally, since the treaty links compliance with funding and since action on contaminated sites is not obligatory, it is likely that no funding will be available through the treaty's financial mechanism to identify or clean up contaminated sites.



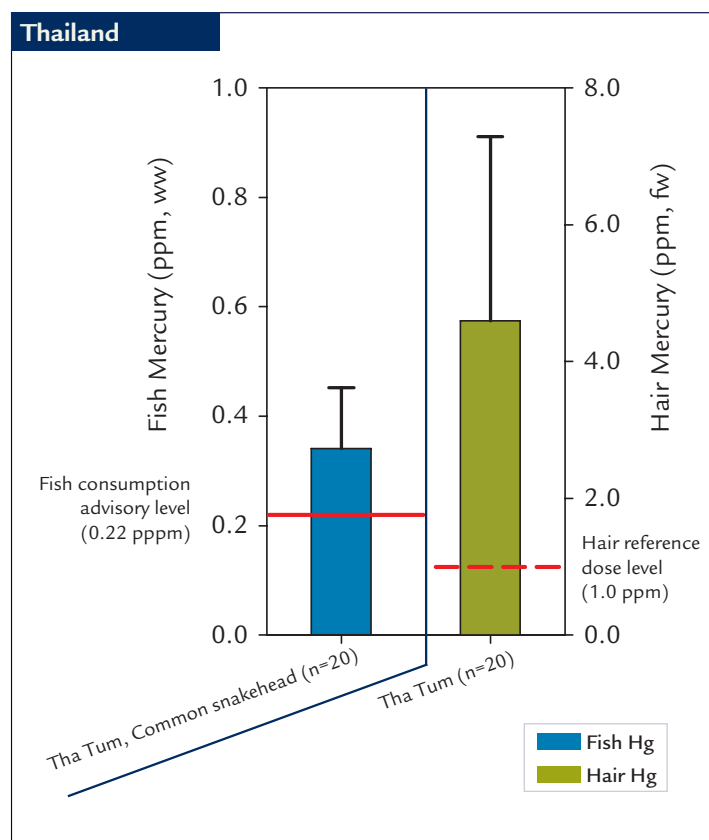
# Mercury Source: Coal-Fired Power Plants

## Hotspot in Thailand

Coal is the most abundant fossil fuel on Earth and the combustion of coal releases mercury into the environment. Air emissions from poorly controlled plants can emit large quantities of particle-bound mercury, which tend to fall to Earth downwind of these power plants. Mercury in fly ash, which is captured by air pollution control devices, can also be subsequently released to the environment. Pulp and paper plants can be another mercury source when phenyl mercury acetate is added to inhibit the growth of fungi and contaminates the discharge water.

### Tha Tum, Thailand

The Tha Tum site contains 75 factories including a coal-fired power plant consuming 900,000 tons/year of coal (adjacent to a pulp and paper mill producing 500,000 tons/year of paper that can also release significant amounts of mercury [Kim et al. 2010]). Fish are commonly eaten from the Shalongwaeng Canal, which runs nearby the pulp and paper plant, and the open-air storage of coal and fly ash from the power plant.



**Figure 7.** Mercury content in fish and hair sampled from a site near a coal-fired power plant in Tha Tum, Thailand.



Top: Hair samples were taken from people who lived near mercury sources.



Left: Fish most often consumed by the local population, like this common snakehead, were sampled for mercury content.

### Results of Mercury Exposure

Snakehead fish regularly exceeded the fish consumption advisory level (over 85 percent of the samples; Figure 7). In addition, all 20 hair samples from residents living 0.5–2.0 km from the power plant and pulp mill exceeded the U.S. EPA reference dose, and average levels were more than 4.5 times higher than 1.0 ppm (Figure 7).

### Relevance to the Global Mercury Treaty

The current treaty text on air emissions offers vague options for controlling existing coal-fired power plants if they are above a certain thermal input (not yet determined). However, these provisions are not likely to reduce mercury emissions from individual plants on a scale sufficient to offset the new mercury emissions that are likely to result from the rapid growth of this sector. Pulp and paper mills are not listed as a mercury source in the current treaty text, although the UNEP Mercury Toolkit and U.S. Toxics Release Inventory data suggest it is a significant source of emissions.

# Mercury Source: Artisanal Small-Scale Gold Mining

## Hotspots in Tanzania and Indonesia

Artisanal small-scale gold mining (ASGM) is the largest intentional use of mercury (30 million people are engaged in artisanal gold mining around the world), causing extreme pollution and contributing directly to human body burdens through mercury vapors and high levels of methylmercury in food items such as fish from local waterways near ASGM sites.

### Matundasi and Makongolosi, Tanzania

The Tanzanian ASGM sites in the Matundasi and Makongolosi areas burn mercury-gold amalgam in the open air without recovery systems (see Box 2). Most of the water that is used for sluicing and amalgamation drains into the Lupa River which flows into Lake Rukwa, an important waterway which supports livelihoods in the southern highland part of Tanzania and borders a large Ugandan game reserve.

### Sekotong and Poboya, Indonesia

In 2010, about 280 tons of illegal mercury was imported to Indonesia for ASGM. This figure has doubled in 2011 (2012 Ismawati personal communication). In Sekotong Village, almost every household operates a ball-mill unit, located in the backyard or near the rice field. Miners process ore all day long without personal protection equipment.

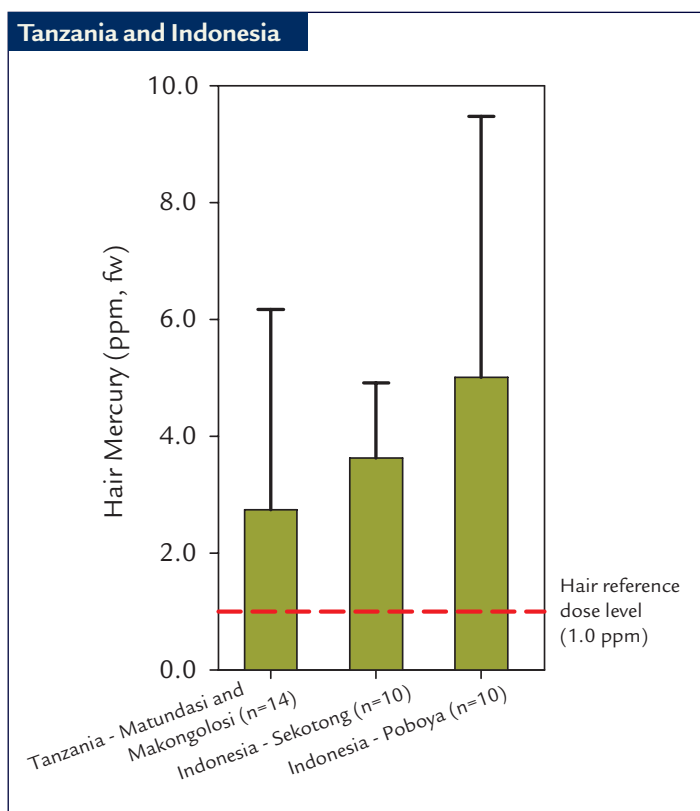
In Poboya, the ball-mills are concentrated in clusters and release very high levels of mercury vapor to the air and the environment (Serikawa et al. 2011; Ismawati and Gita 2011). In both hotspots, the mercury-contaminated tailings are either processed further in a cyanide leaching plant or disposed directly into rivers.

### Results of Mercury Exposure

In Tanzania, two-thirds of the samples exceeded the U.S. EPA reference dose. The average mercury concentration was  $2.74 \pm 3.4$  ppm (fw), excluding a significant outlier of 236 ppm (fw). The average mercury level in human hair at both sites in Indonesia (Sekotong Village and the Poboya area in Palu) was more than three times greater than the U.S. EPA reference dose. The mean mercury level in hair from Sekotong Village was  $3.6 \pm 1.3$  ppm (fw). The mean mercury level in hair from Poboya was  $5.0 \pm 4.7$  ppm (fw) with a maximum concentration of 13.3 ppm. Overall, 19 of the 20 samples collected from these Indonesian villages exceeded the U.S. EPA reference dose (see Figure 8).



Although mercury use for ASGM is illegal in Tanzania, there are approximately 150–200 miners working at the two sites noted in this report. The Indonesian sites in Poboya and Sekotong encompass 40,000 miners and 300 active milling operations.



**Figure 8:** Mercury content in human hair from ASGM sites in Tanzania and Indonesia.





## Box 2 Mercury in the Artisanal Small-Scale Gold Mining Process

To extract gold dust from the earth, artisanal miners add mercury to the silt. This can be done in an apparatus known as a ball-mill (mercury is poured into large drums that contain silt, as shown at left). The gold particles attach to the mercury, which acts like a magnet to the precious metal. The result is a solid mercury-gold amalgam that can be separated out by screening the silt.

The mercury-gold amalgam is then heated to vaporize the mercury, leaving the gold nuggets behind. Because this process is often conducted in the open air, usually close to family dwellings, anyone in the near vicinity is at risk of inhaling the airborne mercury.

Excess mercury that is left in the silt (known as mine tailings) finds its way into local waterways during disposal.



## Relevance to the Global Mercury Treaty

The current treaty text requires actions if Parties determine that ASGM is “more than insignificant,” however there are no guidelines to determine “significance.” In addition, the current text allows countries to import unlimited quantities of mercury for use in ASGM with no phase-out date. Finally, no obligations exist to identify or clean up contaminated ASGM sites.

Photos from top: In the Indonesian village of Sekotong, workers add liquid mercury to the ball-mill; the mercury-gold amalgam is heated, releasing mercury into the air. Right: In Poboya, a local miner operates a gold shop—the fumes from his makeshift torching apparatus (stacked barrels) stands in close proximity to the family dwelling.





# Mercury Source: Mixed-Use Chemical Industrial Sites

## Hotspots in Mexico and Cameroon

Mixed-use industrial sites can include chlor-alkali production, oil refining, waste incineration, cement manufacturing, and other potential mercury sources that contribute varying amounts of mercury to total releases. This type of hotspot represents a real-world situation that most cities and countries will face—identifying and dealing with mercury pollution released by a complex mixture of mercury sources.

The industrial sites examined in this study are adjacent to rivers that flow into the ocean. These sites were analyzed to determine whether a mixture of mercury sources can result in human body burdens of mercury.

### Coatzacoalcos and Minatitlán, Mexico

In Mexico, the city of Coatzacoalcos, Veracruz contains a mercury-cell chlor-alkali plant inside of a petrochemical complex that includes a waste incinerator. Another site in Mexico, located in Minatitlán, Veracruz, contains an oil and gas refinery which was recently configured to increase processing capacity to 350,000 barrels per day. Both sites are located on the Coatzacoalcos River, which flows into the Gulf of Mexico.

### Douala, Cameroon

Douala, the largest and most industrial city in Cameroon is located at the mouth of the Wouri River which empties into the Gulf of Guinea. Douala contains a cement plant (more than 1.2 million tons produced in 2009), waste incinerator, e-waste dumping and open burning, and a variety of other potential mercury sources including skin-whitening products. The study focused on the fishing community of Youpwe-Takele.



A woman on the way back from fishing in Douala, Cameroon. Wetland areas are especially prone to creating high concentrations of mercury in fish.



In Douala, Cameroon, local fishermen clean their catch from the Wouri River.

## Relevance to the Global Mercury Treaty

The current treaty text offers some vague options for controlling air emissions from existing cement kilns and waste incinerators if they are above a certain output threshold (not yet determined). However, these provisions may not reduce mercury emissions from individual plants on a scale sufficient to offset the new mercury emissions that come from increased numbers of cement kilns or incinerators.

Neither cement kilns nor waste incinerators are included as a possible source of mercury releases to land or water.

There is also no agreement about whether to include oil and gas production and processing facilities in the treaty, so this possible source of mercury may not be addressed. The current treaty text prohibits soaps and cosmetics containing mercury but there is no agreement on the phase-out date.

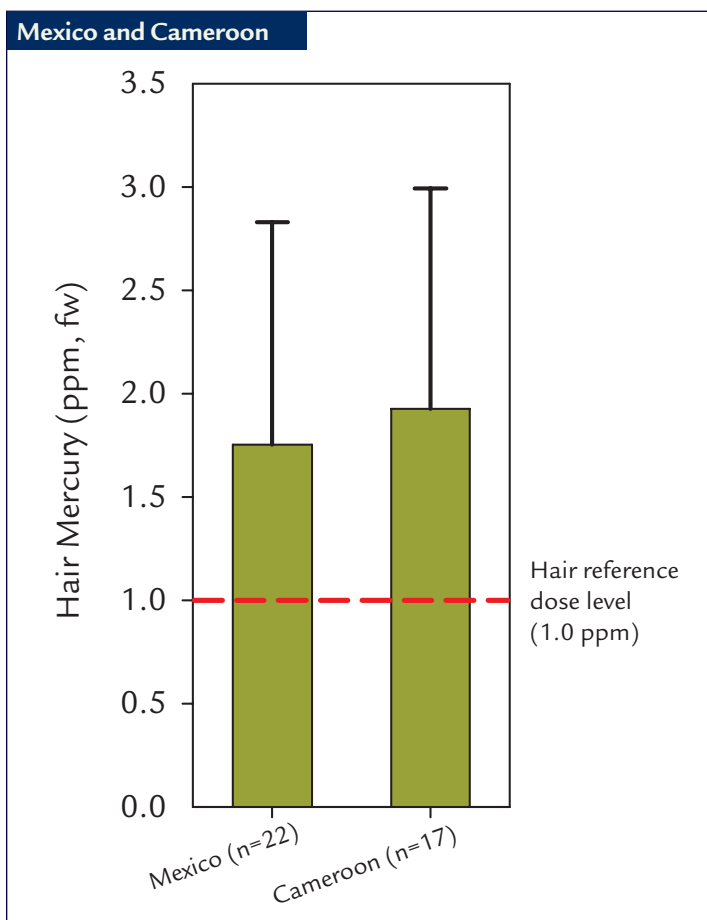
The current treaty text also permits new mercury-added products to be introduced into the market if it can be justified based on “compensating environmental or human health benefits.”

Used electronic devices such as computers and/or e-waste could also be one of potential sources of mercury releases in Douala, as it is in other African countries. The current treaty text does not include open burning of these types of wastes as an air emission source.





The sprawling Pajaritos petrochemical complex in Coatzacoalcos, a major port city in Veracruz, Mexico that lies on the Coatzacoalcos River.



**Figure 9.** Mercury content in human hair near mixed-use industrial sites in Mexico and Cameroon.

### Results of Mercury Exposure

The average mercury level in human hair from Mexico was  $1.75 \pm 1.1$  ppm (fw) with 73 percent of samples exceeding the U.S. EPA reference dose of 1.0 ppm (fw) (Figure 9). The maximum concentration of 4.32 ppm was more than four times higher than the reference dose.

In Cameroon, the average mercury level in human hair was  $1.93 \pm 1.1$  ppm (fw) with 76 percent of the samples exceeding the U.S. EPA reference dose of 1.0 ppm (fw) (Figure 9). The maximum concentration of 3.77 ppm was nearly four times higher than the reference dose.

This excludes two samples with extremely high mercury levels of 541 and 546 ppm (fw). Pathways for such high mercury exposure in humans could include cosmetics such as skin-lightening products. These individual hair samples were re-analyzed to confirm the accuracy of the initial analysis, and the second round of analysis confirmed highly elevated mercury levels in the hair.

# Mercury Sources: Global Atmospheric Deposition

## Hotspots—The World's Oceans as Reservoirs for Mercury

The release of mercury is of global importance because of its ability to move across large spaces via air and water currents (Figure 10). It is released into the environment predominantly through human activities and such inputs over time have increased the biosphere levels of mercury by at least three-fold (Mason et al. 2012).

Atmospheric processes can carry emitted mercury around the world for approximately one year until being deposited on the Earth's surface. The world's oceans are one of the primary environmental reservoirs where mercury is deposited from the air or from inputs from river watersheds. While atmospheric deposition is the greatest source of mercury to oceans, internal production from the upper 3,300 feet (1,000 meters) of water in the open ocean provides the greatest input of methylmercury in marine fish (Mason et al. 2012).

Based on models by Sunderland et al. (2009), present atmospheric mercury deposition rates will result in mercury concentrations doubling in the North Pacific Ocean by 2050; such deposition rates are likely to result in significant mercury increases in pelagic marine fish, such as the Pacific bluefin tuna, if methylmercury production and accumulation mimics projected mercury additions. Fish mercury concentrations vary by ocean basin because of mercury inputs, large-scale ocean circulation, vertical transport processes (Mason et al. 2012), and species composition and harvest pressure (Evers et al. 2012).

### Indicators of Ocean Basins

Apex marine predators such as tuna, swordfish, and other large pelagic fishes are important species for the global marine fisheries (Evers et al. 2012, FAO 2012, Karimi et al. 2012). However, these same species are also most susceptible to mercury exposure because of their position at the top of the marine food web.

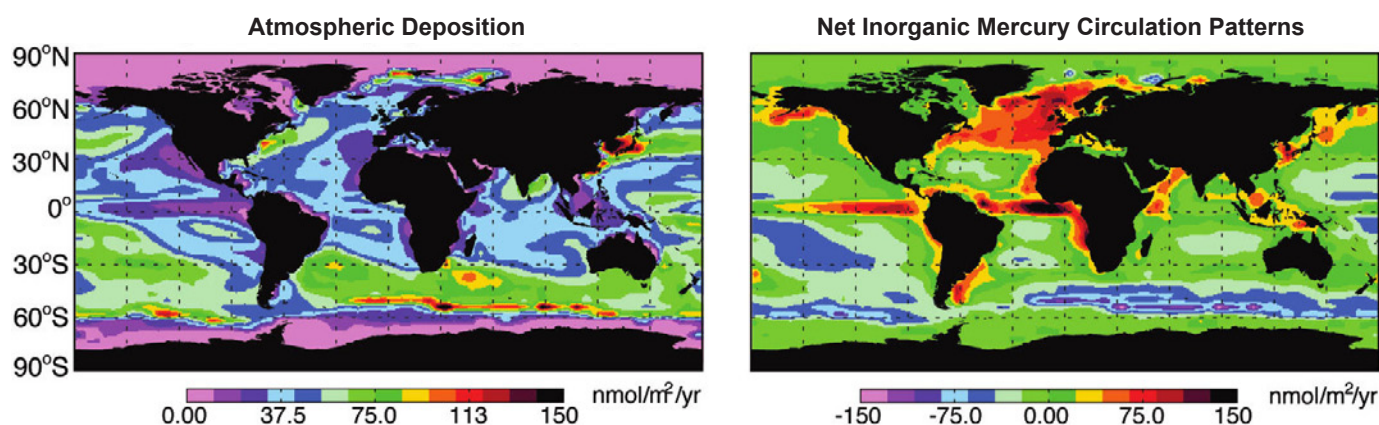
We selected six sites from across the Earth's oceans (Table 1) to examine mercury concentrations in top marine predatory fishes and also the potential risks of exposure in human populations that rely on marine fisheries for their diet.

### Relevance to the Global Mercury Treaty

The current treaty text offers few true mechanisms for controlling existing emissions sources and there are significant gaps including:

- Only vague options for controlling emissions from existing coal-fired power plants
- Unlimited importation of mercury for ASGM purposes with no phase-out date
- No language identifying VCM production as a mercury source and no text prohibiting mercury during VCM production

Without a more deliberate effort to address these issues, global mercury emission and deposition will likely continue to increase.



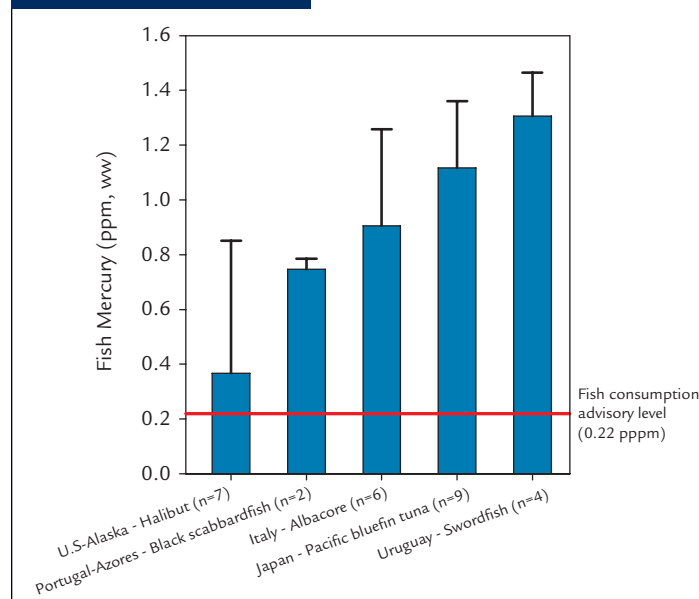
**Figure 10.** Map shows global mercury (Hg) deposition and total Hg entrainment across the Earth's oceans. Global deposition including wet, dry, and particulate Hg, shows peaks in the North Atlantic, adjacent to the northeastern U.S. as well as in the North Pacific, adjacent to Asia. Additional peaks in deposition at higher latitudes are associated with long-term transport of Hg in the upper atmosphere and subsequent deposition. High concentrations of inorganic Hg in the North Atlantic and the tropical regions are largely controlled by surface ocean circulation patterns. (Image derived from Soerensen et al. 2010.)



**Table 1.** Ocean basins and countries where samples were collected.

Ocean Basin	Country	Tissue Type Sampled
Northern Pacific	Japan	fish / hair
Northern Pacific	United States (Alaska)	fish
Southern Pacific	Cook Islands	hair
Eastern Atlantic	Portugal - Azores	fish
Southern Atlantic	Uruguay	fish
Mediterranean Sea	Italy	fish

#### Global Ocean Basins



**Figure 11.** Mercury content in large pelagic fish.

#### Results of Mercury Exposure

Of the 28 fish samples collected from the global atmospheric deposition sites, 86 percent were above the fish consumption guideline of 0.22 ppm (Figure 11). Forty-three percent were above the EU and WHO limit of 1.0 ppm.

Swordfish from the Southern Atlantic Ocean (Uruguay) had the highest average mercury level of  $1.31 \pm 0.16$  ppm (ww), followed by Pacific bluefin tuna ( $1.12 \pm 0.24$  ppm, ww) from the Northern Pacific Ocean (Japan). Albacore tuna from the Mediterranean Sea (Italy) had an average mercury level of  $0.91 \pm 0.35$  ppm (ww).

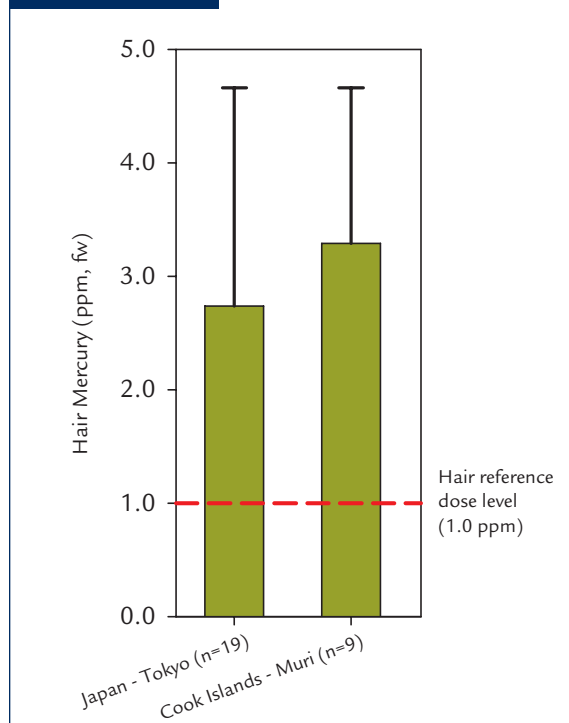
Average mercury levels in hair from Tokyo were 2.7 times higher than the U.S. EPA reference dose, and the Cook Islands hair samples contained average mercury levels that were 3.3 times higher than the reference dose (Figure 12).

Overall, 95 percent of the hair samples from Japan and 89 percent of the samples from the Cook Islands exceeded the U.S. EPA reference dose for mercury.



Bluefin tuna sold at the Tsukiji market in Tokyo, Japan. The bluefin tuna sampled in this project, purchased from this market, contained among the highest mercury levels detected.

#### Pacific Oceans



**Figure 12.** Mercury content in human hair from local populations in Japan and the Cook Islands.

## Summary

This study identified global biological mercury hotspots that are of particular concern to human populations and the ecosystems on which they depend. Five types of major mercury point sources were chosen to examine mercury pathways from their origin to methylmercury exposure in fish and people.

Sites represent releases of mercury to air, land and water. The major source type of global deposition originates from nonpoint sources. The data in this report represents 108 fish samples from nine countries and 152 human hair samples from eight countries. The countries represent all regions in the United Nations regions and include a mix of developed countries, developing countries, and countries with economies in transition along with one Small Island Developing State.

### Mercury in Fish

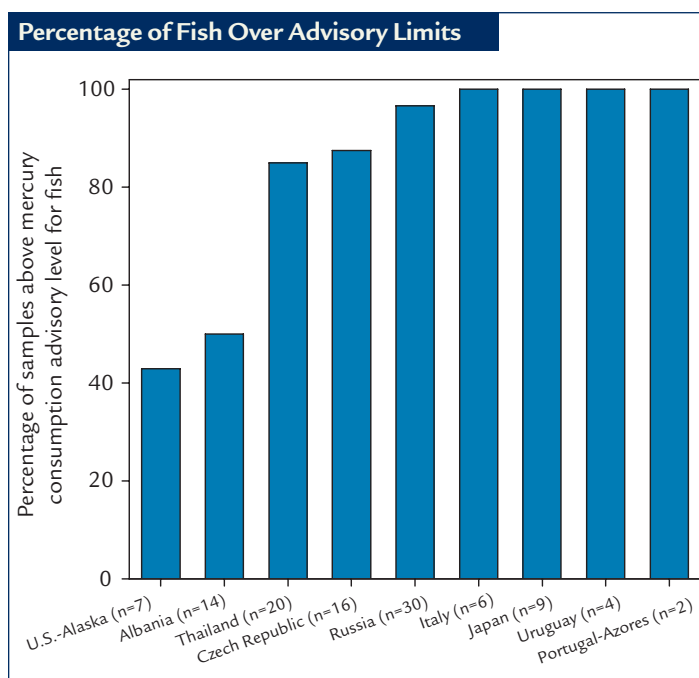
The IPEN-BRI collaboration generated fish mercury concentrations from three types of common mercury point sources: contaminated sites, chlor-alkali facilities, and coal-fired power plants. Sites likely related primarily to nonpoint sources, or global deposition, are also identified. Each of the nine countries contained high proportions of fish over the USEPA reference dose-based consumption guideline of 0.22 ppm (where only one fish meal of 170 grams [or 6 ounces] per month should be consumed). Our findings demonstrate that 84 percent of the fish sampled were not safe for consumption for more than one meal per month (Figure 13). Over 13% of the fish sampled would not be recommended by The World Health Organization and the European Commission for commercial sale.

### Mercury in Human Hair

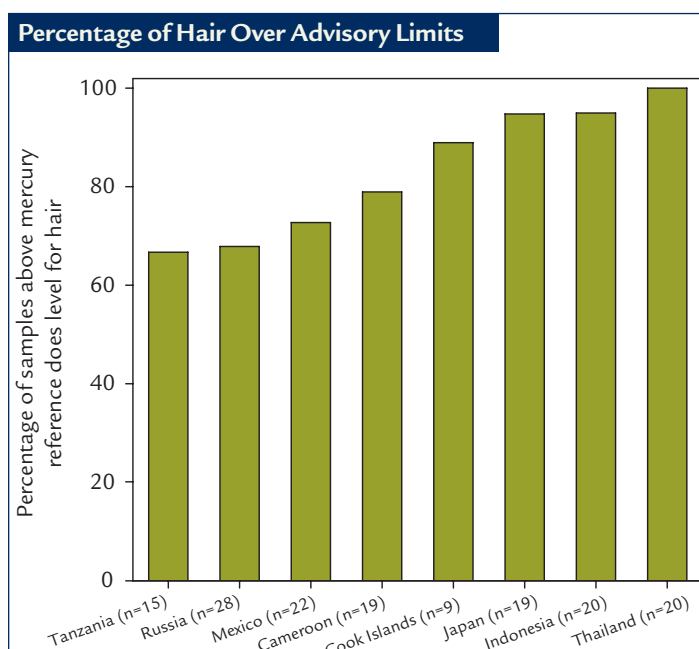
Mercury in human hair was collected from two countries with global deposition as a source, while other countries are directly related to three types of point source releases; artisanal small-scale gold mining (ASGM), coal-fired power plants, and mixed industrial sites that contain mixtures of chlor-alkali production, oil refining, waste incineration, and cement manufacturing. More than 82 percent of the 152 individuals contained mercury concentrations greater than the USEPA reference dose level of 1.0 ppm.

### Relevance to the Global Mercury Treaty

The United Nations Environment Programme (UNEP) is supporting intergovernmental negotiations to develop a global, legally binding treaty on mercury to reduce risks to human health and the environment. This IPEN-BRI study highlights the global scale and ubiquitous nature of mercury contamination and reinforces efforts to develop a comprehensive and effective global mercury treaty.



**Figure 13.** The percentage of fish samples from nine countries above the fish consumption advisory guideline of 0.22 ppm.



**Figure 14.** The percentage of human hair samples from eight countries above the U.S. EPA reference dose of 1.0 ppm.



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# APPENDIX: Methods Behind the Data

## Identifying Potential Hotspots and Sample Collection

Work on the Global Fish and Community Mercury Monitoring Project was conducted in three phases. In Phase 1 and 2, IPEN and its network of more than 700 public interest NGOs from across the globe collected hair and fish samples and identified potential mercury contamination hotspots. During Phase 3, BRI utilized its Global Biotic Mercury Synthesis (GMBS) database to further identify potential hotspots.

Fish and hair sampling protocols were adapted from approved sampling methods for mercury risk assessment in fish (U.S. EPA 2000) and human hair (UNEP/WHO 2008). For fish sampling, we targeted high trophic level fish and fish commonly consumed by the local population.

Hair samples were collected from individual volunteers (of legal age) who live adjacent to the hotspot.

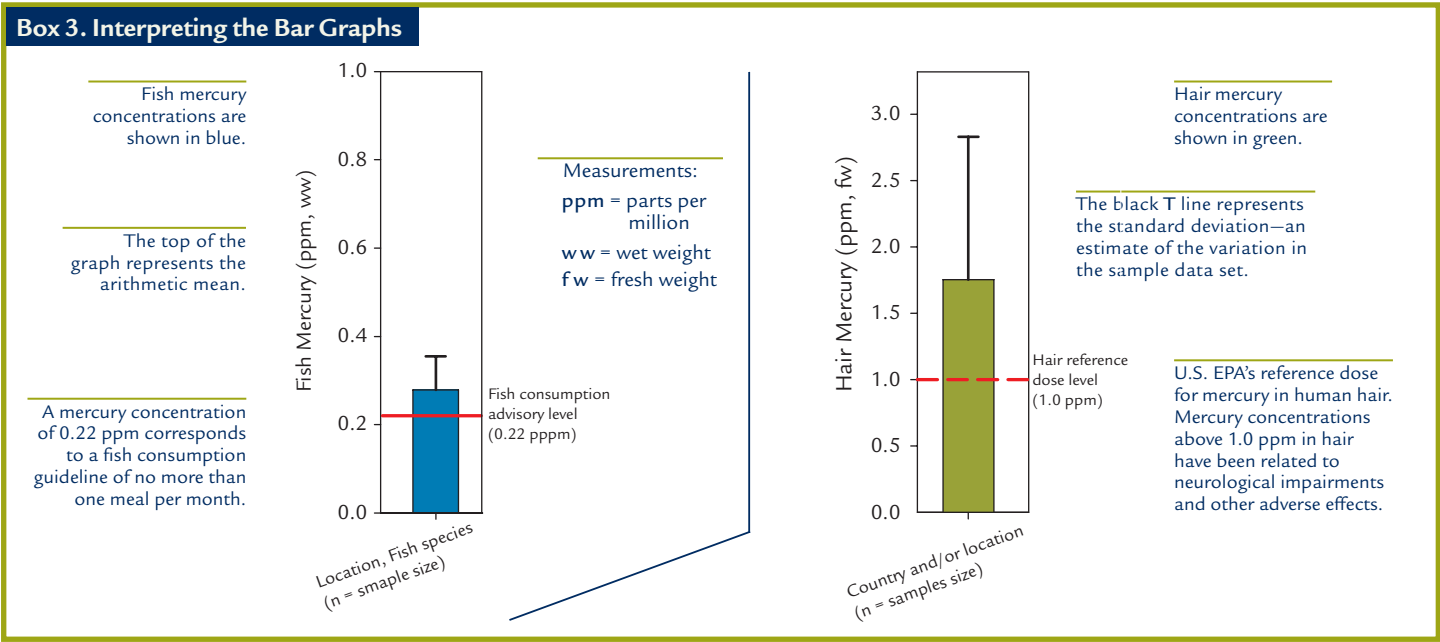
The majority of samples (fish and hair) were shipped by expedited international shipping to BRI's Wildlife Mercury Research Lab for analysis. Results are shown in this report using bar graphs that depict the average mercury measured in parts per million (Box 3).



Samples were analyzed on BRI's Milestone DMA 890, using a U.S. EPA-approved method (SW-846 Method 7473).

## Evaluating the Results

Based on the U.S. EPA's reference dose of 0.0001 mg methylmercury per kg of body mass per day, we calculated fish consumption guidelines using an average body mass of 60 kg (132 pounds) and an average fish meal size of 170 grams (6 ounces). Fish containing mercury concentrations of 0.22 parts per million (ppm) should be consumed no more than once per month. Fish with mercury concentrations less than this value (<0.22 ppm) can be consumed more frequently. Fish with mercury concentrations greater than 0.95 should be avoided entirely. (Table 2.)



**Table 2.** 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 meal/week
>0.22-0.95	1 meal/month
>0.95	no consumption



# The Global Biotic Mercury Synthesis Database

## A Platform for Evaluating the Effectiveness of the UNEP Mercury Treaty

There is a gap in our understanding about the relationship between human-generated releases of mercury into the environment (through air, water, and land), subsequent biomagnification and bioaccumulation of methylmercury (how the toxicity of mercury intensifies as it moves up the food web over time), and how this translates to exposure and risks at local, regional, and global scales.

BRI has compiled a Global Biotic Mercury Synthesis (GBMS) database in association with the Global Mercury Partnership's Mercury Air Transport and Fate Research Group (Evers et al. 2012).

The GBMS database contains a large number of data sets on mercury concentrations in shellfish, sharks and rays, fin fish, birds, and marine mammals from various regions of the world over the past several decades. It provides an important tool to:

1. Understand the spatial patterns and temporal trends of mercury concentrations in the ecosystem;
2. Identify species or groups of organisms that are of greatest concern for ecological and human health;

3. Locate global biological mercury hotspots, link with major mercury source types and determine if concern is related to contaminated sites or ecosystems sensitive to even small amounts of mercury input;
4. Distribute information in easy-to-access and understandable approaches for interested parties at local, regional, and global levels; and
5. Evaluate the effectiveness of the future global legally binding treaty on mercury.

GBMS represents a comprehensive, standardized, and cost effective approach for documenting and tracking changes in environmental loads of mercury as reflected in fish and wildlife. The use of key indicator organisms, such as apex marine predators, that are sensitive to environmental change is an integral part of a long-term monitoring program (Evers et al. 2008; Chen et al. 2012).

The data included in GBMS represents an important opportunity to better integrate mercury science into important policy decisions related to the long-term management of natural resources (Lambert et al. 2012).

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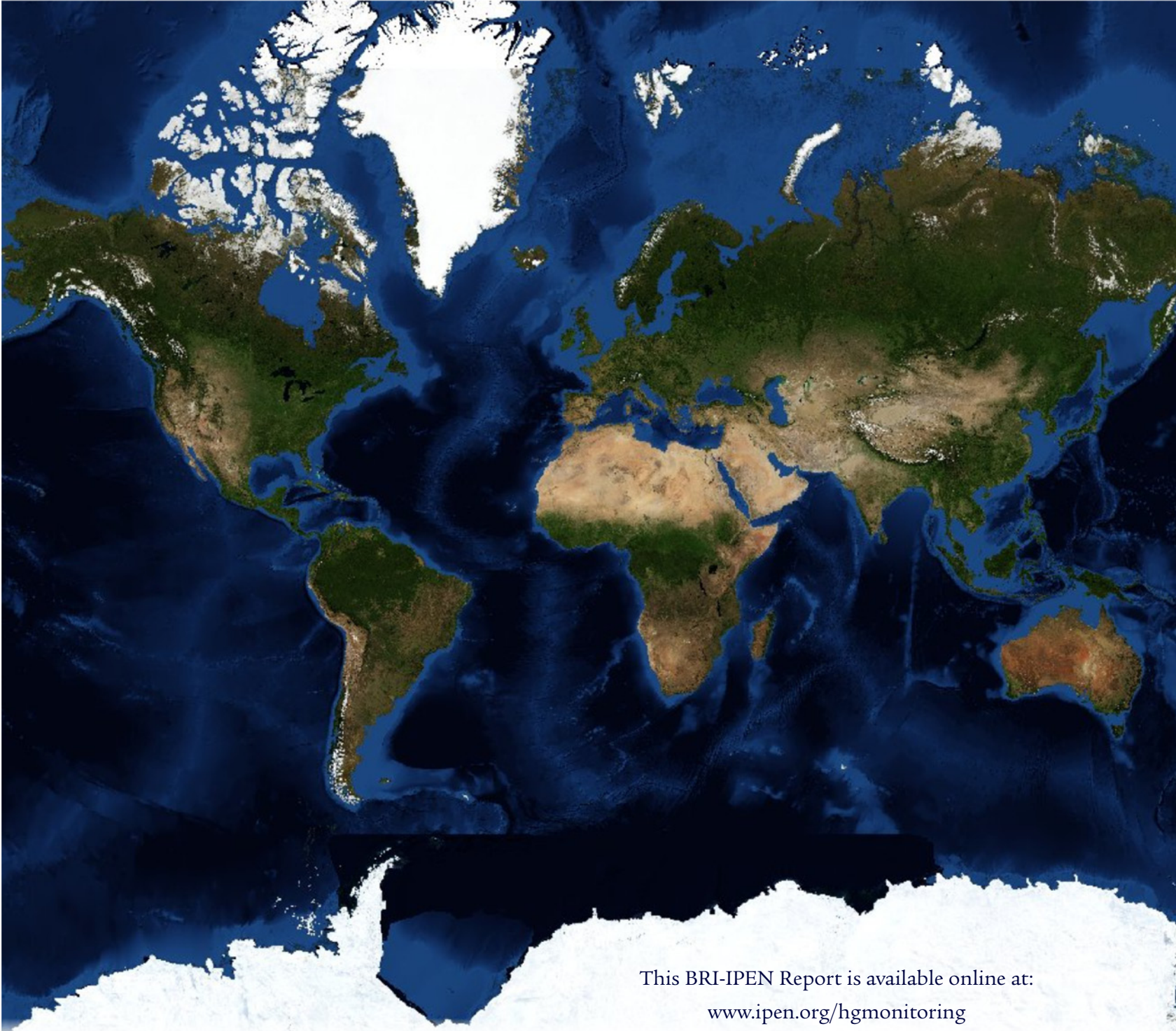
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