UN environment

Global mercury

supply, trade and demand

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Executive Summary

A response by the world's nations to the abundant evidence of the negative effects of mercury pollution on human health and the environment, the Minamata Convention on Mercury entered into force on 16 August 2017. The Convention includes provisions to control the supply, trade and use of mercury. This report provides an overview of the current state of these activities in order to assist governments and other stakeholders as the Convention moves into the implementation phase. The most important findings and observations are summarized here.

Mercury supply

Chlor-alkali residual mercury

One of the major changes in mercury supply since 2011 is the reduced volume of chlor-alkali residual mercury available on the open market, due in large part to restrictions imposed by export bans. In the European Union alone, an estimated 650 tonnes per year of chlor-alkali related mercury are no longer available. Despite such advances, many countries do not yet have plans to move away from the mercury process in this industry.

Mercury mining

A second fundamental change in mercury supply is the emergence of new mercury mining in Mexico and Indonesia, with production estimated at 800-1 100 tonnes in 2015. In neither of these cases is the extent or the rate of growth of production very clear. The Minamata Convention requires Parties to phase out existing mercury mining. Once such operations are established, however, and mining communities become accustomed to the economic benefits, it may be difficult to phase out these mining activities and disrupt the social structure that has developed around them.

Mercury price

The greatly reduced global supply of mercury during 2011 and 2012 encouraged a spike in the market price between 2011 and 2013, and this likely encouraged some of the new mining activities. That price spike appears to be past, but the free market price of mercury remains high in historical terms. Also as a result of the export bans, a two-tiered pricing system has emerged in the United States and European Union. With export bans in place, the domestic price of mercury in these two regions, where supply is plentiful and demand limited, has become significantly lower than the free market price. This low domestic price of mercury may act to discourage the collection and recycling of mercury-added products and "scrap".

The two-tiered pricing system also creates an incentive for less scrupulous operators to attempt to profit from the price difference. Some have already tried to circumvent export restrictions in an attempt to sell mercury for a higher price on the open market. Authorities aware of this possibility are in a better position to counter such activities.

Recent trends

While the quantity of mercury available on the open market from the chlor-alkali industry has declined in recent years, primary mercury mining has increased overall in response to strong demand, such that the global mercury supply in 2015 was in the range of 3 850 to 4 400 tonnes per year. Better information to be provided under the Minamata Convention will permit more precise estimates.

Mercury trade

Mercury trading hubs

Largely due to restrictions on mercury exports from the European Union and the United States, since 2010 there has been a major shift in the locations of the key mercury trading hubs. The main United States and Spanish mercury traders operating in 2010 are no longer in the international trading business, and the main European trader operating mostly out of Rotterdam in 2010 has moved all mercury stocks outside the European Union. The former European Union and United States trading hubs have given way to Singapore and Hong Kong, and to a lesser extent Turkey and Viet Nam, which have become the major storage and transit points for global mercury trade. Periodic reporting on stocks held in such locations would help to clarify the links between the sources and final destinations of international mercury trade.

Undocumented and illegal transfers

As mercury trade has been subjected to additional scrutiny, and the market price remains relatively high, undocumented or illegal transfers have increased. In one example, a German company illegally exported large quantities of mercury (improperly characterized as waste) from Germany to Switzerland. Customs agents in Indonesia and the Philippines have intercepted Indonesian mercury and cinnabar ore smuggled in shipping containers. Mercury from China has appeared informally in sub-Saharan Africa and Myanmar. Undocumented Mexican mercury moves across the country's southern border. Large quantities of mercury imported by Colombia and Bolivia are transferred informally to neighbouring countries such as Peru, primarily for use in artisanal and small-scale gold mining.

Potentially dangerous practices

Along with the increase in informal mercury trade, there are also accounts of substandard mercury shipping flasks being used in Asia. In some cases non-certified steel flasks have been found with plastic bags inserted as internal liners in order to prevent mercury leakage. Forged hazardous transport safety labels have been fixed to substandard mercury flasks.

Quality of trade data

This research has confirmed that, although databases such as Comtrade and Eurostat are populated by data furnished by national statistical agencies, they are imperfect resources for understanding demand for and trade of mercury, and even more so, mercury-added products. For example, these databases do not show informal or illegal transfers. Moreover, in light of the enormous number of shipments and related documentation that customs agencies deal with, the authorities are able to carry out no more than spot checks to confirm that shipping manifests are consistent with the commodities carried; the trade data typically do not differentiate between mercury-added and mercury-free products; there is occasional difficulty in identifying the actual origins and final destinations of shipments; and there are sometimes mistakes (some of them intentional) in the tariff codes listed with shipments of certain commodities. These sorts of errors could be reduced by closer scrutiny of mercury shipments, and by the creation of additional tariff codes for mercury-added products. Even with such improvements, however, there would still be limits to the level of detail available from trade data, especially as some of the shipping information is considered to be commercially sensitive and therefore not accessible to the public.

Recent trends

It is notable that global imports and exports of mercury have decreased significantly during the last five years. According to the Comtrade database, in 2010 global imports were about 2 600 tonnes, and exports were about 3 200 tonnes. By 2015 global imports were less than 1 200 tonnes, and exports were just more than 1 300 tonnes. This decreased level of trade suggests that there are fewer steps in the mercury supply chain, and probably implies that the end uses are increasingly focused on specific sectors such as artisanal and small-scale gold mining and the production of vinyl chloride monomer. Even while the total volume of mercury trade has decreased, the fact that the overall supply of mercury has increased during the same period is a reminder of the significant challenges faced in the implementation of the Minamata Convention.

Mercury demand

Principal industrial processes using mercury

Since 2005 the major mercury uses continue to be in artisanal and small-scale gold mining (primarily in Africa, Asia and Latin America) and for the production of vinyl chloride monomer (mostly in China). These two applications are responsible for over 60 per cent of global mercury demand. The extent of artisanal and small-scale gold mining has steadily increased (along with the spot price of gold) since about 2000, and shows no sign of falling off as long as the price of gold remains historically high. Multiple programs are in place to help miners shift to mercury-free mining processes, but the challenges are vast. Mercury use in the production of vinyl chloride monomer is also at an all-time high, although measures are in place to reduce and ultimately phase out the mercury-based process.

In contrast, the use of mercury in chlor-alkali production has shown a significant global decline over the past ten years as mercury-cell facilities age, and a number of nations are encouraging their closure and/or replacement with mercury-free processes. Provisions in the Minamata Convention further encourage the mercury-free transition in all of these processes – artisanal and small-scale gold mining, vinyl chloride monomer and chlor-alkali production.

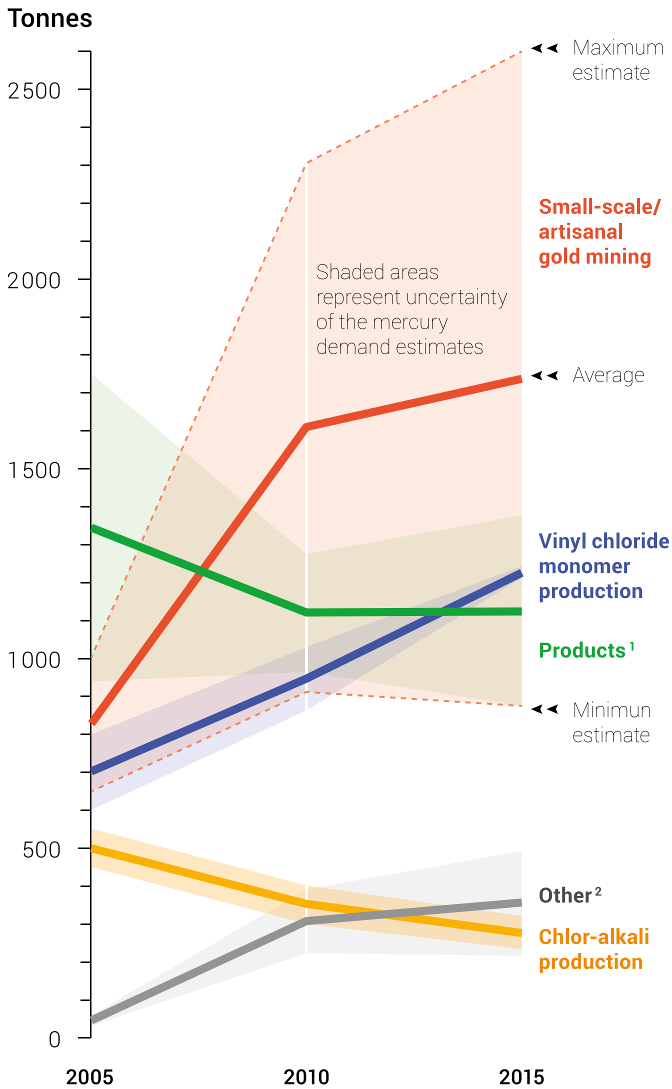
Mercury-added products and other uses

For mercury-added products, China remains a major manufacturer of such key products as measuring instruments, batteries and lamps. Mercury demand for all of these products has declined modestly in recent years, although some are subject to competing influences. For example, incentives for reduced energy demand have encouraged the substitution of incandescent lamps (that do not contain mercury) by compact fluorescent lamps (that do contain mercury) in many countries. At the same time, wealthier economies are already witnessing the replacement of compact fluorescent lamps by such energy-efficient and mercury-free alternatives as light-emitting diodes.

The use of dental amalgams, which contain about 50 per cent mercury, is also widespread, although global mercury demand has declined somewhat as mercury-free composites and other alternatives become more available and more reasonably priced. Many countries are seeing a growing preference for alternatives to amalgam and some, like Sweden and Norway, have already effectively phased out the use of mercury in dental care. In this sector as well, however, improvements in dental health care in less prosperous countries, where cost-effective mercury-free alternatives to amalgam may be less available, have led to increases in the use of amalgam (and therefore mercury) in those countries.

The accompanying figure summarizes the evolution of mercury demand in different sectors over the last 10 years, although the marked increase in the category of "other" uses should be seen more as a reflection of the recent availability of better information about these uses, than as an indication of a significant increase in demand. The shaded areas bordering each trend line in the figure show the extent of the uncertainties in the data.

Evolving mercury demand by sector, including uncertainties



1. Batteries, dental applications, measuring and control devices, lamps, electrical and electronic devices
2. Paints, laboratory, pharmaceutical, cultural/traditional uses, etc.

Sources: UNEP, 2006; AMAP, 2013; this report.

Recent trends

Largely due to the increases in demand for mercury in artisanal and small-scale gold mining and the production of vinyl chloride monomer, the global demand for mercury in products and processes has increased during the past ten years. For 2015, global demand for mercury was in the range of 4 500 to 4 900 tonnes, of which over 50 per cent was attributed to East Asia and Southeast Asia. These trends in certain sectors informed the negotiations leading up to the Minamata Convention, which includes provisions addressing all of the main categories of mercury demand.

Linking global mercury supply and demand

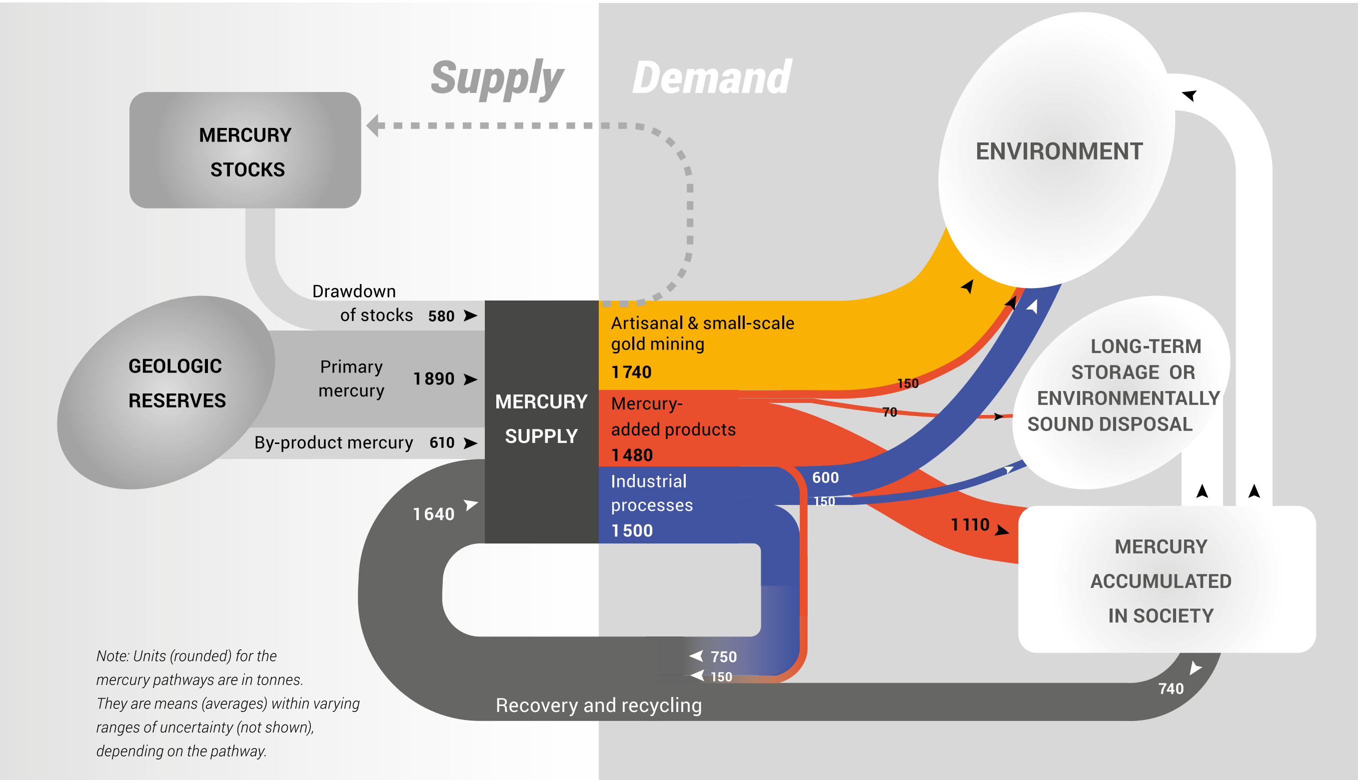
The analysis summarized in this report permits the visualization of global mercury pathways, from sources of supply to uses and sinks. The overview presented in the next figure is predicated on the assumption that all of the sources or intentional inputs of mercury to the economy must - even if they remain accumulated in the economy for some years - eventually become outputs from the economy. This model simplifies the outputs as:

1. Mercury in products or wastes that go to recycling
2. Releases to the environment
3. Transfers to long-term storage or disposal (e.g., hazardous waste landfill or salt mine)

Of all the intentional uses of mercury in a given year, only about one-third of the mercury supply comes from recovery and recycling, while approximately twice that quantity still ends up as releases to the environment, if one includes releases from mercury-added products and applications that were previously accumulated in society (e.g., mercury fever thermometers, blood pressure cuffs, batteries, etc., going into the municipal waste stream).

Mercury demand presently exceeds the basic supply by a significant amount, and it is likely that much of the difference in 2015 was made up through a drawdown of mercury stocks or inventories. Unless mercury demand can be reduced rather rapidly, this imbalance will further stimulate formal and informal mercury supplies and trade, and will add to the difficulty of changing course.

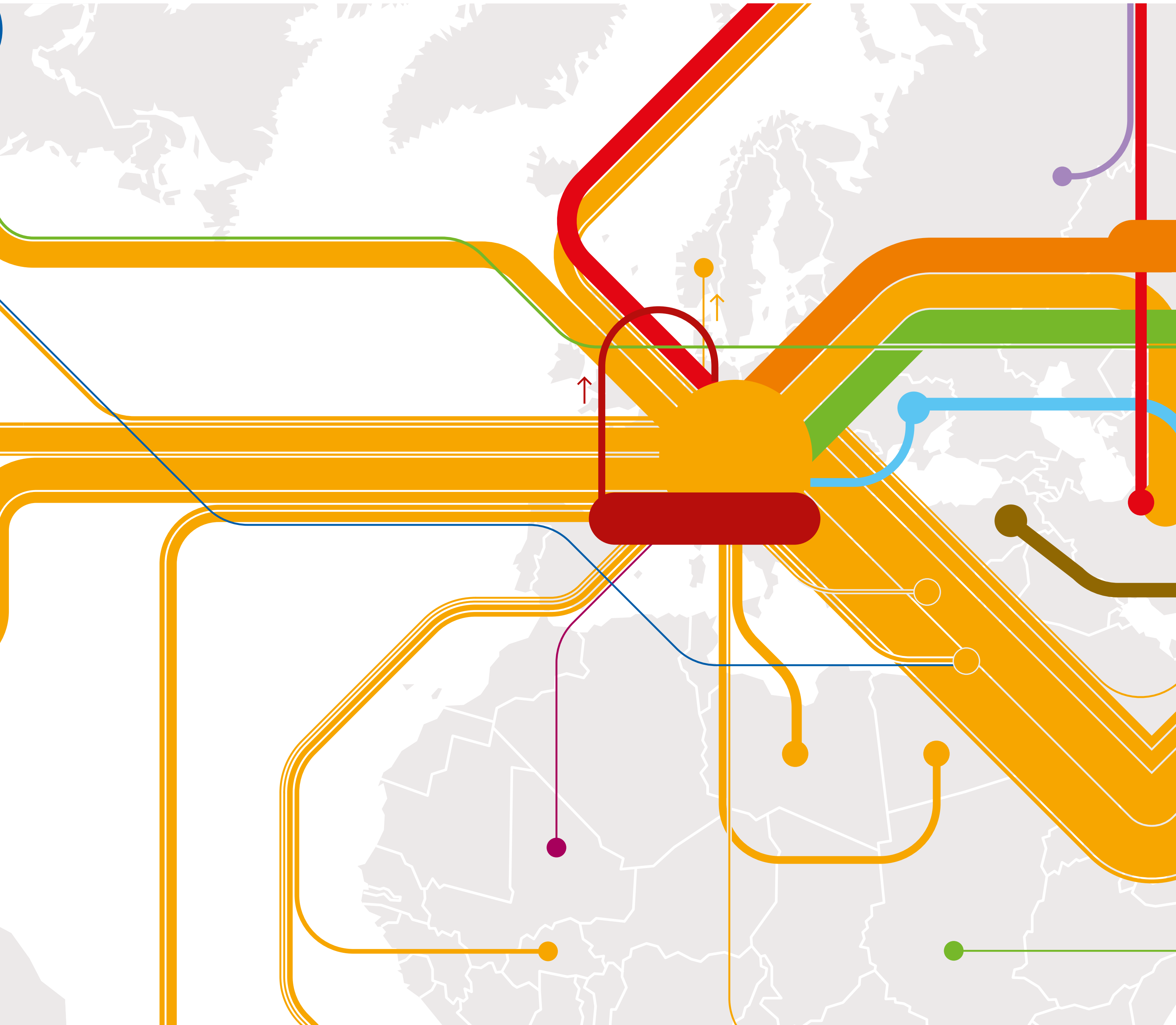
Global mercury supply and demand, 2015



1. Introduction

The Minamata Convention on Mercury[1] entered into force on 16 August 2017. In support of the ongoing discussions concerning the implementation of the provisions of the Convention, this report provides an overview of the global mercury market, which has seen fundamental changes in recent years, including major disruptions that have occurred during periods sometimes as brief as a year or two.

1 For details, see <http://www.mercuryconvention.org/>



In 2006 UN Environment published the *Summary of Supply, Trade and Demand Information on Mercury.* The report helped countries better understand the sources, trade flows and end uses of mercury. Now 10 years later, there are many differences in the ways that mercury moves through global commerce. The recently adopted Minamata Convention on Mercury includes various provisions to control the supply, trade and use of mercury, providing an ideal opportunity to take a fresh look into the global market.

The purposes of this report are:

- To provide an updated perspective on global mercury supply, trade and demand
- To identify key changes over the last ten years
- To support the Minamata Convention, especially regarding the availability and quality of data
- To determine the extent to which supply/trade/demand "snapshots" may be more readily developed than in previous iterations or reports

The main audiences for the report include governmental decision-makers, intergovernmental organizations, non-governmental organizations and others seeking to better understand current mercury movements so as to integrate these findings into policy decisions. To support this goal, analysts need to:

- Identify gaps in understanding and information concerning mercury supply and trade
- Identify methods for collecting additional (and/or better) trade data
- Understand the scope and reliability of the data reported to Comtrade and other data sources
- Identify measures that may help countries implement the Convention

Global mercury trade flows, marked by sometimes large annual variations and often conflicting data, only make sense when put in the context of the relevant mercury supply sources and ultimate demand, that is, intentional use in products and processes.

This report includes:

1. Identification of the main mercury producers and exporters
2. Appreciation of the rate at which mercury cell chlor-alkali facilities are decommissioning
3. Discussion of the importance of the Minamata Convention, especially in generating better information, in setting priorities, in educating stakeholders, in catalyzing concrete actions, and in training technical staff
4. Information about some of the main impacts of the export restrictions imposed by the European Union Regulation on Mercury,[2] and its predecessor, and the United States Mercury Export Ban Act[3]
5. Descriptions of the substantial flows of mercury from primary mercury mining destined for artisanal and small-scale gold mining activities, which will receive particular attention during the early implementation of the Minamata Convention
6. Insights into illegal and undocumented mercury trade
7. Updated information on mercury-added products and other uses of mercury that may not be specifically cited in the Minamata Convention

Among other resources, this report benefits from the UN Environment Mercury Inventory Toolkit, a valuable resource for educating users and focusing attention on priority mercury uses and releases. At the same time, this research has confirmed that even the best available information still provides an imperfect picture of global mercury sources, flows and uses.

2 Formally known as Regulation (EU) 2017/852 of the European Parliament and of the Council of 17 May 2017 on mercury, and repealing Regulation (EC) No 1102/2008. See European Union (2017).

3 Certain exemptions to the US and EU export "bans" permit limited mercury exports under specific circumstances. These regulations may therefore be technically regarded as export "restrictions" rather than "bans". In order to respect the intentions and titles of these legal measures, however, as well as for purposes of clarity, this report will continue to refer to them as export "bans".

1.1. Scope

This report does not cover health and environmental impacts of mercury releases and exposures. Health effects are treated in publications of the World Health Organization (e.g., WHO 2010). Nor does this report deal with mercury emissions and releases, which are periodically updated by the Global Mercury Assessment reports (AMAP/UNEP 2013).

Rather, this report provides a comprehensive update of global sources of mercury, global trade flows and end uses of mercury by geographical region and by category of end use. It includes:

- Quantification of the global mercury supply for 2015
- An overview of global mercury trade from 2007 to 2015, with a particular focus on trade during 2013-2015
- An assessment of the global demand for mercury in products and processes in 2015
- Discussion of shifts in the global and regional trade flows during the last 10 years, especially taking into consideration the export restrictions imposed by the United States and European Union mercury export bans
- Identification of major gaps in our understanding of the mercury supply-trade-demand continuum

1.2. Methodology

Comprehensive and precise information on most aspects of mercury supply, trade and demand is not readily available. At the same time, however, the extensive information that is available touches on virtually all aspects of this matter, and permits a reasonable understanding of conditions as the Minamata Convention enters into force. The development of the report entailed:

- Organizing a stakeholder discussion to obtain broad input regarding the structure of the study
- Compiling all relevant information, as described below
- Compiling data in such a way that it can be adapted to the needs of the periodic update of the Global Mercury Assessment
- Highlighting the major uses of mercury and the main challenges anticipated in early implementation of the Minamata Convention
- Producing appropriate graphics, visualizations, and summaries to assist in communicating the results of the analysis and any trends identified
- Organizing stakeholder review of the draft final report, and incorporating comments into the final draft, as appropriate
- Disseminating the updated results in both digital and print formats

All documents consulted are listed in the references and the appendix. A literature search was carried out for relevant peer-reviewed papers published since 2010. Also reviewed were consultant reports, other "grey" literature, latest revisions to the UN Environment Mercury Inventory Toolkit, and online sources.

The report relies on published and unpublished reports and research, mercury production and trade databases, personal contacts and interviews, reporting from the field, and input from experts and national authorities. Personal contacts included communications with industry operators (some of whom preferred to remain anonymous), specialty metals brokers, academic researchers, consultants and ASGM experts. Non-governmental organizations and other contacts with knowledge of the sector were also a valuable source of information, and helped with cross-checking other information. Also included are preliminary data or Toolkit-based mercury inventories from countries undertaking Minamata Initial Assessments, as available, to complement other information on mercury-added products.

The trade section of the report relies heavily on international trade statistics available from the United Nations International Trade Statistics Database (Comtrade), with reference to certain national and other databases. Trade statistics submitted by national agencies to the United Nations Statistics Division may be assumed to be consistent with national and international guidelines such as the European Union Waste Shipment Regulation, the European Union Prior Informed Consent Regulation and relevant US laws. All statistics used in support of the analysis in this report may be found in the appendix to the report or in online appendices referenced in the body of the report.

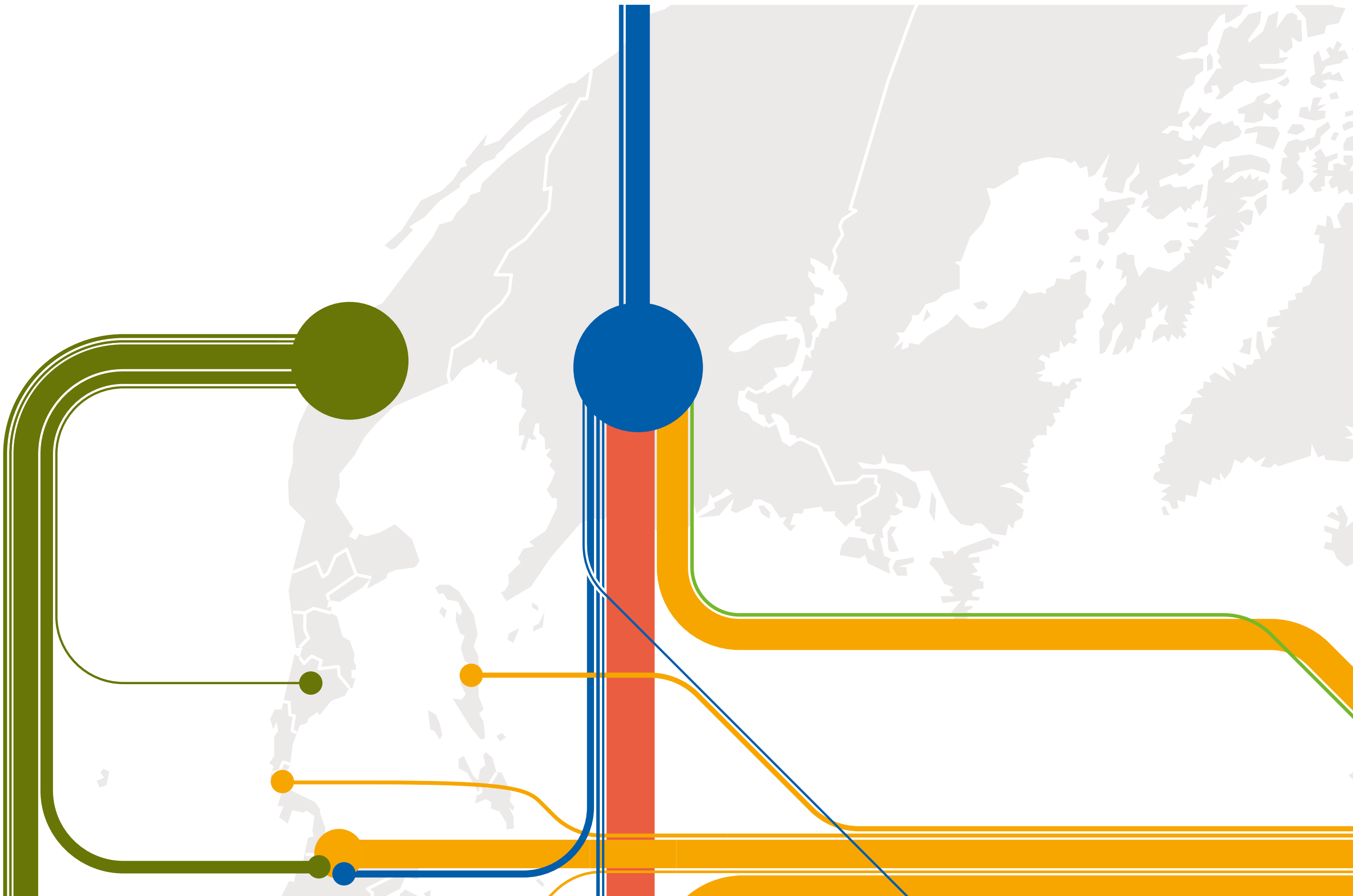
As a structure for analysis and as a resource of mercury information, the Mercury Inventory Toolkit has proven valuable. However, the ranges of mercury content in products, presented as default factors in the Toolkit – and reflecting the real world situation – are often broad, and some researchers have simply used these broad ranges when lacking the resources necessary to carry out a more fundamental investigation. As a result, imprecision in national inventories has been observed in cases where researchers may have limited previous experience collecting and analyzing the relevant data.

2. Sources and supply of mercury

The objective of this chapter is to roughly quantify the global mercury supply in 2015, including estimates of undocumented mercury that may have been produced or marketed. The mercury supply is derived from five main sources:

- Primary mercury mining, involving the processing of cinnabar ore
- By-product mercury recovery or "production" from other non-ferrous mining operations, as well as oil and gas processing
- Decommissioning (closure or conversion) of chlor-alkali facilities, followed by the recovery of mercury from the electrolytic cells and other parts of the plant
- Recycling of mercury-added products and other mercury-bearing wastes
- The net change in government or private stocks of mercury[4]

4 Most commonly the original source of mercury in government and private stocks would have been primary or by-product mercury, or mercury recovered after chlor-alkali decommissioning.



As contrasted with primary (mined) mercury, various references use the term "secondary mercury" to refer to by-product sources, to mercury recovered from processing operations and even to recycled mercury. In order to avoid confusion regarding these mercury sources, therefore, the term is not used in this report.

Important issues with regard to changes and trends in global mercury sources include the following:

1. Recent EU and US export bans have greatly restricted the export of previously important mercury supplies (especially mercury coming from the chlor-alkali industry), and other countries have adopted, or are considering similar export bans.

2. In the past, virtually all mercury recycled and recovered in the European Union and the United States was expected to be sold; now, due to limited domestic demand, severe export restrictions and limited options for dealing with hazardous waste, mercury recycling is increasingly viewed as an intermediate step on the way to stabilization and final disposal (B. Lawrence, personal communication, 29 July 2016; Dieter Offenthaler, personal communication, 18 July 2017).

3. Due to the domestic or regional surplus, the value of mercury inside the United States and the European Union is substantially lower than its value on the global market, providing an incentive for the illegal export of elemental mercury, as has occurred in the European Union, or the legal export of compounds that could be transformed back into elemental mercury.

4. Prior to the export bans, when mercury inside the European Union and the United States had a higher value, scrap metal dealers would routinely collect and deliver mercury-added products for recycling. Now there is less incentive for mercury scrap collection.

5. Sources of mercury will be increasingly scrutinized as the Minamata Convention provisions to restrict the use of mercury from certain sources become operational. For example, primary mined mercury should no longer go to ASGM now that the Convention has entered into force.[5]

6. Ongoing demand (especially for ASGM and vinyl chloride monomer production) combined with uncertain supply in recent years has contributed to increases and volatility in the free market price of mercury, which in turn has encouraged new mercury mining in Mexico and Indonesia.

7. Major stocks of mercury (in one recent case, an older Russian inventory that reportedly originated in Kyrgyzstan) continue to appear on the market periodically.

8. In the United States, some companies such as gold mines are storing more of their by-product mercury in the hope that the cost of handing it over to the government will not be excessive when eventually the government is obliged to take ownership of the mercury and manage it consistent with the 2016 amendments to the Mercury Export Ban Act of 2008.[6]

2.1. Primary mercury mining

Greer et al. (2007, 108) note, "It is crucially important that any mercury reduction strategy ratchet down supply and demand in a coordinated manner. This will ensure that steps taken to reduce demand do not flood the market with excess mercury supplies, which would invite mismanagement. Similarly it will ensure that a plummet in supply does not trigger a re-opening of already closed primary mines to meet unsatisfied demand."

This chapter deals with the supply side of the equation. A separate chapter deals with the demand side.

Mercury is currently mined only in China, Mexico, Indonesia and the Kyrgyz Republic. USGS (2015) mentions mercury mining in Tajikistan, but since the main output of the Anzob facility is antimony, its mercury production has been included with by-product mercury in this report. Likewise, USGS (2015) and previous USGS publications have reported 50 tonnes of mercury production in Russia, but this is by-product mercury addressed later in this chapter.

5 Two separate Convention requirements apply to this mining activity. First, effective upon the Convention entering into force, primary mined mercury cannot be used for ASGM. Second, all primary mercury mining must be phased out within 15 years of when the Convention enters into force for the Party.

6 The 2016 Toxic Substances Control Act statutory amendments provided non-ferrous mining and some related operations relief from Resource Conservation and Recovery Act hazardous waste storage requirements, allowing on-site storage for an extended period of time.

China has previously reported (Lin et al. 2016; Hui et al. 2017) mercury mining, although sources do not agree on the quantity of primary mercury produced. A recent report put production at approximately 780 tonnes annually (GEF 2015). Other estimates in the same range, such as 664 tonnes in 2014 (CNIA 2015), and some much higher (Qiu et al. 2016), have also been published. Considering the magnitude of China's domestic mercury demand, however, and the existence of artisanal mercury mining (Hu 2010; Qiu et al. 2016), the range of 800-1 000 tonnes is a reasonable estimate for the purposes of this report. China's trading partners have documented some mercury coming from China, and there are periodic reports of undocumented Chinese mercury appearing in Africa (World Bank 2016b; CEC 2017). Meanwhile China's trade relationship with Hong Kong remains fluid. For example, shipments from mainland China to Hong Kong are not reported as exports. When Hong Kong ultimately reports significant exports of mercury, it is logical that some of those may have originated on the mainland. Moreover, at the ultimate destination, it is not necessarily clear whether the mercury originated in China or in Hong Kong.

Official primary mercury mining in Mexico ceased in 1994 due to low global mercury demand and prices (Díaz 2013), but in 2011 the Mexican Geological Service, a federal agency, reported that three mercury mines appeared to have reopened and were working intermittently (Díaz 2011). In June 2016, UN Environment officials conducted a field visit and verified the existence of five resurrected mines, inferring that there are others as well (see box). In addition, some operations have long recovered mercury from mine tailings, as discussed in the section on by-product mercury. When funding becomes available from the Global Environment Facility (GEF), and in collaboration with UN Environment, a detailed assessment of mercury mining operations is to be carried out by Semarnat, the Mexican Ministry of Environment and Natural Resources.

As seen in Table 1, Mexican exports reached about 300 tonnes in both 2014 and 2015, with main destinations in Latin American countries engaged in ASGM (SIAVI 2016). There are also indications of important informal transfers of mercury from Mexico to Latin America, also likely destined for ASGM. One expert (L. Bernaudat, personal communication, 14 September 2016) has estimated that total mercury mine production in recent years may be twice the level of documented (as contrasted with informal or undocumented) exports, while others (J. Castro Díaz, personal communication, 14 September 2016) believe the total is not that high. The best estimate of primary mercury production in 2015 is in the range of 400-600 tonnes.

Both China and Mexico have ratified the Minamata Convention. For Parties to the Convention, new primary mercury mines are not allowed to start up after the Convention enters into force, and all existing mines are to be phased out within 15 years of that date (UNEP 2013c). Moreover, under Article 3 of the Convention, any primary mined mercury cannot be used for ASGM, which is a restriction some countries will find challenging to monitor and to enforce.

Table 1. Mercury exports to all countries, 2010-2015, as reported by Mexico

	Value (US$)	Quantity (kg)	Price per kg (average, US$)	Price per flask (average, US$)
2010	$958 941	25 513	$37.59	$1 297
2011	$8 669 938	134 302	$64.56	$2 227
2012	$21 454 783	261 841	$81.94	$2 827
2013	$23 406 327	267 645	$87.45	$3 017
2014	$17 681 581	300 931	$58.76	$2 027
2015	$13 909 189	306 695	$45.35	$1 565

Source: SIAVI database, available at <http://www.economia-snci.gob.mx/siavi4/fraccion.php>; accessed 24 July 2016.

Mercury mining in **Mexico**

Mexico has a long history of mercury mining at least 300 former mines have been identified. The richest mercury deposits are found in locations in the central states, such as Nuevo Mercurio in Zacatecas, Sierra Gorda in Querétaro, and the High Plateau in San Luis Potosí (Diaz 2013; Camacho et al. 2016).

Since the 1970s, however, other than ongoing recovery of about 24 tonnes of mercury per year from silver mine tailings in the state of Zacatecas, mercury mining had not been considered an economically viable activity. This assessment began to change around 2010 as the economic situation in the country and the rise in the price of mercury encouraged some individuals to organize the collection of mercury from artisanal miners for export. From 2010 to 2011 formal (as compared with undocumented, or informal) mercury exports increased from 26 to 134 tonnes, and even more in subsequent years, as in the table below (SIAVI 2016).

Mexican documented mercury exports and imports, 2010-2015 (kg)

	2010	2011	2012	2013	2014	2015
Exports	25 513	134 302	261 841	267 645	300 931	306 695
Imports	14 543	13 892	26 583	733	28	239

Source: SIAVI database, available at <http://www.economia-snci.gob.mx/siavi4/fraccion.php>; accessed 24 July 2016.

A number of the old mines that had been closed in the 1970s have been reopened. Studies from the University of Querétaro and the University of San Luis Potosí, a neighbouring state, estimated that 300-400 tonnes of mercury are extracted in their states each year. One expert on a mission to Mexico in 2017 estimated that mercury production only in the province of Querétaro involved 1000 miners producing nearly 300 tonnes of mercury per year (Spiegel et al. 2017). Bolivia, Colombia and Peru are the main destinations. These three countries are known to have extensive ASGM operations, although recent government controls in Peru have recently reduced documented imports of mercury for ASGM.[7]

Recent site visits confirmed the artisanal mercury extraction techniques typically employed, consisting of hand crushing and manual selection of material to roast, roasting in cylindrical chambers, and natural condensation of the gases. The various sites visited used mostly wood for the roasting process, although some used gas burners. Experts from the University of Querétaro have estimated that 20-25 per cent of the mined mercury is not recovered, either remaining in the cinnabar ore due to inefficient crushing, or lost to the environment as vapour leaks during processing (Source and photo: Bernaudat 2016).

7 In 2012 Peru published Legislative Decree No. 1103 establishing control measures for the distribution, transport and marketing of chemicals used in illegal mining. In 2014 it published Supreme Decree No. 029-2014-PCM, in which the President and the Council of Ministers endorsed a strategy and measures for the reduction and ultimate elimination of mercury in ASGM.

National government officials acknowledged in March 2015 that primary mercury mining was occurring in Indonesia. At that time their estimate for primary mining output was a minimum of 13 tonnes, while some Indonesian non-governmental organizations believed it was higher (Davis 2016). Not long afterward, in 2016, it was confirmed that Indonesian demand for imported mercury had declined significantly. In a recent paper, Spiegel et al. (2017) reported for the first time that mercury mining in Indonesia has substantially increased after starting quietly in 2012, encouraged by the high price of mercury (imported mercury is more than twice the price of locally produced mercury, though generally of higher purity) and substantial domestic demand from ASGM operations (see box). After exporting less than 20 tonnes of mercury in previous years, in 2015 Indonesia documented mercury exports of 284 tonnes (mostly to Hong Kong, Switzerland, Singapore and Viet Nam), as in Table 2.[8]

Since ASGM activities in Indonesia during that period were estimated to consume on the order of 150-200 tonnes of mercury (AMAP/UNEP 2013), questions were raised about the sources of so much mercury. Documented imports of mercury were minimal, although some undocumented imports were possible, mercury recovered from the oil and gas industry did not exceed 20-30 tonnes, and mercury in local storage had apparently been drawn down. Despite the many uncertainties, it is likely that mercury mining in Indonesia amounted already to 400-500 tonnes in 2015, and has surely increased since then (Spiegel et al. 2017).

Table 2. Mercury exports to all countries, 2010-2015, as reported by Indonesia

	Value (US$)	Quantity (kg)	Price per kg (average, US$)	Price per flask (average, US$)
2010	$42 687	14 370	$2.97	$102
2011	$9 610	19 467	$0.49	$17
2012	$8 530	16 250	$0.52	$18
2013	$1 929	6 978	$0.28	$10
2014	$255	810	$0.31	$11
2015	$2 615 999	283 767	$9.22	$318

Source: Comtrade database, available at <https://comtrade.un.org/data>, accessed 28 August 2017.

8 In 2016 mercury exports of 350 tonnes were reported only from the main seaport of Jakarta, primarily to Singapore, India, Hong Kong, the United Arab Emirates and Viet Nam (Indonesian Customs 2016).

Mercury mining in **Indonesia**

As mercury prices skyrocketed from 2011 to 2013, and local demand from ASGM continued to increase, artisanal mercury mining in Indonesia gradually took on a much larger role (Spiegel et al. 2017) – first to supply domestic ASGM demand, and then for the export market.

Prior to 2015 the Indonesian government had not acknowledged the existence of domestic mercury mining. In March 2015 the government acknowledged mercury mining amounting to at least 13 tonnes, while some Indonesian non-governmental organizations were convinced the production was much greater (Davis 2016). During the course of 2015 Indonesian Customs seized at least 14 shipping containers of cinnabar and metallic mercury prepared for export and believed to be obtained from domestic mining. Two of the destinations listed were Hong Kong and the Philippines. Some of the goods were accompanied by a false export declaration, and in one case the exporter used another company's name for exporting the goods (Lestaripost 2015; Jakarta Globe 2015).

Mercury mining permits are rarely granted by the government, so these operations   located mainly in Maluku Province, West Kalimantan and East Java   are mostly illegal. Initially, most of the cinnabar was transported to Jakarta for smelting, and some to Surabaya. More recently, smelting operations have opened in Sukabumi (West Java), Ambon City and Seram (one of the Maluku islands).

The manager of one of the smelting operations in East Jakarta, which has been operating only since the last quarter of 2016, reports that his operation receives extraordinarily high-grade cinnabar (50-65 per cent mercury content) flown to Jakarta from Seram. The smelter receives cinnabar in sacks, crushes the cinnabar, and fills iron cylinders with the material (and a small amount of "catalyst") for smelting over a fire in a long trench, as in the photo provided. The distilled mercury condenses down long tubes welded to the cylinders and drips into cups filled with water (personal communications, March 2017).

This operation has a present production capacity of 4-5 tonnes of mercury per week, although average sales so far are about one-third of that amount. The manager is actively looking for international buyers, who will pay more for the mercury than local merchants, and has already sold mercury to buyers from China, Hong Kong and India. He says he is able to arrange export of the mercury, but prefers that buyers make their own transport arrangements for export.

The Kyrgyz Republic's Khaidarkan mine once supplied primary mined mercury to the global marketplace. During the last 10 years production has been in decline due to technical challenges related to deep mining, and a lack of adequate investment in an uncertain economic environment. The United States Geological Survey (USGS 2016b) estimated mine production at 70 tonnes in 2015, although the main western buyer estimated the output at no more than 30 tonnes (personal communication, 9 August 2016), especially as Khaidarkan is no longer refining the antimony-mercury concentrates it used to receive from Tajikistan.

For some years, with leadership from the governments of Switzerland and the United States, UN Environment has made it a priority to assist the Kyrgyz government in transitioning away from primary mining (UNEP undated 1). In October 2009, the government of the Kyrgyz Republic announced its willingness to consider closure of the Khaidarkan mine under certain conditions (UNITAR 2009), but outstanding issues have not been resolved. Since that time there have been other international efforts to encourage closing the mine. The most recent is a Global Environment Facility project designed to replace primary mercury mining with alternative sources of income (GEF 2013).

Other informal mercury mining activities may take place in a few other countries such as Peru, but the output would not be significant enough to change the general conclusion of this analysis, which is that global primary mercury production, both formal and informal, is estimated to be in the range of 1 630-2 150 tonnes, as summarized in Table 3.

Table 3. Global primary mercury mining, 2015

Country or region	Mercury marketed (tonnes)
China	800 – 1 000
Mexico	400 – 600
Indonesia	400 – 500
Kyrgyz Republic	30 – 50
Peru and other countries	minimal
TOTAL	**1 630 – 2 150**

2.2. By-product mercury

2.2.1. Non-ferrous ores

For the purposes of this report, by-product mercury is defined as mercury that is a naturally occurring component of an ore from which it is separated through an industrial or chemical process, as contrasted with a material or product to which mercury is intentionally added. Mercury may appear as a trace contaminant in other non-ferrous ores, especially zinc, gold, lead and copper ores, but also sometimes silver and antimony. If the mercury content in a non-ferrous ore is high enough to warrant removal, there are various methods for removing it at some stage of the refining process in order to produce a metal of the required purity. After removal, the by-product mercury is typically in the form of calomel (Hg_2Cl_2) or metallic mercury, or it may be captured on activated carbon filters or at other stages of the removal process.

It is evident that for reasons of limiting the total quantity of mercury circulating in the biosphere, when mercury is needed in commerce it is preferable to use by-product mercury than to mine primary mercury. By-product mercury is most frequently generated from non-ferrous metal refining operations, however, and most of this mercury still goes to disposal or is released to the environment (AMAP/UNEP 2013). This poses a challenge in determining how much by-product mercury is eventually marketed, since the recovery of mercury from other ores does not necessarily imply that the recovered mercury will be put on the market.

Until recently, in the United States by-product mercury in elemental form, calomel, mercury-bearing sludge, mercury-zinc precipitates and mercury collected on pollution control devices were typically sold to US recycling companies for further processing (USEPA 2009). Now that the recyclers can no longer export the refined elemental mercury, some of this by-product is going to disposal and some is put in storage. Since 2006, in order to better monitor the trace mercury in many of the local non-ferrous ores, the US state of Nevada Mercury Control Program has required that local companies must report annual mercury production and emission statistics to the Nevada Division of Environmental Protection (USGS 2013).

Barrick Gold Corporation, a major mining company operating in various countries as well as Nevada, states:

> *"… elemental mercury captured from air pollution controls at our US operations is currently stored pending the construction of the federal mercury repository. Mercury compounds are disposed of at a licensed hazardous waste facility…. In the case of operations at Latin American sites, mercury is currently securely stored on site…."*[9]

In Canada, Teck Metals Ltd./Cominco/Trail Operations in Trail, British Columbia, in 2014 sent 3.7 tonnes of mercury (including the mercury content of mercury compounds) from non-ferrous ore processing to the United States[10] for recycling and stabilization, followed by eventual disposal in Quebec, Canada (B. Lawrence, personal communication, 29 July 2016). Alternatively the recycled mercury could have been sold in the US domestic market, or kept in long-term storage and management consistent with the provisions of the Mercury Export Ban Act.

The USEPA Chemical Data Access Tool (CDAT)[11] shows that Barrick Goldstrike Elko in 2010 reported as by-product and sent for recycling nearly 55 tonnes of mercury (13 tonnes elemental and nearly 42 tonnes of mercury in mercury(II) chloride).[12] Although most US gold mining takes place in Nevada, Barrick is responsible for only about 50 per cent of the total (Perry and Visher 2016), so the industry-wide figure for the United States is evidently larger.

9 See <http://www.barrick.com/responsibility/environment/tailings-waste/default.aspx>, accessed 24 August 2017.

10 Data from Canada's National Pollutant Release Inventory (NPRI) database, available online at <http://ec.gc.ca/inrp-npri/donnees-data/index.cfm?do=substance_details&lang=En&opt_npri_id=0000003802&opt_cas_number=NA%20-%2010&opt_report_year=2014#recycling>

11 The Chemical Data Reporting (CDR) Rule, issued under the Toxic Substances Control Act (TSCA), requires manufacturers (including importers) to give EPA information on the chemicals they manufacture domestically or import into the United States. The USEPA's Chemical Data Access Tool (CDAT) permits a search of the reported data by chemical name, and company. <https://java.epa.gov/oppt_chemical_search/> accessed 21 June 2016.

12 For its worldwide operations Barrick reported generating 142 tonnes of by-product mercury in 2015 and 275 tonnes in 2016. See <http://www.barrick.com/responsibility/environment/tailings-waste/default.aspx>, accessed 24 August 2017.

In China, despite the large quantity of mercury (estimated by Wu et al. (2016) at 1 005 tonnes in 2014) in non-ferrous metal ore concentrates processed annually, it is only in recent years that some mercury has been recovered from the processing of zinc and antimony concentrates. Currently, there is one antimony-mercury mine located in Xunyang, Shaanxi, that produces mercury at a relatively large scale (Lin et al. 2016). In 2014, antimony ores contributed 70-90 tonnes of mercury (CNIA 2015). A figure was not given for zinc, but since Wu et al. (2016) estimated recovered mercury at 63 tonnes total in 2014, the quantity for zinc in 2015 would not be expected to be greater than that for antimony. It should also be noted that these sources of mercury may not be considered to come from primary mercury mining, and therefore are not subject to the Minamata obligations associated with phase-out and use restrictions.

The US Geological Survey (2016) estimated total mercury by-product from non-ferrous metal mining in Peru, Argentina and Chile at 70 tonnes, which was a substantial reduction from USGS estimates published less than a year before, and inconsistent with the quantities of by-product mercury Peru exported to the United States in previous years (B. Lawrence, personal communication, 18 July 2017). In Argentina alone, Barrick's Veladero gold mine produced 59 tonnes of by-product mercury in 2015 and 135 tonnes in 2016.[13] Some of the US Geological Survey estimates are based simply on export data, and would not necessarily include mercury stored on site. Referring to information previously reported in UNEP (2008), the total by-product mercury recovered from these mining operations is therefore estimated to be more than 100 tonnes.

Stepanov and Moiseenko (2008) estimated by-product mercury recovered from Russian gold mining at 50 tonnes. Since gold mine output has increased by at least 30 per cent (approx. 250 tonnes mined in 2014) since the Stepanov and Moiseenko estimate, it may be assumed that at least as much mercury continues to be recovered. USGS (2016) did not estimate Russian mercury production, although in previous years it supported the estimate of 50 tonnes.

Several years ago a large antimony mining operation in Tajikistan began to recover on site and sell on the open market by-product mercury from antimony concentrates,

13 Ibid.

amounting to nearly 30 tonnes of mercury per year. Formerly these concentrates had been sent to Kyrgyzstan's Khaidarkan complex for recovery of the mercury (personal communication, 9 August 2016).

For many years miners in Mexico have recovered silver and mercury from mine tailings in Zacatecas using the lixiviation method. These tailings were generated by silver mines (operating between 1556 and 1900) that used the amalgamation method (Díaz 2013). Production of mercury in 2015 has been estimated at around 25 tonnes. Meanwhile a new plant – also with mercury production capacity estimated at 25 tonnes per year – has been constructed and has applied to Semarnat (Mexican Ministry of Environment and Natural Resources) for an operating permit (CEC 2017).

Apart from gold ores, in light of the quantity of ore mined and the trace mercury content, zinc ores have the potential to supply the greatest quantity of by-product mercury globally. In 2007, based on the equipment installed worldwide for removing mercury from zinc ores, Boliden officials calculated theoretical by-product mercury production based upon the design capacity of the units, the amount of gas managed in the units, and the typical mercury content of the gas. Globally, they estimated that about 260 tonnes of mercury content in calomel could be generated annually at zinc smelters, with major uncertainties related to individual plant operating characteristics, the operating status of the mercury removal units, and other factors (UNEP 2008). This information is used here only for an order-of-magnitude indication of by-product mercury production in other countries not identified above, of which relatively little mercury appears to reach the marketplace.

As regards the generation of mercury compounds during the purification of ores, according to the Comtrade database, in 2015 the United States exported over 200 tonnes of mercury compounds (HS code 2852), mostly to Canada, although there is no indication as to what part of that total may have been generated as by-product.

According to the Comtrade database, the 28 member states of the European Union exported between 118 and 160 tonnes of mercury compounds (HS code 2852) from the EU each year from 2012 to 2014. Again, there is no indication as to what part of that total may have been by-product. Beginning in 2015, however, this trend had reversed and the EU-28 became a net importer of mercury compounds with a net import of 28.5 tonnes, followed by 120 tonnes in 2016. Based on a recent study for the European Commission (2015a), it is estimated that 50-100 tonnes of equivalent mercury in compounds were put on the EU market in 2015.

2.2.2. Oil and natural gas

Most oil and natural gas contain mercury in trace quantities. In many regions of the world, depending on geology, especially some gas fields in the Netherlands, North Sea, Algeria, Croatia, Malaysia, and Indonesia, the trace mercury content is high enough to cause serious equipment problems during processing if the mercury is not removed.[14]

Crude oil

As cited in UNEP (2015), the production weighted global average mercury concentration in crude oil was somewhere between 3.4 mg/tonne and 5.7 mg/tonne, or on the order of 15-20 tonnes of mercury in 2015, assuming crude production of about 30 billion barrels, or about 4 billion tonnes of oil equivalent. Oil refineries often remove mercury when it exceeds certain levels, but the total removed and then recycled is small in relation to other sources of by-product mercury, so will be ignored for the purpose of this report.

Natural gas

Mercury in natural gas, on the other hand, should not be ignored, especially considering the quantities of gas that are flared regardless of the mercury content. As mentioned, the mercury concentration in natural gas varies considerably with the geology, and may even vary significantly between gas fields in the same region. The variation is wide enough that a global average mercury concentration would have little meaning.

Pirrone et al. (2001) reported that "a reduction of mercury to below 10 μg/Nm^3 has to be obtained before the gas can be used," although mercury at far lower concentrations is often removed from gas as well. An equipment provider has suggested that it is desirable to reduce the mercury concentration to as little as 0.01 μg/Nm^3 in order to avoid mercury damage (UoP-Honeywell, CalgonCarbon). This is a level that is exceeded in most gas fields – not infrequently by several orders of magnitude. UNEP (2015, 83) provides examples of a dozen measurements taken in the field, varying from close to zero in some parts of the Netherlands, to nearly 50 μg/Nm^3 in the Middle East, and to 300 μg/Nm^3 in East Asia and other parts of the Netherlands. An industry technical report gives a range of 1-2 000 μg/Nm^3 based on assessments from five continents (UOP 2010). A single gas field in Indonesia estimated it could recover 85 kg of elemental mercury (plus 1-3 kg of mercury recovered from spent catalyst) per month if it set up the necessary recovery system (Indonesia 2010).

14 Specifically, mercury condenses as liquid mercury on the inside of piping and equipment, or it amalgamates with aluminum (most problematic) or other metals (except iron), gradually corroding and weakening the metals, which has resulted in serious industrial accidents.

Therefore, a specific mercury analysis for each well is a prerequisite for the operators of these facilities. In order to avoid damaging production equipment, gas is typically cleaned at the wellhead. In some countries, such as Oman, all mercury in gas cleaning systems (such as mercury "guard") is recovered and marketed as by-product mercury. In other countries, such as Malaysia, the mercury "guard" or other contaminated system is simply collected and disposed of as hazardous waste (personal communication, 19 July 2017).

Considering global gas production of 3.59 trillion cubic metres in 2015 (IEA 2016), an average concentration of 0.1 µg/Nm3 would imply total mercury of 359 kg, while an average mercury content of 50 µg/Nm3 would imply total mercury amounting to 180 tonnes. This large range of uncertainty in trace mercury concentration, combined with the potentially damaging effects, reinforces the need for routine reporting for each well.

No broad analysis of mercury recovered from natural gas has been carried out since UNEP (2006). A Dutch recycler continues to treat filters and sludge from the Dutch oil and gas company (K. 't Hoen, personal communication, 12 August 2016). Based on this and other sources mentioned, it is unlikely that the quantity of by-product mercury recovered and marketed globally from the cleaning of natural gas exceeds 30 tonnes.

Table 4 reflects the reality that many countries generate by-product mercury from mining and gas cleaning operations, although not all of this mercury finds its way to the market. For example, by-product mercury originating in the European Union and the United States may no longer be lawfully exported if it is in the form of elemental mercury or certain mixtures of elemental mercury. If the by-product is in the form of a mercury compound, however, it may still be exported legally.[15]

Table 4. Global by-product mercury production, 2015

Country or region	By-product source	Mercury captured (tonnes)	Mercury marketed (tonnes)*
Russia	Gold ores	40-70	40-70
Peru, Chile, Argentina	Gold, zinc, copper ores	150-200	100-150
Tajikistan	Antimony ores	30-40	20-30
China	Zinc, antimony ores	120-240	100-200
United States	Gold, silver ores	150-250	20-30
European Union	Non-ferrous concentrates	no estimate	50-100
Mexico	Silver ores	25	25
Japan	Zinc ores	20-30	20-30
Other countries	Zinc ores	100-300	20-60
Other countries	Gold, copper, lead, antimony ores	100-200	30-50
All countries	Natural gas	30-100	15-30
TOTAL		**765-1 455**	**440-775**

* Including mercury sold on the domestic market as well as for export, where permitted.

15 Section 3.2.4 discusses current and pending restrictions on the export of mercury compounds.

2.3. Chlor-alkali industry

The chlor-alkali industry produces chlorine and sodium hydroxide (caustic soda) or potassium hydroxide (potash), which are important commodity chemicals. There are three main production methods: mercury cell, diaphragm cell, and membrane cell.

The mercury cell process, which accounts for about 8 per cent of the global chlorine production capacity of some 60 million tonnes, subjects a brine solution to an electrolytic process that separates the chlorine (or potassium) from the sodium hydroxide. Essentially, a layer of mercury at the bottom of large "cells" full of brine acts as a cathode for a heavy electric current applied to the brine.

Mercury waste is generated during the normal operation of mercury cell chlor-alkali facilities, some of which may be sent to recycling, while the rest goes to disposal. Also, as the mercury cell process is gradually replaced by mercury-free processes throughout the industry, the large amounts of metallic mercury in the cells can be recovered. Similarly, mercury that has settled in sumps and drains, and mercury that has adhered to the inside of piping systems, among other parts of the plant, can be recovered. Within their own regions, the European Union and United States mercury export bans have effectively designated all of this mercury as waste for disposal and/or mercury for long-term storage.

The European Union, which for many years relied heavily on mercury cell technology, still had 27 plants operating in 2015, with chlorine production capacity of about 2.8 million tonnes. The European Union's Industrial Emissions Directive mandates that mercury-cell technology cease before 11 December 2017 (Euro Chlor 2016), but realistically some plants may not manage to close that soon. According to Regulation (EC) No 1102/2008 (superseded by Regulation (EU) 2017/852), which greatly restricts exports of mercury outside of the European Union (European Commission 2017), any mercury coming from this industry is considered waste and must either be sent to safe storage or be used to satisfy demand within the member states of the European Union. The European Commission has estimated that the EU Regulation prevents about 650 tonnes of chlor-alkali industry mercury per year from reaching the global market (European Commission 2015).

At the end of 2015 there were only two mercury cell facilities still operating in the United States. ASHTA Chemicals (Ohio) announced in June 2014 that it intends to shift to membrane cell technology (ASHTA 2014). Once that transition is complete, Westlake Chemical Corporation's plant in New Martinsville (West Virginia) will be the only remaining mercury cell facility in the United States. Under the Mercury Export Ban Act, mercury recycled or recovered from the chlor-alkali industry can no longer be exported.

In 2016 Mexican industry was in search of financial support to convert its two remaining chlor-alkali plants to membrane cells (UNEP 2016a). The conversion will free up an estimated 265 tonnes of mercury from the production cells (Díaz 2013). Like all Parties to the Minamata Convention, Mexico will be required to phase out mercury-cell chlor-alkali production by 2025 (UNEP 2016b) or seek a time-limited exemption.[16] At present, however, the government has placed no restrictions on the potential marketing of this mercury.

In recent decades, the decommissioning or conversion of chlor-alkali plants using the mercury cell process has been a major source of mercury worldwide. The rate of change in the industry, and availability of mercury to the global market is typically influenced by private business decisions regarding chlorine/caustic markets, the economics of conversion, public policy and occasional government incentives. Some recent events include:

- India closed its last mercury cell facility at the end of 2015
- One of the plants that closed recently in the United States paid for its mercury to be recycled, stabilized as mercury sulfide and disposed of in Canada (B. Lawrence, personal communication, 29 July 2016)
- Serbia marketed 18 tonnes of mercury from a Pancevo chlor-alkali facility that had been damaged during the Balkan conflict, as well as 6 tonnes recovered from another chlor-alkali source
- Chemical Industries Limited (CIL), Singapore, sold approximately 1 200 flasks (about 41 tonnes) of recovered mercury from their chlor-alkali plant to Major Metals Ltd. of India

16 The Minamata Convention mandates a phase-out of mercury cell chlor-alkali facilities by 2025 (Minamata Convention, Annex B). It also requires each Party to take measures to ensure that, if it determines that it has excess mercury from these facilities, to dispose of it in ways that do not lead to the recovery, recycling, reclamation, direct re-use or alternative uses of the mercury (Minamata Convention, Article 3). In the meantime, it requires Parties to take measures to address emissions and releases of mercury from these facilities, and to regularly report on progress (Minamata Convention, Article 5).

- The European Union continues to reduce its reliance on mercury cell technology. A Romanian chlor-alkali plant managed by Oltchim SA has recently been closed, and the disposition of 158 tonnes of mercury awaits a decision on a final destination, which, according to European Union regulations, cannot be outside of the European Union

Worldwide, at the end of 2015 there remained about 75 plants using the mercury cell chlor-alkali process operating in 40 countries, plus two plants in Germany using the mercury cell process to produce sodium methylate (WCC 2016; Euro Chlor 2015; UNEP 2016b).

As mentioned above, global chlorine and caustic production using the mercury cell process have been on the decline for many years. In 2005 there were roughly 9 million tonnes of global chlorine capacity using mercury cell technology. In 2010 there were nearly 7 million tonnes (AMAP/UNEP 2013), and in 2015 around 5 million tonnes (UNEP 2016). Since roughly 2 tonnes of mercury are needed[17] per thousand tonnes of chlorine production capacity, the total inventory of mercury in use in the industry globally is about 10 000 tonnes. Of this total, more than half is located in the European Union (with another 2 per cent in the United States) and is therefore subject to export restrictions.

Since 2005 the global mercury cell chlorine capacity has declined by an average of about 400 000 tonnes every year – and more in 2015 due to the pressure put on the industry by European Union regulations – effectively freeing up nearly 1 000 tonnes of mercury in 2015. After 16 August 2017, however, Parties to the Minamata Convention are no longer permitted to market mercury from chlor-alkali plants, but will have to send it for disposal.

The calculation of the quantity of chlor-alkali industry mercury that may have become commercially available in 2015 is complicated. For example, the removal of mercury from the cells may not occur until many months after shutdown. Or the mercury may be transferred to other plants that have not yet closed, or to other domestic markets using mercury. Or government restrictions may prevent the mercury from being marketed commercially.Considering the dominance of European Union mercury cell capacity combined with the current pressure to close or convert those plants, one might simply assume that two-thirds of the 2015 shutdowns occurred in the European Union, and the recovered mercury (approx. 2/3 ⅔*1 000 = 670 tonnes) could not be marketed outside the industry. Inside the industry, however, the 70-100 tonnes consumed by the European Union chlor-alkali industry in 2015 would have been supplied from the recovered mercury. This should be added to the 300-350 tonnes of mercury recovered outside the European Union that likely reached the market, as summarized in Table 5.

Table 5. Mercury recovered from chlor-alkali for commercial use, 2015

Mercury source	Region	Mercury marketed
Chlor-alkali electrolysis cellrooms	Global (except EU and US)	300 - 350
Chlor-alkali electrolysis cellrooms	European Union	70 - 100
TOTAL		**370 - 450**

17 On average, 85-90 per cent of the mercury is in the electrolytic cells, and 10-15 per cent in storage.

2.4. Recycled mercury

Mercury may be recycled from mercury-added products and related wastes, or it may be recovered from certain industrial processes and wastes. The primary focus of this analysis is sources of mercury available to the commercial sector. This analysis will separate out the mercury recycled only for the purpose of subsequent disposal.

Mercury can be recycled from discarded mercury-added products, typically using a retorting process. In the United States in 2015, some 50 companies collected mercury-added automobile convenience and anti-lock braking system (ABS) switches, barometers, compact and tube fluorescent lamps, computer components, dental amalgam, thermometers and other medical devices, thermostats, mercury-added toys, and other such items, and forwarded them to six companies in the US for recycling (USGS 2016a).

Most mercury recycling takes place in China, the European Union, the United States and India. Changes in the mercury markets have affected the European Union recycling business. In the past, recyclers charged a basic recycling fee that was then reduced according to the mercury content of the waste, that is, the value of the metallic mercury to be recovered. Now recyclers are obliged to charge more because the European Union market for mercury is limited, and there is no assurance that all recycled mercury can be sold. Some of the mercury may eventually have to go to stabilization and safe disposal.

In addition, 20-25 metal scrap companies in the European Union that regularly received small quantities of mercury (in total up to 2-3 tonnes/year) previously sold the material to recyclers for purifying or recovery for resale, or for disposal. Now that this mercury waste has a negative value and a scrap merchant needs to pay the recycler to accept it, there is less incentive for the scrap merchant to collect the material and send it on to the recycler (K. 't Hoen, personal communication, 12 August 2016). It was not within the scope of this report to determine how much this business may have declined in recent years.

For China there are several estimates of mercury produced by recycling (Lin et al. 2016; Hui et al. 2016), but the most reliable appears to be CNIA (2015), which estimated 520 tonnes of mercury retrieved from the recycling of vinyl chloride monomer (VCM) catalysts and wastes in 2014. Estimates using the significantly higher GEF (2015) figures for mercury use for VCM production suggest that recycling may have risen to 600-650 tonnes in 2015. In addition, CNIA (2015) estimated over 200 tonnes of mercury recycled from wastes (separate from by-product mercury recovered from antimony processing) in 2014.

Based on reported production of VCM and other data from China's VCM industry, Russia and India are estimated to consume only about 10-15 tonnes of mercury for vinyl chloride monomer production (Russia 2017; Chakraborty et al. 2013); half of this amount is assumed to be recycled.

In the European Union, Claushuis (recycling batteries, dental amalgam and other waste) and Begemann (recycling filters and sludge from the Dutch oil and gas company, among other things) are well-established recyclers based in the Netherlands. There are three German recyclers, of which NQR is the largest, and one in Switzerland – Batrec. One recycler estimates the EU market for recycled mercury at 30-40 tonnes per year (K. 't Hoen, personal communication, 12 August 2016). Some recyclers have been storing mercury they have not been able to sell partly because it is less costly than stabilizing and sending the mercury for disposal, and partly in the hope that they can sell the mercury in the EU - therefore gradually accumulating stocks. Although several EU firms were investigating mercury stabilization processes to enable safe disposal of mercury, some efforts were put on hold after an accident in Germany in 2016. [18] Before the accident, Remondis advertised a process to convert mercury to mercury sulfide using a dry process. The mercury sulfide would then be packaged for long-term safe storage in the salt mines managed by K+S Entsorgung GmbH in Herfa-Neurode, Germany.

Since Switzerland is not a member of the European Union and does not have an export ban or similar restrictions on elemental mercury, Batrec has been free to sell recycled mercury on the open market. In 2006 and 2007 Batrec recycled 8.4 and 8.9 tonnes of mercury respectively (H. von Gunten, personal communication, 27 June 2008). Batrec's mercury production in 2015 is not available. In recent years Batrec has also developed a "wet" process for stabilization of mercury, which is typically followed by disposal in the German salt mines.

18 Following the DELA GmbH affair, the German company Remondis took over the DELA mercury processing/stabilization facility in Dorsten (Germany) during the first quarter of 2016. On 24 May 2016 there was an explosion at the Dorsten facility that killed one person and injured three others. See <http://www1.wdr.de/nachrichten/ruhrgebiet/arbeitsunfall-dorsten-vier-verletzte-100.html>.

Of the several mercury recyclers in the United States, Bethlehem Apparatus has long handled the largest quantities of mercury. They estimate that the US market for recycled mercury amounts to 40-50 tonnes per year (B. Lawrence, personal communication, 29 July 2016). Bethlehem Apparatus has put into operation its own dry process for stabilizing elemental mercury by converting it to mercury sulfide, after which it is currently sent to Canada to be mixed with concrete and interred in a special landfill.

Formal and informal recycling of mercury in India is quite active, but no details are available concerning the quantities recycled. India typically reports importing 150-200 tonnes of mercury per year. In order to include recycling of mercury-added products and wastes in India and other countries not already quantified, especially in Asia, a broad range of 50-200 tonnes is suggested.

Apart from VCM catalysts, there are some other mercury-bearing VCM process wastes, but these may be considered to be included in the VCM data above. Likewise, apart from the mercury removed from chlor-alkali cells, mercury is periodically recovered from chlor-alkali facility sumps and drains, and the decommissioning process permits mercury recovery from the building floor and structure, surrounding soils, sludge and other wastes. Some of this waste is recycled in the European Union and may be reused in the industry. The preceding section on chlor-alkali assumes that European Union consumption in the chlor-alkali industry is satisfied by mercury recovered from the electrolytic cells. Mercury use in the US chlor-alkali industry, likewise, may be assumed to be included in US recycling discussed above. In other countries, however, some 50-150 tonnes of mercury may be recovered from such sources in both closed and operating facilities during a typical year.

It is assumed that other industrial process wastes, activated carbon filters from flue gas streams, crematoria, and other facilities, also go to recycling, especially in the European Union and the United States. Due to their export bans, however, any recovered mercury would appear in commerce only to the extent that there is internal EU or US market demand, as discussed above. Total recycled mercury made available to the commercial sector is summarized in Table 6, which confirms that, overall, recycling remains an important contributor to the mercury supply, especially in China.

Narvaez (2010) cited an estimate of 600-800 tonnes of mercury recycled or recovered globally from mercury catalysts, wastes and products in 2007. Considering the fact that more and more mercury is now recycled only for disposal, and is therefore not included in the table above, it would appear that recycled mercury production is considerably greater than in 2007.

Table 6. Recycled mercury introduced into commerce, 2015

Recycled mercury source	Country or region	Mercury marketed
VCM catalyst and waste recycling	China	600 - 650
VCM catalyst and waste recycling	Russia, India	5 - 10
Recycling products and wastes	China	200 - 220
Recycling products and wastes	Japan	60 - 80
Recycling products and wastes	European Union	30 - 40
Recycling products and wastes	Switzerland	5 - 10
Recycling products and wastes	United States	40 - 50
Recycling products and wastes	India and other countries	50 - 200
Chlor-alkali industry (non-cell room)	Worldwide (except US and EU)	50 - 150
TOTAL		**1 040 – 1 410**

2.5. Mercury stocks

The Minamata Convention calls for Parties to endeavor to identify individual stocks of mercury or mercury compounds exceeding 50 tonnes, as well as sources of mercury supply-generating stocks exceeding 10 tonnes per year located within each Party's territory (Minamata Convention, Article 3).

Depending on how Parties report under the Minamata Convention, the quantities of mercury stocks available around the world should in the future become much better known. For now, without access to reliable information about many stocks, rough estimates must be based on a certain number of months of demand for each mercury application. Due to the uncertainty of such estimates, this analysis will restrict itself to the overall annual change in stocks, which may be derived from the difference between the global mercury supply and the global demand, which is already uncertain enough.

A number of examples illustrate the diversity of mercury stocks in different parts of the world:

- Of the estimated 10 000 tonnes of mercury in chlor-alkali cells and associated warehouses, one chlor-alkali plant (Akzo Nobel, Frankfurt) recently sent 250 tonnes of mercury to Remondis for stabilization and subsequent disposal in a German salt mine
- Many far smaller quantities of mercury are held in storage in hospitals, schools, universities, research laboratories, maintenance facilities and dental clinics
- Manufacturers of mercury-added products, catalysts, and compounds typically keep inventories of mercury equivalent to 2-6 months' demand
- As confirmed by Barrick, elemental mercury is accumulated and held in temporary storage by gold mining companies and some recyclers
- There are 2 356 flasks (approx. 82 tonnes) of former "DELA" mercury (see section 3.2.3) held at a Steinweg warehouse in Singapore, requested by the German government to be returned to Germany[19]
- Lambert Metals, the largest international mercury dealer, maintains varying stocks of mercury in warehouses mainly in Singapore, Hong Kong and Istanbul
- One of the most important Indian mercury dealers, Beri Mercurio, recently held about 4 000 flasks (138 tonnes) in storage in Singapore; other mercury dealers in many countries maintain mercury stocks of varying sizes
- An inventory of about 4 022 tonnes (4 436 US tons) of mercury is in long-term storage by the US Department of Defense (DoD) at Hawthorne Army Depot, Hawthorne, Nevada (USGS 2015)[20]
- Another inventory of about 1 088 tonnes (1 200 US tons) of mercury is held in long-term storage by the US Department of Energy (DoE), Oak Ridge, Tennessee (USGS 2015)[21]
- A Russian company in 2016 offered to sell a stock of 14 000 flasks (approx. 483 tonnes) of reportedly post-1990 Kyrgyzstan mercury, accompanied by pictures, confirming that such stocks may still be found in various countries (personal communication, 9 August 2016)
- A long-term storage facility owned by MAYASA near Almadén, Spain, contains 50 tonnes of mercury (see box)
- A salvage company wishes to recover an estimated 250-450 tonnes of mercury that sank with a Spanish galleon in 1724 off the coast of the Dominican Republic (see box)

19 Traders are wary of purchasing this mercury since it was exported from Germany in breach of EU export ban regulations. Meanwhile the warehouse (Steinweg) hazardous storage fees continue to accumulate so that, combined with the cost of shipping the mercury back to Germany in five containers, the basic cost of simply returning the mercury to Germany is already in the vicinity of US $200 000.

20 Under the US Mercury Export Ban Act, the sale, distribution or transfer of the stockpiles held by this agency is prohibited.

21 Ibid.

MAYASA mercury stock and sales

Mercury mines at Almadén, Spain, were exploited for more than 2 000 years. For MAYASA, the Spanish state-owned entity responsible, the extraction of cinnabar from the last Almadén mine finally ended in 2001, and the smelting of ore and primary mercury production ended in 2003. Subsequently most of the chlor-alkali plants in the European Union agreed to send residual mercury to MAYASA, which then sold the mercury until the European Union export ban took effect on 15 March 2011. The following table summarizes MAYASA mercury production and sales from 2000 until 15 March 2011.

During this period, with the understanding that many countries would be faced with the challenge of safe long-term storage or disposal of mercury, MAYASA engaged in an extensive research program to provide viable long-term storage of mercury as one alternative to permanent sequestration. As in the case of nuclear waste disposal, the program had to deal with fundamental disagreement as to the definition of permanent sequestration, and how that might be achieved.

The container shown below was designed and fabricated after extensive research into mercury related corrosion of materials, and includes security systems to ensure no mercury releases for more than 50 years. The container is located near Almadén, at the MAYASA facility, and was filled in 2010 with 50 tonnes of metallic mercury. The container remains at MAYASA with its permanent monitoring system activated, and it is the only stock of mercury remaining at Almadén.

In parallel the company also developed a process to stabilize mercury for safe disposal. In the first stage the procedure involves the transformation of liquid mercury into mercury sulfide (metacinnabar). In the second stage the mercury sulfide is mixed and microencapsulated in a stable sulfur polymer cement that is able to accommodate a large percentage of mercury.

MAYASA mercury production and sales, 2000-2011

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Production (tonnes)	237	524	727	745	0	0	0	0	0	0	0	0
Sales (tonnes)	1 095	655	780	848	594	495	291	457	344	239	657	149

Source: MAYASA, courtesy of the Spanish Ministry of Environment

The **Quicksilver** Galleons

During the summer of 1724 the Nuestra Señora de Guadalupe and the Conde de Tolosa, part of General Baltasar de Guevara's New Spain Armada, set sail from Cadiz, Spain, to Havana, Cuba and then on to Veracruz, Mexico. The two galleons took on supplies at Aguadilla, on the northwest point of Puerto Rico, and then continued their journey. A few days later, on the night of 24 August 1724, the ships were near Samaná Bay, Dominican Republic, when a hurricane struck.

During the hurricane, the Tolosa was eventually wrecked on a large coral reef. The Guadalupe grounded on a sandbank along the coast of the Dominican Republic about 200 miles from Santo Domingo. These were large ships, classified as azogues, which means they carried mercury. Mercury was essential for extracting pure silver from ore, and the silver mines in the New World were dependent on this supply. When mercury was shipped from Spain it had to be packaged very carefully. Mercury was poured into a goatskin pouch and then placed into a wooden box along with 1 or 2 more pouches. The box was then carefully closed and wrapped in protective covering.

In 1976, the company Caribe Salvage S.A. came to an agreement with the Dominican Republic government giving it the right to search Samaná Bay for wrecks. The Guadalupe was the first one to be salvaged. After excavating tonnes of sand, the team reached the second deck but could go no further. The heavy timbers and solid construction prevented them from reaching the lower hold where the mercury was stored (DiscoverSea Museum 2013).

In subsequent years the stock of mercury has been estimated at 250-450 tonnes, but it had never been salvaged. At the end of 2016, Mr. Wilf Blum of Deep Blue Marine was in search of partners and funding to salvage the mercury and sell it. It is not known whether he has found any partners for this venture, or whether he has been able to obtain the necessary salvage permit from the Dominican government.

This is one example of the many unexpected and sometimes large stocks of mercury that may unexpectedly turn up in different parts of the world. It is also evident how readily, under certain circumstances, such a large quantity could be recovered and added to the global supply, unless the local authorities legally mandate that any such mercury should go to safe disposal.

2.6. Summary

The estimated global mercury supply of just over 4 000 tonnes is the result of a gradual increase since 2005. This finding is not surprising since global demand has also increased during the same period. The sources of supply have changed significantly, however, particularly the decline in mercury available from the chlor-alkali industry, and the increase in primary mercury production during the last five years.

The relative changes in the sources of mercury since 2010 demonstrate the shifting nature of the global mercury supply in response to national legislation and market conditions. Additional and perhaps more dramatic changes may be anticipated especially during the next five to ten years, as the Minamata Convention enters into force (depending to some extent on which countries and how many countries are Parties to the Convention), the supply and trade obligations in Article 3 become operational, and the demand reduction measures in Articles 4, 5 and 7 have their intended effects.

Table 7 summarizes the elements contributing to the global mercury supply discussed in this section. It is important to keep in mind the limitations of these data. Each of these sources is made up of a number of smaller contributing estimates, and many of those smaller estimates are shadowed by considerable uncertainty. Note also that the mercury supply drawn down from global stocks has not been separately estimated for 2015 because stocks from chlor-alkali facilities and other supply sources are otherwise accounted for, and useful estimates of changes in mercury stocks for any particular year are impossible to quantify from available data, except possibly as a net change to balance out estimates for global supply and demand (see section 5).

Table 7. Global mercury supply, 2015

Mercury source	Min. mercury supply (tonnes)	Max. mercury supply (tonnes)
Primary (mined) mercury	1 630	2 150
By-product mercury	440	775
Chlor-alkali residual mercury	370	450
Mercury recycling	1 040	1 410
Total supply	**3 480**	**4 785**

Primary mining remains the most significant source of mercury used in products and processes, responsible in 2015 for 1 630 to 2 150 tonnes (just under 50 per cent of the total mercury supply). China, Mexico and Indonesia are the sources of most primary production of mercury. Mexico and Indonesia each reports mercury exports on the order of 300 tonnes. Although China does not formally export mercury, its trade situation with Hong Kong is quite fluid, and there is speculation that Chinese mercury is sometimes transferred "internally" to Hong Kong, and then formally exported from there.

The next largest source of mercury supply – 1 040 to 1 410 tonnes – is due to product and waste recycling, dominated by Chinese recycling of spent catalysts used in the production of VCM. This is followed by the recovery of by-product mercury – 440 to 775 tonnes – associated with the processing of non-ferrous metal ores and, to a lesser extent, cleaning of natural gas.

Most mercury production is concentrated among a relatively small number of countries. These are countries with either primary mercury mining, significant by-product mercury from non-ferrous metal mining or processing operations, or mercury retort facilities capable of producing mercury from waste treatment or the recycling of mercury-added products. Table 8 lists the main mercury-producing countries – in this case those that produced more than 25 tonnes/year during 2013-2015.

Some governments have already enacted export bans that prevent these sources of mercury from being used outside their geographic boundaries, particularly for ASGM purposes. Four of the 17 countries have enacted partial or total export bans, Japan has an export ban that has not yet taken effect, and an export ban is currently under consideration in Switzerland.

Table 8. Countries producing more than average 25 tonnes/year, 2013-2015

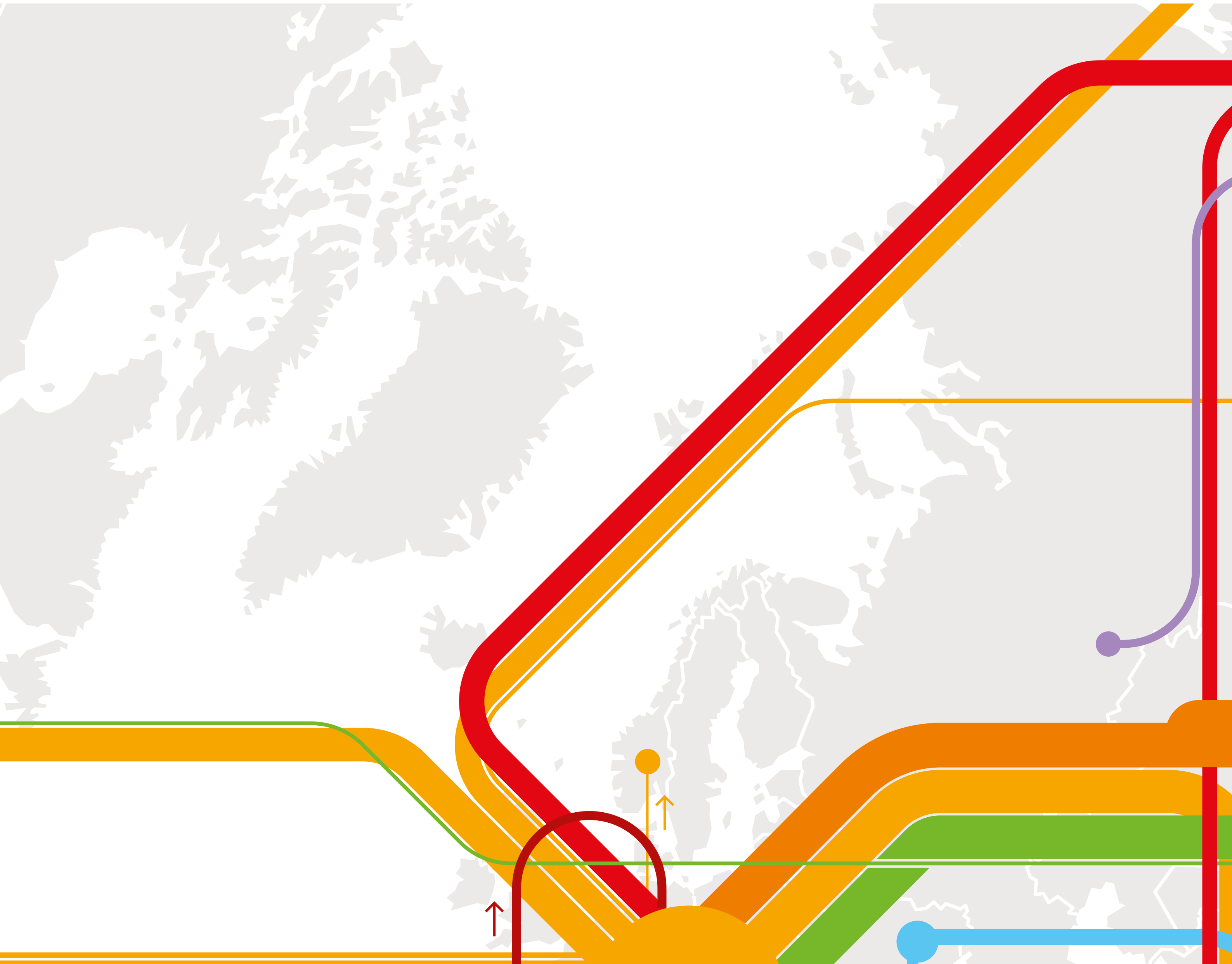
Country	Mercury source(s)
Argentina	by-product
Chile	by-product
China	primary mining, recycling, by-product
Germany*	recycling, by-product
India	recycling, by-product
Indonesia	primary mining
Japan	recycling, by-product
Kyrgyzstan	primary mining
Mexico	primary mining
Netherlands*	recycling, by-product
Peru	by-product
Russia	recycling, by-product
Spain*	recycling, by-product
Switzerland	recycling
Tajikistan	by-product
United States*	recycling, by-product
Ukraine	by-product

*These countries are subject to mercury export bans at the time this table was prepared (July 2017). Germany, the Netherlands and Spain are permitted to export mercury to other countries in the European Union, but not outside.

3. Global and regional mercury trade

The global mercury trading community involves everyone from miners, ore refiners and recyclers, to shipping agents, warehousing facilities and metals brokers, to importers and agents representing industrial processes and manufacturers of mercury-added products.

This section of the report deals only with the part of that community that is reflected in the mercury import and export data as reported to the United Nations Commodity Trade Statistics Database (Comtrade) by customs and statistical agencies of countries around the world.



Some of the key questions behind the analysis of trade data reported as mercury[22] include:

- How have mercury trade routes changed since the last similar assessment, and especially since the imposition of certain export bans?
- How can trade data support the implementation efforts of Parties to the Minamata Convention?
- How comprehensive are the available trade data?
- What mercury commodities can be identified in the trade data?
- What policy insights can be gained from the data on mercury movements and changes over time?

3.1. Mercury in commodity trade databases

3.1.1. Standardization of data

The Harmonized Commodity Description and Coding System, also known as the Harmonized System (HS) of commodity nomenclature, is an internationally standardized system used to classify traded commodities. As of 2015, there were 180 countries or territories applying the Harmonized System worldwide. HS codes are used by customs authorities, statistical agencies and other government regulatory bodies to monitor and control the import and export of commodities, to produce economic reports such as trade balances, to develop customs tariffs, and to track international trade statistics, rules of origin, and monitoring of controlled goods (such as hazardous wastes, endangered species, and weapons).

Since most mercury-added commodities – other than lamps and some batteries – do not have separate codes from similar mercury-free commodities, the ones of most interest here are HS 2805.40 (mercury) and HS 2852 (inorganic or organic compounds of mercury), the latter of which is further divided into two main subheadings, 2852.10 and 2852.90, depending on whether the mercury compounds are "chemically defined" or "other".

This analysis focuses especially on trade in elemental mercury as the key focus of attention as the Minamata Convention enters into force. The trade of mercury compounds is also important, but occurs in a somewhat different environment with different stakeholders. For example, elemental mercury may be transferred to a facility that manufactures mercury compounds, so the trade of both may be closely linked. Or the compound mercurous chloride (mercury(I) chloride), also known as calomel, for example, may be generated in the process of removing trace mercury from non-ferrous ores. Then, depending on the circumstances, calomel may be transported either as a waste for eventual recycling or disposal, or as a commodity for other uses.

3.1.2. UN Comtrade

Comtrade, or UN Comtrade, is the publicly accessible commodity trade database of the United Nations Statistics Division (UNSD). UNSD maintains a detailed merchandise trade statistics database as mandated by the United Nations Statistical Commission. This database contains annual trade data (imports, re-imports, exports and re-exports) as submitted by reporting country or area, by commodity and by trading partner country, for most countries of the world (Comtrade 2016).

3.1.3. Other national databases

Comtrade typically receives the same data that are collected in national databases. As examples, this report briefly mentions the national databases of Canada, Mexico and the United States.

The Canadian International Merchandise Trade (CIMT) database offers detailed online trade data using the Harmonized Commodity Description and Coding System classification of goods, based on the 6-digit commodity level (CIMT 2016).

The Mexican online commodity tariff database, SIAVI, is an online tool that provides information on regulations and tariffs, as well as annual and monthly trade data on the value and volume of Mexican imports and exports. The SIAVI database consolidates the raw trade data received from the General Customs Administration (SIAVI 2016).

22 The term "trade data reported as mercury" calls attention to the fact that mistakes sometimes occur in the coding and reporting of trade information, with the result that some trade reported as mercury may in fact be another commodity, and vice versa.

The United States International Trade Commission (USITC) database was developed around the Harmonized Tariff Schedule of the United States. The USITC trade data website provides access to US international trade statistics (and US tariff data). All trade statistics are compiled from official data retrieved from the US Bureau of the Census, an agency within the US Department of Commerce (USITC 2016).

A review confirmed that Comtrade includes all of the same mercury trade data that appear in these three national databases.

3.1.4. Data gaps and discrepancies

Despite keeping “mirror” records of the same international transactions, trading partners sending data to Comtrade sometimes use different data reporting guidelines and formats, such as in the manner in which they record the origin and destination of commodities in transit through their territory, how they record (or not) shipments below a given value, how they treat re-exports[23] and re-imports, and other such details of cross-border trade. Comtrade standardizes these data according to its own rules, in agreement with the member countries of the United Nations Statistical Commission, which oversees the work of the UNSD.

The data appearing in the Comtrade database are therefore only as reliable and consistent as the data submitted by member countries. While the data concerning international trade in elemental mercury are relatively comprehensive, some countries do not necessarily report their trade statistics every year, and the statistics that are reported are subject to revision for a given period of time. Comtrade does not make estimates in place of missing data. Therefore, trade data for a given country or year could be unreliable due to unavailable or incorrect data provided by the country, or due to incomplete reporting. As a result, for any of a number of reasons, one country’s reported imports may not entirely agree with its trading partners’ reported exports to that country, and vice versa.[24]

With the objective of examining these issues more closely, the Commission for Environmental Cooperation recently carried out a detailed analysis of the completeness and accuracy of official data on mercury trade between Canada, Mexico and the United States (CEC 2017). Research and interviews led to the conclusion that the most common factors behind observed data discrepancies were the following:

- The statistical manner in which re-exports and transshipments or transiting goods were treated
- Errors in transferring information from manual documents to digital
- Lack of clarity with regard to the actual origin and destination of goods
- Inaccurate coding of commodities
- Undocumented shipments, especially goods passing through bonded warehouses or Foreign Trade Zones

Figure 1 and Figure 2 list the countries with the largest discrepancies between their average annual imports and exports (2013-2015), as reported by themselves, and the “mirror” exports and imports reported by their trading partners. The data supporting these figures may be found in the online appendices to this report.[25]

23 Re-exports are exports of goods of foreign origin that have previously entered but have not been materially transformed in Country A, including foreign goods withdrawn for export from bonded customs warehouses.

24 Some of these issues are also raised in MAAMA (2016).

25 The online appendices are available at <http://www.unep.org/chemicalsandwaste/>

Figure 1. Discrepancies in reported mercury IMPORT data, 2013-2015

Source: UN Comtrade Database.

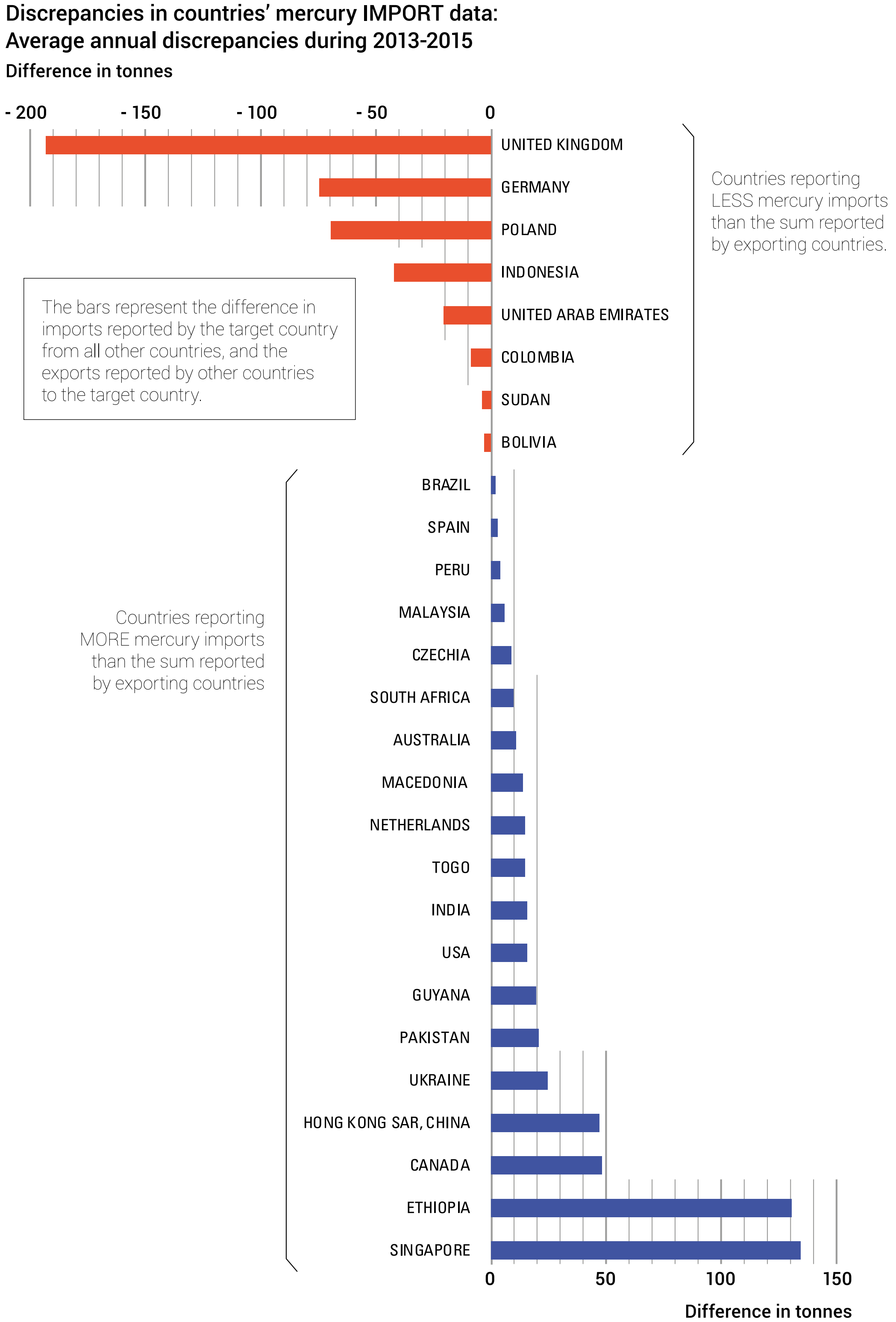
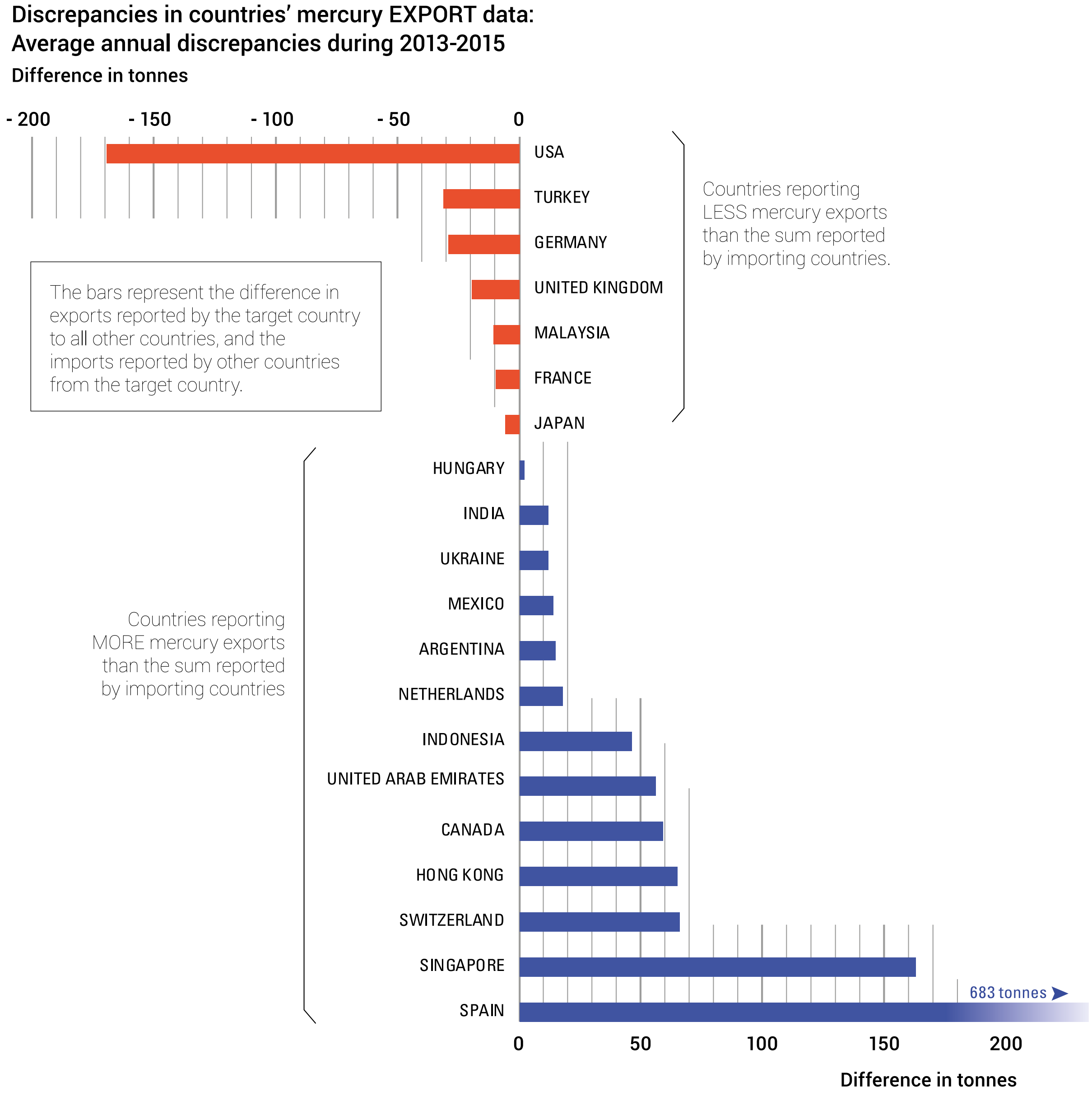


Figure 2. Discrepancies in reported mercury EXPORT data, 2013-2015

Source: UN Comtrade Database.



The figures show that in some cases a country's reported imports are greater that its partners' mirror exports, and in some cases it is the other way around. To take the example of the United Kingdom in Figure 1 above, it reported average annual imports of mercury for this period of just over 16 tonnes, while its trading partners said they exported nearly 209 tonnes (annual average) to the UK during the same period. Thus there is a difference of 193 tonnes between the UK's reported imports and its partners' reported exports to the UK. The reason for any specific discrepancy is not necessarily clear without taking a closer look at individual shipping documents, the details of which are generally held by customs agencies as confidential commercial documents, and are therefore not open to public scrutiny.

Although the reasons for this discrepancy in the UK trade data have not been confirmed, a likely explanation may have to do with one of the metals trading companies based in the UK. During this period of time, 2013-2015, mercury exports from the European Union were no longer permitted. The UK-based trading company would therefore not have wanted its mercury purchases to enter the European Union, knowing they would not be permitted to leave. So the company might have purchased mercury stocks in its own name and, perfectly legally, asked for them to be shipped to and stored either in a bonded warehouse[26]– effectively outside the customs territory of any one country – or in a location outside the European Union.

Since goods stored in a bonded warehouse do not have to clear customs until they enter the formal customs territory of some country, and since the final destination of the stocks purchased by the metals trading company was not known, the seller would have had no choice but to list the country of the buyer – the UK – as the best known destination. This is also the destination that would be recorded in the database and would ultimately be forwarded to Comtrade.

A somewhat similar case could be made for mercury traded through Singapore. Even though much of the mercury in that case is not held in a bonded warehouse, it is well known that Singapore has become a major trading hub and is not the final destination of most of the mercury stored there. Singapore is obliged to record all mercury arriving in its Customs Territory as imports, even though the seller and local customs officials know that Singapore is not likely to be the final destination.

In order to improve the accuracy and transparency of the available data on international mercury trade, the Commission for Environmental Cooperation report cited above suggested that more of the commercially sensitive shipping details should be made public (especially considering that they involve trade in an internationally restricted toxic substance), that international trade classification codes be created to better identify products containing mercury, that efforts be made to better differentiate between mercury compounds destined for disposal and those destined for recycling or recovery, that customs agencies be better informed about the provisions of the Minamata Convention in order to more closely monitor relevant shipments, and that country working groups be established to elaborate and monitor the implementation of the previous measures (CEC 2017).

26 A bonded warehouse, while physically situated within the borders of a given country, may be authorized by customs for storage (and/or processing) of goods "outside the Customs Territory." As such, payment of any duties is deferred until the goods are taken back into the Customs Territory. Alternatively, the goods are not subject to local duties if they are merely in transit via the bonded warehouse, and are then shipped on to a foreign destination.

3.2. Country and regional trade flows

3.2.1. Country imports and exports of elemental mercury

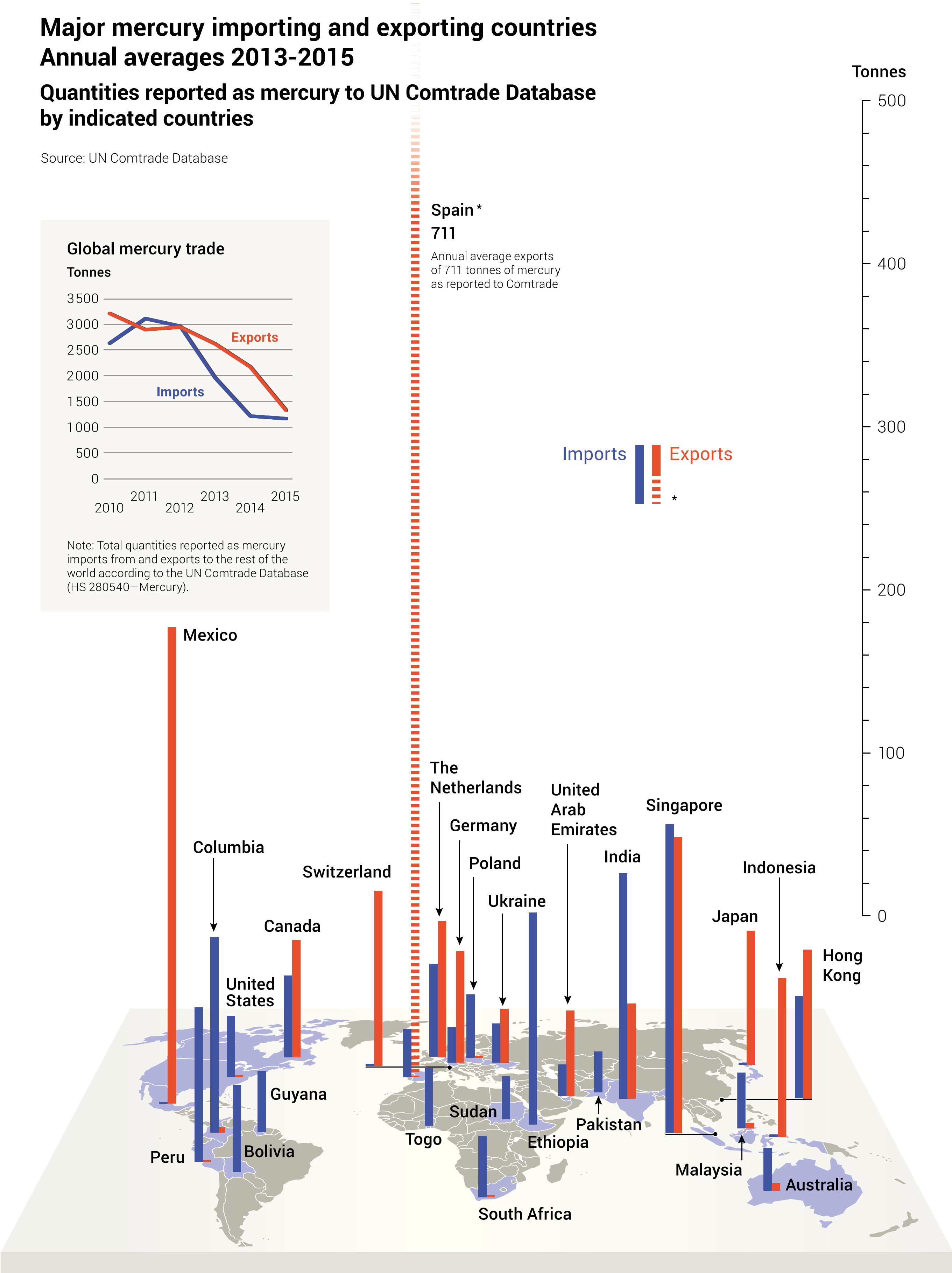
This section presents trade data of the most active mercury trading countries from 2013 to 2015. The data used in this section are the countries' own imports and exports as reported to Comtrade (and as reported to Eurostat, in the European Union), not influenced or revised in this case by any confirming or conflicting data that may have been recorded and submitted by their trading partners. This is to ensure maximum consistency in the data when comparing the trading activities of different countries, although one should be aware of the possible sources of data inaccuracy discussed in section 3.1.4.

As an example of data issues, the Spanish Ministry of Environment has indicated that all data submitted to Eurostat and Comtrade for the years 2011-2015 was in fact for shipments that were not mercury. The Spanish National Focal Point for the mercury negotiations and the Competent Authority regarding the EU Mercury Regulation stated: "...we have checked and investigated, together with the Customs Authority and the Environmental Attorney, all the export/import Comtrade data where the name of Spain was reflected and the conclusion of the investigations is: there is no mercury export from Spain to any other country since 15 March 2011" (Davis 2016).

While the data problems mentioned above are being investigated and revised as necessary, the data currently available in Comtrade are summarized in Figure 3, which shows the most active mercury traders over the period 2013 to 2015. The data supporting this figure are included in the online appendices to this report.[27]

27 The online appendices are available at <http://www.unep.org/chemicalsandwaste/>

Figure 3. Key mercury importers and exporters, as reported to Comtrade



* After reviewing these statistics with the Customs Authority, the Spanish Competent Authority for the EU Mercury Regulation indicated that no mercury was exported from Spain after 15 March 2011.

Apart from the input from Spain as discussed above, other key observations related to mercury trade include:

- Singapore and Hong Kong received large stocks from Lambert Metals storage in Rotterdam and other sources before the imposition of the European Union mercury export ban
- Bethlehem Apparatus also sent its stocks out of the United States before the US mercury export ban took effect
- The exports (reported as mercury) of Mexico and Indonesia have greatly increased during the last five years, reflecting the increase in primary mining in both countries
- India continues to be a major mercury importer, mostly for internal use but also increasingly for exports
- Very high imports of mercury by Ethiopia were reported in 2013 and 2014, but the World Bank (2016b) concluded that it was likely there were some mistakes in those customs entries
- Colombia and Peru, among others, appear to be importing large amounts of mercury for ASGM, either directly or via neighboring countries
- Exports reported as mercury from Switzerland increased significantly after 2011 after Switzerland received large amounts of mercury exported illegally by DELA GmbH from Germany (see section 3.2.3)
- Germany exported 134, 58 and 12 tonnes of mercury per year respectively during 2013-2015, all to countries inside the European Union, respecting the European Union export ban
- The United Arab Emirates has become a significant transit point for mercury, in recent years importing mercury mostly from Singapore, India and Indonesia, and exporting 110, 47 and 31 tonnes of mercury during 2013-2015 respectively, mostly to Iran, Sudan and Chad

3.2.2. Global mercury trade, 2015 vs. 2008

Mercury traders or brokers facilitate the trade of mercury by arranging for international transactions. They may accumulate and store mercury in warehouses for subsequent sale and distribution. For example, when a large quantity of residual mercury becomes available at a chlor-alkali facility, a trader may send empty flasks to the site and arrange for transport of the full flasks to a recycler, who would then clean and repackage the mercury for delivery to a warehouse identified by the trader. Several countries serve as key trading hubs for the international transfer of mercury, but there may be several more intermediate stops, depending on the end use, before mercury reaches its final destination. Consignments of mercury may therefore be shipped and re-shipped several times during a calendar year.

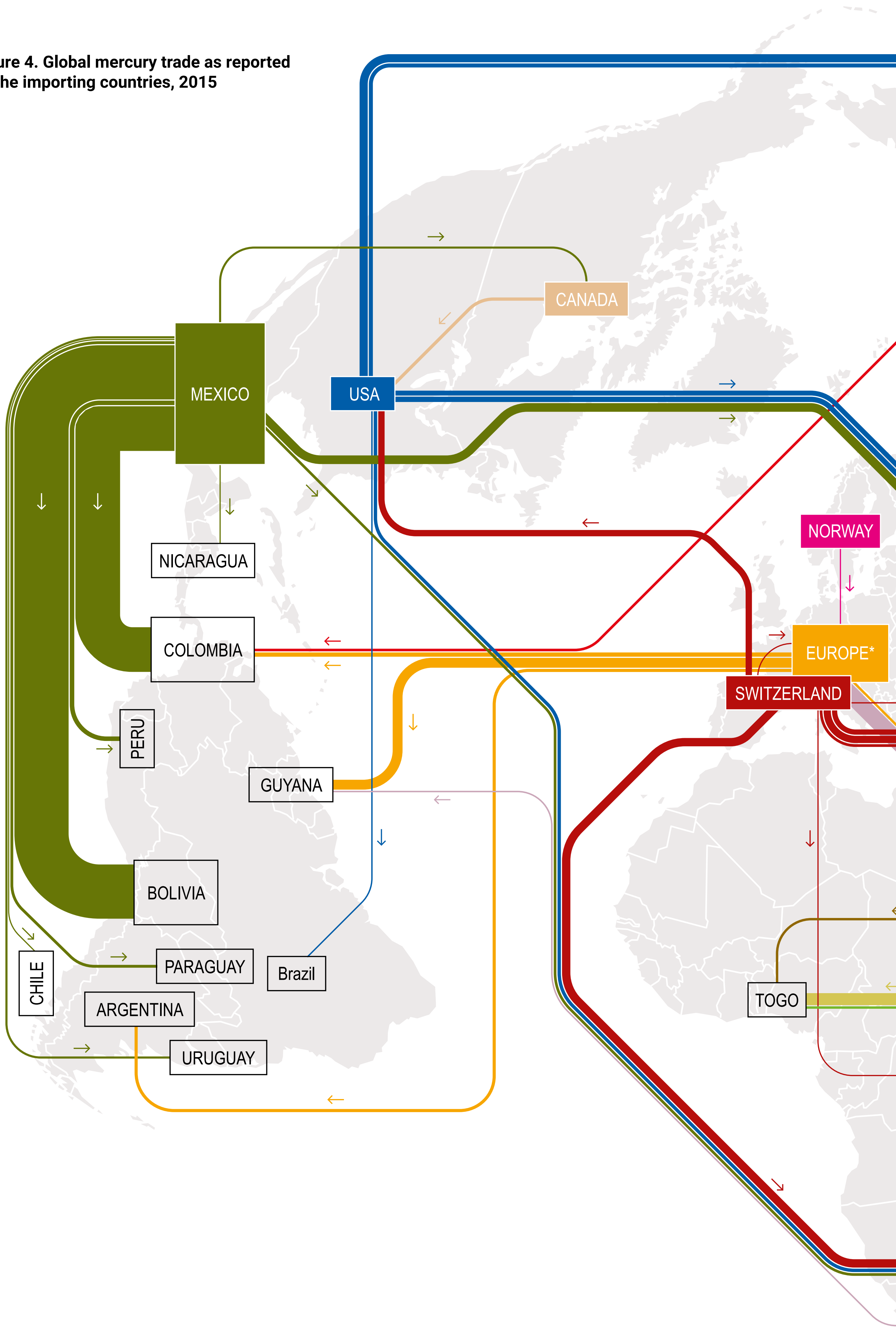
Providing a single-year snapshot, and using only import data reported to Comtrade,[28] Figure 4 illustrates global mercury trade in 2015. The supporting data may be found in the online appendices to this report.[29] In 2015 Mexico was a major source, with other countries reporting mercury imports from Mexico of more than 300 tonnes. Countries importing mercury from Indonesia reported receiving more than 150 tonnes in 2015, while Indonesia itself reported exporting 284 tonnes. Such discrepancies have been discussed in section 3.1.4.

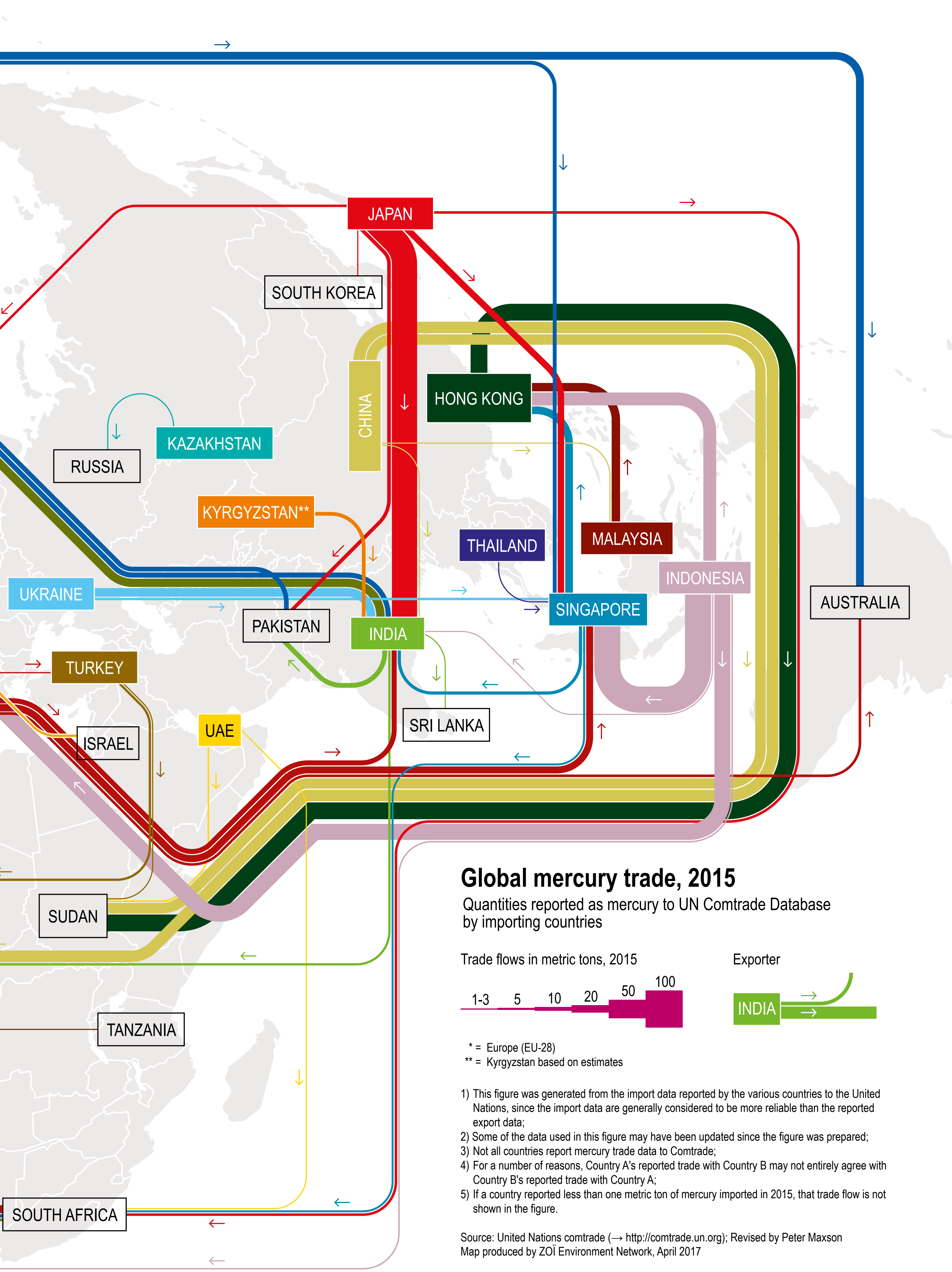
....

28 In order to avoid the problems raised by the sorts of data discrepancies discussed in section section 3.1.4, and given a choice between developing a figure based on all countries' import data or export data, it is generally accepted that customs authorities pay closer attention to import data since they are the basis for most trade related tariffs.

29 The online appendices are available at <http://www.unep.org/chemicalsandwaste/>

Figure 4. Global mercury trade as reported by the importing countries, 2015





Global mercury trade, 2015

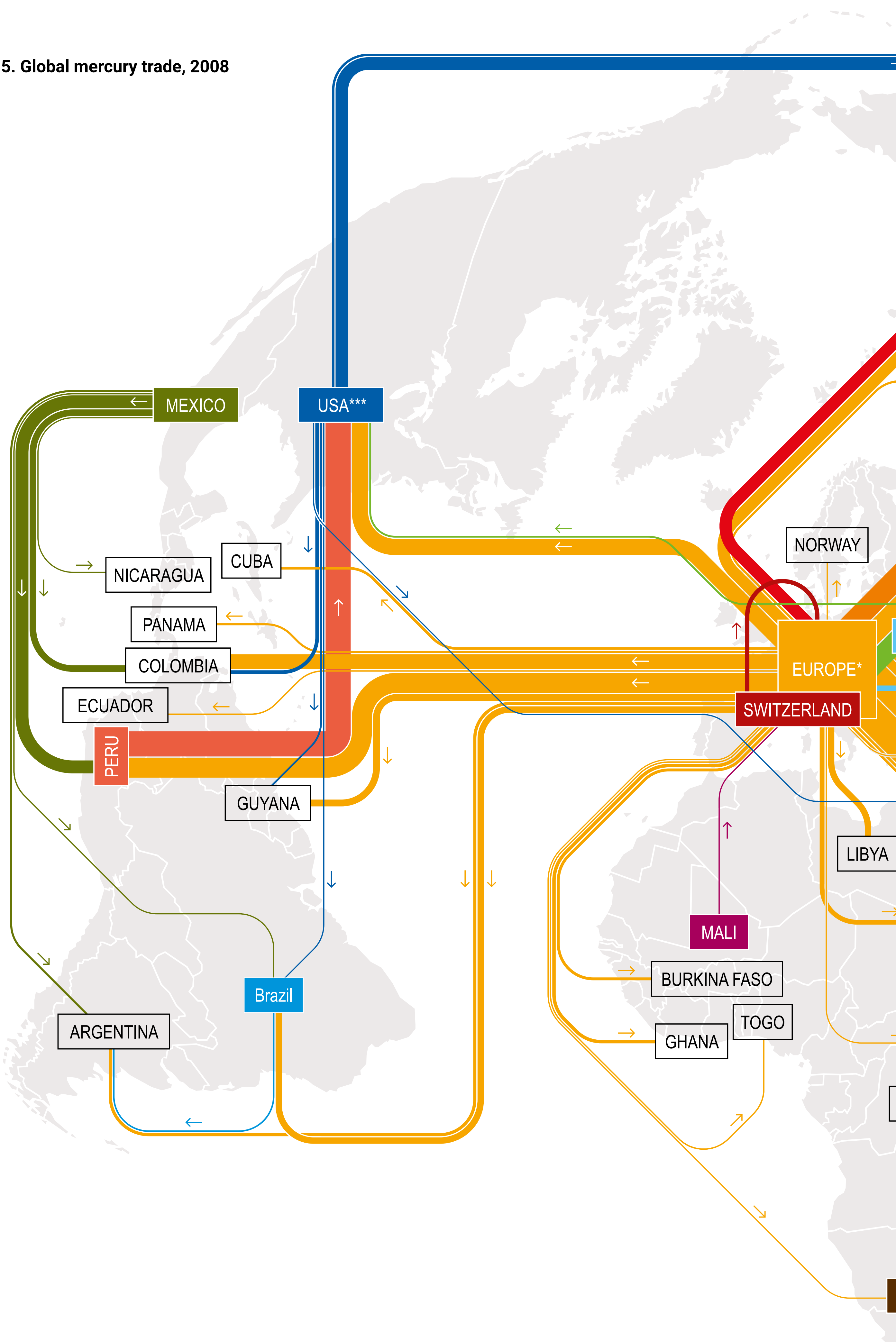
Quantities reported as mercury to UN Comtrade Database by importing countries

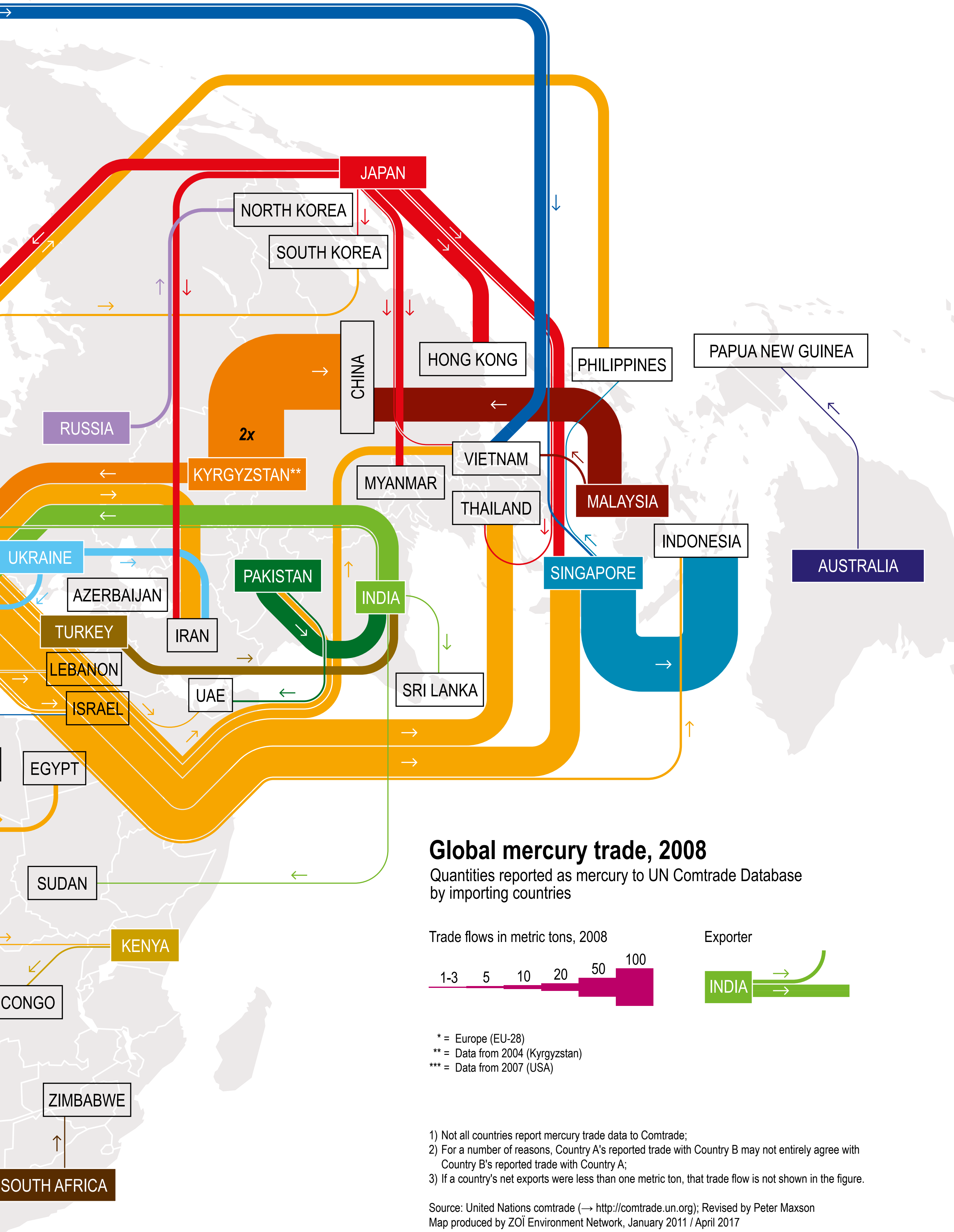
* = Europe (EU-28)
** = Kyrgyzstan based on estimates

1) This figure was generated from the import data reported by the various countries to the United Nations, since the import data are generally considered to be more reliable than the reported export data;
2) Some of the data used in this figure may have been updated since the figure was prepared;
3) Not all countries report mercury trade data to Comtrade;
4) For a number of reasons, Country A's reported trade with Country B may not entirely agree with Country B's reported trade with Country A;
5) If a country reported less than one metric ton of mercury imported in 2015, that trade flow is not shown in the figure.

Source: United Nations comtrade (→ http://comtrade.un.org); Revised by Peter Maxson
Map produced by ZOÏ Environment Network, April 2017

Figure 5. Global mercury trade, 2008





Global mercury trade, 2008

Quantities reported as mercury to UN Comtrade Database by importing countries

1) Not all countries report mercury trade data to Comtrade;
2) For a number of reasons, Country A's reported trade with Country B may not entirely agree with Country B's reported trade with Country A;
3) If a country's net exports were less than one metric ton, that trade flow is not shown in the figure.

Source: United Nations comtrade (→ http://comtrade.un.org); Revised by Peter Maxson
Map produced by ZOÏ Environment Network, January 2011 / April 2017

These trade flows may be compared with 2008, as seen in Figure 5, when both countries' exports were reported as small or zero. In both cases, the restricted supplies of mercury available after the European Union and United States export bans, combined with the high price of gold and subsequent demand for mercury in ASGM, provided an incentive for miners to search for alternative sources. Between 2013 and 2015 the majority of Mexico's reported mercury exports went to Peru, Colombia, Bolivia, Brazil, Sudan, Nicaragua and Guyana – countries where ASGM is known to occur. As noted earlier, when the Minamata Convention comes into force, primary mined mercury cannot be used for ASGM, so Mexican (and other) exporters will have to soon adapt to new rules.

Likewise, since 2008 there has been a major shift in the main mercury trading hubs, triggered by European Union and United States export bans and other increasing restrictions in those regions, such as restrictions on the final disposition of mercury recovered from the chlor-alkali industry. In 2008, the United States, the European Union and Singapore, to some extent, were the main mercury trading hubs. The Kyrgyz Republic, with its own mine, historically supplied mercury mostly to the larger customers in Asia and the Commonwealth of Independent States, as well as brokers in Europe, who had ties to a range of smaller customers. European sources and traders tended to supply countries in Africa and the Middle East, while US brokers tended to serve Central and South American countries.

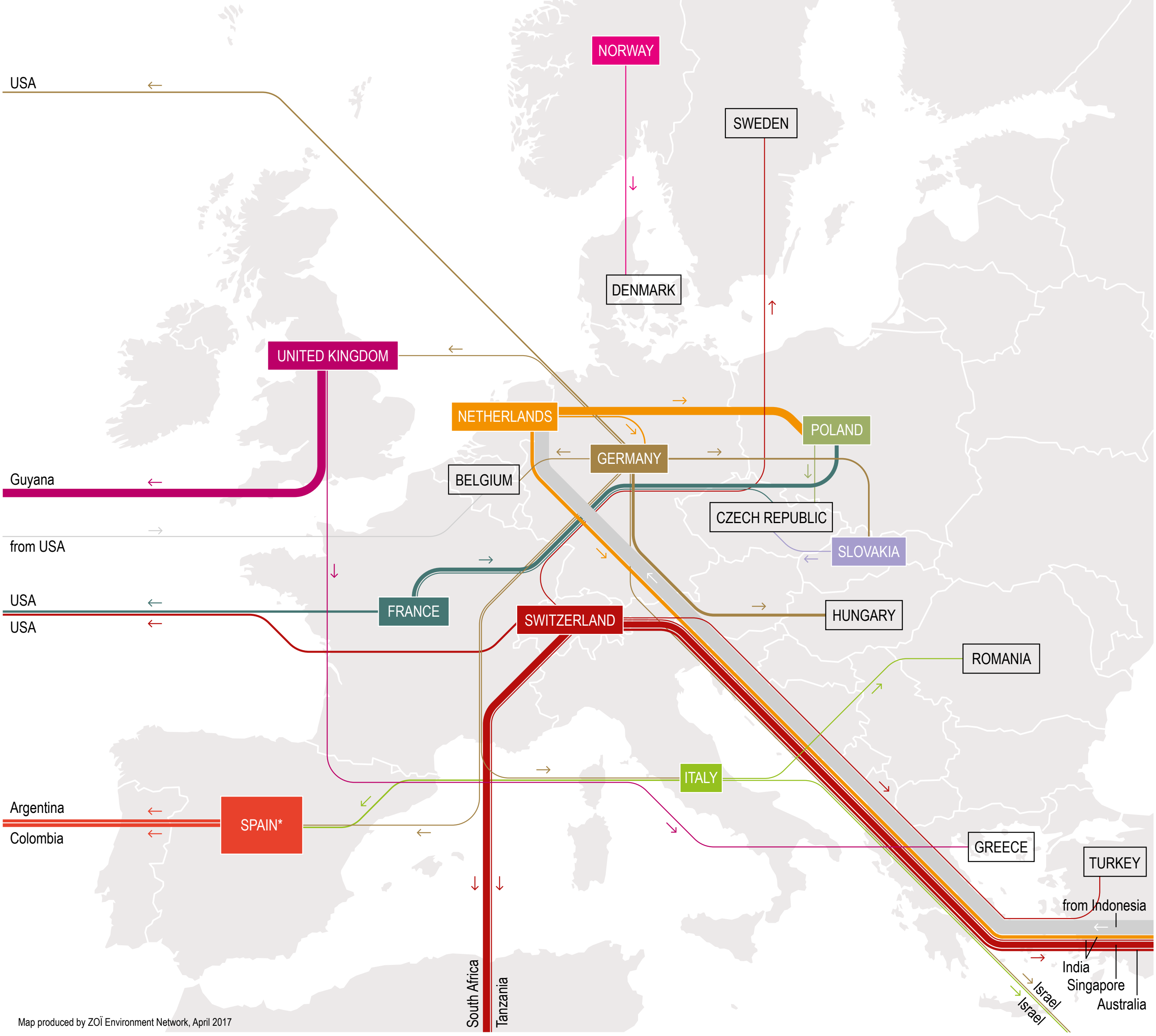
For reasons mentioned previously, by 2015, while the global volume of mercury trade had declined somewhat, the trading hubs had shifted to Hong Kong and Singapore, primarily, and India to a lesser extent. The rationale behind these locations tended to be based on language similarities, geographical proximity to customers, established commercial links and attractive warehousing and shipping costs. Hong Kong provides easy commercial access to the Chinese mainland, as well as other countries in the Asian region. Singapore also offers a business friendly environment, and better access to certain trading partners. Although less visible in these two figures, Turkey is also said to play an increasingly important role as a trading hub, especially facilitating access to African countries (personal communication, 9 August 2016).

3.2.3. European mercury trade, 2015 vs. 2008

Europe provides an interesting regional view of changes in mercury trade during the last 8-10 years. Once again, Figure 6 is based only on countries' reported import data. In 2015, although the trade volumes are much lower than in 2008, importing countries reported that the most active suppliers of mercury were Spain, the Netherlands, the United Kingdom and Switzerland, as seen in Figure 6. While the first three countries reported to Comtrade that their 2015 exports were either zero or entirely to countries within the European Union, the importing countries reported differently. Outside the European Union, Morocco, Colombia, Argentina and India all reported receiving mercury imports from Spain during the 2013-2015 period. Likewise, India reported receiving mercury imports from the Netherlands during the 2013-2015 period. And Brazil and Guyana reported receiving imports from the United Kingdom during the same period.

The data available on Comtrade cannot explain why these countries outside the European Union reported receiving mercury that the European Union did not report as exports. As mentioned previously, however, the origins and destinations of mercury in transit through third countries may be unclear, and the related information appearing in Comtrade or in national databases may be incorrect. This may explain, in some cases, why countries outside the European Union report mercury imports coming from the European Union in spite of the export ban. To take one example, all European Union ports continue to accept mercury in transit if it is shipped by full container load (known in the trade as "FCL") and if the seals on the containers remain unbroken. If, however, a container load of mercury in transit needs to be "broken down" or repackaged into smaller less-than-container-load (known in the trade as "LCL") lots in port, Rotterdam, for example, will no longer accept the transit shipment even though most other European Union ports will do so. This could mean that especially when mercury in transit is repackaged in a European Union port, the European Union might sometimes be listed as the new origin when the repackaged mercury arrives at its final destination.

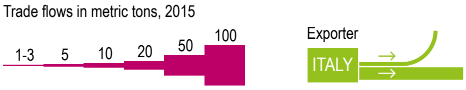
Figure 6. European mercury trade as reported by the importing countries, 2015



Mercury trade in Europe, 2015

Quantities reported as mercury to UN Comtrade Database by importing countries

Trade flows in metric tons, 2015



1) This figure was generated from the import data reported by the various countries to the United Nations, since the import data are generally considered to be more reliable than the reported export data;
2) Some of the data used in this figure may have been updated since the figure was prepared;
3) Not all countries report mercury trade data to Comtrade;
4) For a number of reasons, Country A's reported trade with Country B may not entirely agree with Country B's reported trade with Country A;
5) If a country reported less than one metric ton of mercury imported in 2015, that trade flow is not shown in the figure.

* After reviewing these statistics with the Customs Authority, the Spanish Competent Authority for the EU Mercury Regulation indicated that no mercury was exported from Spain after 15 March 2011.

Source: United Nations comtrade (→ http://comtrade.un.org); Revised by Peter Maxson

During the period 2011-2014, the mercury exports reported by Switzerland had increased to such an extent as to draw some attention. When questions were raised in 2014, it became apparent that a German company, DELA GmbH, had violated the mercury export ban, as explained in the box.

The **DELA** affair

DELA GmbH, based in Dorsten, North Rhine-Westphalia, Germany, specializing in mercury recycling and disposal, was the prime destination after 2011 for unneeded mercury from the chlor-alkali industry and by-product mercury in compliance with the European Union export ban requirement to safely dispose of this mercury. DELA had a recognized procedure for stabilizing the mercury, and good contacts with the German salt mines for final disposal.

Between 2011 and 2014 roughly 1 000 tonnes of mercury were shipped to DELA for disposal. But DELA had a scheme to gain maximum profit from this arrangement, which involved first filling special containers with pure mercury, and then covering the containers with some appropriate soil to give the appearance of hazardous waste. The "hazardous waste" was then shipped to Switzerland, the Netherlands and Greece, where the mercury was easily recovered rather than disposed of.

By the end of 2014, DELA had illegally exported at least 810 tonnes of mercury, with a market value of about US $40 million. Once outside Germany, the mercury would be cleaned up and sent on to Turkey, Singapore, and elsewhere, destined to be sold to other countries. Many of these final destinations would be using much of the mercury for artisanal gold mining, which has become the largest global user.

The buyer of the "waste" in Switzerland – Batrec, specialized in mercury recycling and based in the Swiss canton of Berne – received at least 390 tonnes of mercury. The material was declared as "mercury-containing waste" with a mercury content of 10-70 per cent, and the Swiss Federal Office for the Environment approved the imports without suspecting any fraud. According to legal proceedings, Batrec paid 15 cents per kilo for the waste, which would have been a fair price if they had needed to put the waste through a costly retorting process to recover the mercury. Instead, Batrec simply transferred the mercury into their own flasks and sold it to Air Mercury, another Swiss company that managed export sales from Switzerland. There was also a complex method of returning part of the ultimate profits to DELA.

Partly as a result of abnormally large exports of mercury recorded and published by the Swiss authorities during 2011-2013, questions arose about the source of those exports, and the DELA scheme gradually came to light in 2014.

As of April 2017, officials of DELA have been convicted and sentenced. DELA declared bankruptcy and was taken over by Remondis. Batrec denied that it had any knowledge of illegal activity. Air Mercury declined to appear in the German court. Greece returned 36 tonnes of the 150 tonnes of mercury it received, and the Netherlands returned 98 tonnes of the 270 tonnes of mercury it received. As originally intended, the recovered mercury has been stabilized by conversion into mercuric sulfide and disposed of underground in the salt mines.

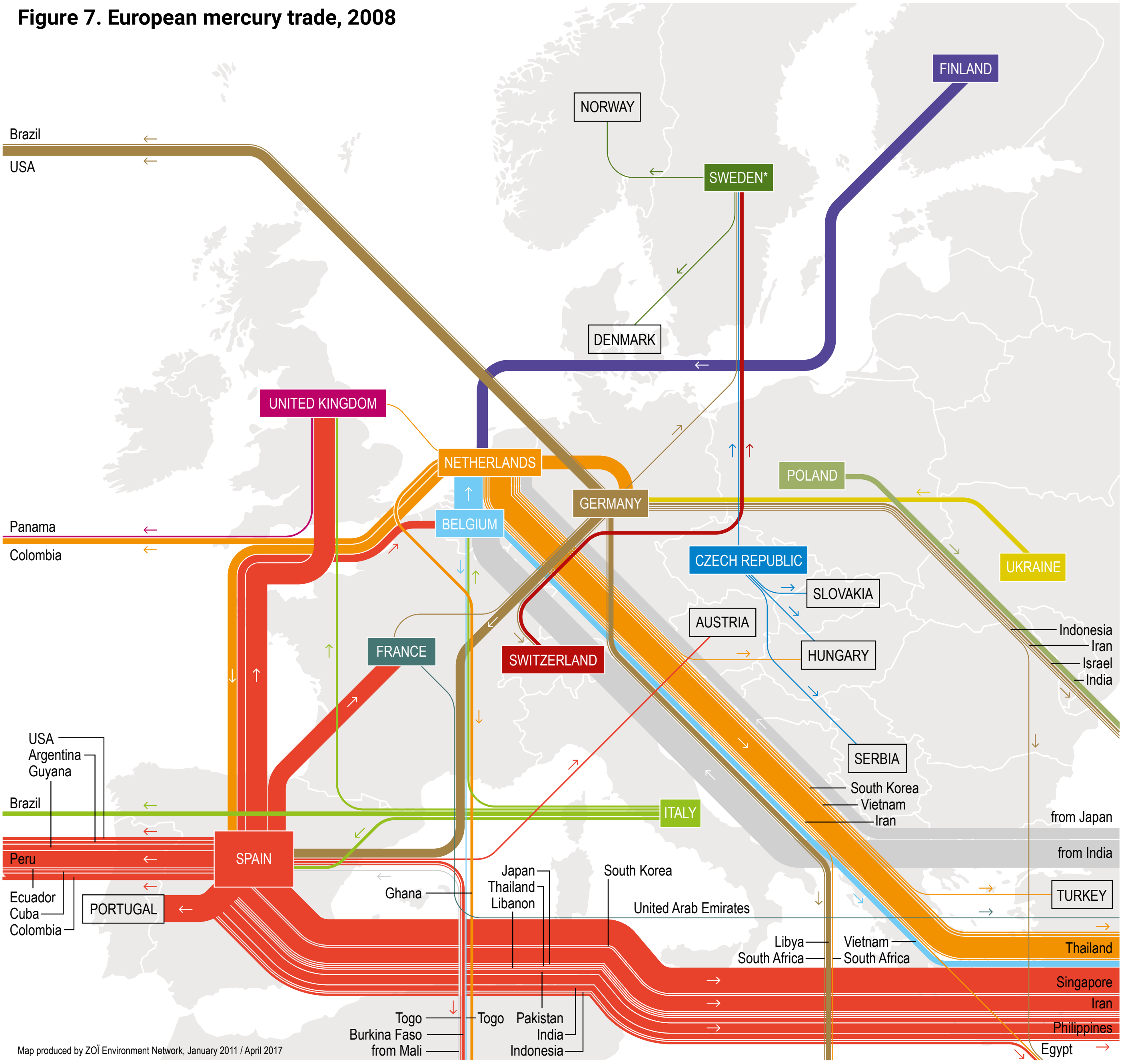
Turkey apparently sold all of the DELA mercury in its possession before it could be returned to Germany, but a warehouse in Singapore still holds 82 tonnes of the DELA mercury, where the storage fees continue to accumulate. Needless to say, while the legal status of this mercury is still under discussion among government authorities, international metals traders are reticent to consider buying this tainted mercury. It is not clear what organization – other than perhaps the European Commission – could provide a legal indemnification for this mercury in return for a commitment that the mercury would be sold only for specific authorized uses.

This affair demonstrates the value of collecting and publishing accurate trade data and the need for careful monitoring of compliance with hazardous waste transfer and disposal regulations.

Sources: Bütler 2014 and 2017; Industry reporting under Articles 6.1 and 6.2 of Regulation (EC) 1102/2008; Comtrade database; diverse communications with German and Swiss government agencies.

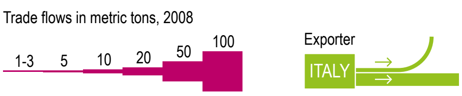
The situation in 2008, before the export ban, was much different, as seen in Figure 7. At that time stocks held in Spain and the Benelux countries were virtually supplying the rest of the world. Spain was receiving mercury from the chlor-alkali industry, and was marketing that mercury along with its accumulated stocks from its previous mining operations. These ample supplies helped to keep world mercury prices relatively low. Likewise, the mercury stocks held in Rotterdam and Antwerp by the largest mercury broker, Lambert Metals, comprised the core of the European business until the European Union banned the export of mercury in 2011.

Figure 7. European mercury trade, 2008



Mercury trade in Europe, 2008

Quantities reported as mercury to UN Comtrade Database by importing countries



* = Data from 2007 (only Sweden)

1) Not all countries report mercury trade data to Comtrade;
2) For a number of reasons, Country A's reported trade with Country B may not entirely agree with Country B's reported trade with Country A;
3) If a country's net exports were less than one metric ton, that trade flow is not shown in the figure.

Source: United Nations comtrade (→ http://comtrade.un.org); Revised by Peter Maxson

3.2.4. Country imports and exports of mercury compounds

Mercury compounds may be intentionally produced for a range of uses such as those discussed in section 4.10, or they may be generated during various industrial processes, such as the Boliden process for removing trace mercury from non-ferrous metal concentrates (especially gold, zinc, copper and lead).

Along with the trade in elemental mercury, the trade in mercury compounds also remains under scrutiny, in particular because of the risk that certain compounds could be shipped to another country and converted back to elemental mercury relatively easily. For this reason as well, the subject may arise in future discussions of certain provisions of the Minamata Convention. The trade in mercury compounds is not presently restricted by the Minamata Convention, but both the European Union and the United States have already, or will soon restrict the export of a number of mercury compounds.

Table 9 below provides an overview of the main global importers and exporters of mercury compounds. All countries with combined average annual import and export activity of more than 500 tonnes are listed.

Table 9. Major importers and exporters of mercury compounds, 2013-2015

Country	Imports and exports reported by country as mercury compounds	
	Average annual imports 2013-2015 (tonnes)	**Average annual exports 2013-2015 (tonnes)**
Belgium	8 143	566
France	3 581	15
United Kingdom	1 650	385
Bahamas	1 263	210
Italy	1 168	3
Czechia	1 022	15
Austria	684	304
Netherlands	677	219
Germany	531	349
Canada	827	24
USA	310	369
Spain	556	103

Note: In the few cases where quantities were not indicated in the database, they were estimated using the average world trade value/kg for that year.
Source: Comtrade statistics accessed 5 July 2017 at <https://comtrade.un.org/data/>

According to the Comtrade database, in 2015 the United States reported exporting over 200 tonnes of mercury compounds (HS code 2852), most of them to Canada. From 1 January 2020, five mercury compounds will be banned from US export, in line with the recently amended Toxic Substances Control Act.

According to the Comtrade database, the 28 member states of the European Union reported exporting to countries outside the European Union between 118 and 160 tonnes of mercury compounds (HS code 2852) each year from 2012 to 2014. Beginning in 2015, however, the EU-28 became a net importer of mercury compounds. The European Union currently prohibits the export of mercury(I) chloride (Hg_2Cl_2), also known as calomel, and mercury(II) oxide (HgO). The EU's new Regulation on Mercury (in force as of 17 May 2017) replaced the previous Mercury Export Ban Regulation. Among other provisions, it will prohibit the export of three additional mercury compounds from 1 January 2018 (European Union 2017).

Meanwhile, inside the European Union large trades of mercury compounds continue to be reported, although the sources and uses of these compounds have not been researched for this report. According to reports to Comtrade of the seven most active European Union traders (Austria, Belgium, France, Germany, Italy, Spain and the United Kingdom), in 2015 these countries imported some 18 000 tonnes of mercury compounds from other countries within the European Union, and exported nearly 3 000 tonnes to other countries within the European Union. In light of these large quantities, the possible inclusion of some industrial wastes bears further investigation.

3.2.5. Mercury trading hubs in Sub-Saharan Africa

Recently the World Bank funded research into mercury trading and use in ASGM in sub-Saharan Africa. Their findings were based on national statistics officially reported to the Comtrade database, as well as local information on actors in the value chain and the informal trade of mercury, collected mainly by field researchers. Their findings suggested that Kenya and South Africa serve as the main supply hubs for mercury used in ASGM especially in the Democratic Republic of Congo, Uganda, Tanzania, Zimbabwe, Mozambique and South Africa itself. The total estimated mercury demand for ASGM in these countries is 55-160 tonnes per year. Apart from the registered export of mercury from South Africa to Zimbabwe and a few other countries, trade between the countries appears to be mostly undocumented. As an example, Kenya did not register any exports at all during 2010-2015. Information from the gold fields in northern Tanzania, Uganda and eastern Democratic Republic of Congo, however, confirmed that their mercury came mainly from Nairobi, likely after entering the country via the port of Mombasa (World Bank 2016b).

The free port in Lomé, Togo, serves as the main hub for the import of mercury into West Africa. Lomé opens a corridor for the import of many commodities to Ghana and other countries in the region. In addition to import via Togo, a significant quantity of mercury is imported directly to Ghana and Nigeria. For the three major ASGM countries – Senegal, Mali and Burkina Faso – hardly any mercury import is documented and no export from partner countries outside sub-Saharan Africa is registered, confirming field research that mercury is informally imported from neighbouring countries, even though the origin of the mercury is unclear (World Bank 2016b).

During the last 10 years Sudan has imported more mercury than any other country in sub-Saharan Africa, although there is little evidence of re-export. The mercury appears to be used primarily for ASGM in Sudan (World Bank 2016b; Comtrade 2016).

Among other observations, the World Bank report discovered that a majority of the transboundary trade between the countries in sub-Saharan Africa is undocumented and does not appear in any official statistics. Trade data available in Comtrade reveals that India, China, the United Arab Emirates and a few other countries appear to be the main sources of mercury shipped into sub-Saharan Africa.

3.3. Trade related problems

Illegal or undocumented mercury trade is common enough to deserve further mention. Likewise, 34.5 kg mercury flasks that do not meet the United Nations Hazardous Material Shipping Requirements or equivalent transport safety standards are a potential hazard.

3.3.1. Illegal and undocumented mercury trade

Countries around the world have implemented varying regulations and restrictions concerning mercury trade, the disposition of mercury containing (hazardous) wastes, and ASGM activities. Such restrictions, along with the related administrative procedures and costs, not to mention import tariffs, are sufficient incentives for many middlemen to look for ways to bypass the normal controls. Likewise, the need to transport mercury to remote regions for ASGM provides a strong incentive to identify the fastest and cheapest solutions, which are generally informal solutions. Thus, while it is impossible to know the volume of illegal or undocumented movements of mercury, it is evident that they comprise a significant percentage of the business. The main strategies appear to involve:

- Hiding mercury among other goods, as in the case of mercury smuggled into West Africa
- Mislabeling the contents of the transport container, as in the case of containers of cinnabar sent from Indonesia to the Philippines
- Smuggling mercury into a country outside the normal ports of entry, as described in the box below concerning the Philippines[30]
- Transporting mercury across a border without proper documentation, as in the case of mercury moving from Mexico into Central America
- Shipping commercial quality mercury as low-value mercury or waste, as in the DELA GmbH affair in Germany

There are also perfectly legal, but not very transparent movements of mercury, such as between the Chinese mainland and Hong Kong. It is difficult to get a permit to export mercury from the mainland, but mercury moves more easily from the mainland to Hong Kong, and from Hong Kong it may readily be exported. Although the statistics of other countries show significant amounts of mercury apparently imported from China (64 tonnes in 2015) and from Hong Kong (45 tonnes in 2015), it is not at all clear where much of that mercury actually originated.

3.3.2. Substandard flasks

Substandard mercury flasks were less of a problem in past years when major mines and traders controlled most of the mercury trade, and had developed reputable suppliers of flasks. With the recent increase in informal mercury mining and commerce, however, more "home-made" flasks that do not comply with UN or equivalent specifications for hazardous materials shipments have appeared on the market.

30 The Indonesian Finance Ministry's director general of customs and excise said that in 2015 his office confiscated 14 containers of illegal mercury, worth an estimated Rp 47.8 billion (US $3.47 million) and destined largely for the illegal gold mining industry. See <http://jakartaglobe.beritasatu.com/news/indonesian-small-scale-miners-historic-pledge-halt-mercury-use/>

Undocumented mercury supplies to ASGM activities in the **Philippines**

The ASGM activities in the Philippines are conservatively estimated to consume 35-105 tonnes of mercury per year. Field investigations have confirmed that mercury trade in the Philippines is challenging to understand and monitor. A tightly controlled network runs the domestic mercury trade. Most mine operators give guarded answers about their mercury sources, and mercury traders provide little information as to the volume and origin of their mercury imports. This tends to support the general belief that mercury is shipped into the country illegally.

It is also common practice among chemical goods importers to receive only one container or shipment at a time, for a number of reasons. One container hardly ever requires storage at the port, not only saving on storage fees, but also minimizing the risk of contraband goods being seized. Moreover, if the goods are seized by Customs, the importer's losses are limited if there is only one container.

Some mercury used to be traded at the Barter Trade in Zamboanga City center, but this facility burned down several years ago. Subsequently mercury trade for the southern Philippines shifted elsewhere and became less visible. Manila has now become the main mercury-trading center for ASGM in Luzon, while Cebu and Davao cities are the main mercury trading centers for the Visayas and Mindanao islands, respectively.

The mercury that enters the country illegally mostly appears to come from Indonesia and Malaysia by fishing boats into three major ports in Mindanao – Davao, Zamboanga and Sarangani. A news article from the Philippine Daily Inquirer reported that a 20-foot motorized vessel carrying 500 kilograms of mercury sank in Sarangani Bay in October 2011. Customs officials have confirmed that Mindanao has become a drop-off point for smuggled mercury, which is then transported by land through Davao City. Although interviews did not reveal the actual volume of smuggled mercury, they did confirm that this route was frequently used.

Sources: BAN Toxics 2012; R. Gutierrez, personal communication, 12 May 2017.

Substandard flasks apparently originating in **Indonesia**

According to more than one company in the business, substandard mercury storage flasks have appeared in Indonesia during the last couple of years. One trader reports that they are copies of US flasks previously supplied to Indonesia – painted the same color, and with labels that show a United States UN flask approval number. On closer inspection, however, one of the buyers observed that these flasks had never been tested or formally approved. Caveat emptor appears to be a requirement for doing business in the international mercury trade. Even more problematic, some of the flasks were apparently believed by at least one mercury supplier to be actually or in danger of leaking, so thin polythene plastic bags were inserted inside the flasks before they were filled with mercury, which is entirely unacceptable practice for the shipment of hazardous materials.

According to industry sources, especially for mercury trade between Indonesia and India, this transport safety issue has been too often overlooked.

3.4. General observations

3.4.1. Reductions in global mercury trade

Although global imports and exports of mercury may have limitations as indicators, in any case they are sufficient to indicate general trends in global mercury trade. Table 10 shows the remarkable decrease in recent years in both indicators, primarily as a result of taking off the market the large mercury sources (especially from the chlor-alkali industry) previously available in the United States and the European Union.

Even if undocumented mercury trade in some parts of the world may have increased during this period, there is no doubt that formal trade has declined to a much greater extent. For example, even in the most extreme case, undocumented exports from Mexico and Indonesia would not have totaled more than 500 tonnes in 2015.

Table 10. Global mercury imports and exports

	Global mercury imports (tonnes)	Global mercury exports (tonnes)
2010	2 636	3 206
2011	3 107	2 904
2012	2 967	2 944
2013	1 958	2 624
2014	1 215	2 172
2015	1 171	1 324

Source: Comtrade statistics accessed 14 July 2017 at <https:// comtrade.un.org/data/>

3.4.2. Increased scrutiny of major mercury exporters

The Minamata Convention will oblige all Parties to gain a better understanding of the sources of mercury used in their countries. For example, since Minamata prescribes that primary mercury and mercury from the chlor-alkali industry cannot be used for ASGM, many mercury users will seek to confirm the sources of their mercury purchases. As a result, all major exporters will be more closely scrutinized in order to determine where their mercury is coming from. Table 11 shows all countries that reported to Comtrade exports of more than 25 tonnes of mercury in 2015.

Table 11. Countries reporting exports of more than 25 tonnes of mercury in 2015

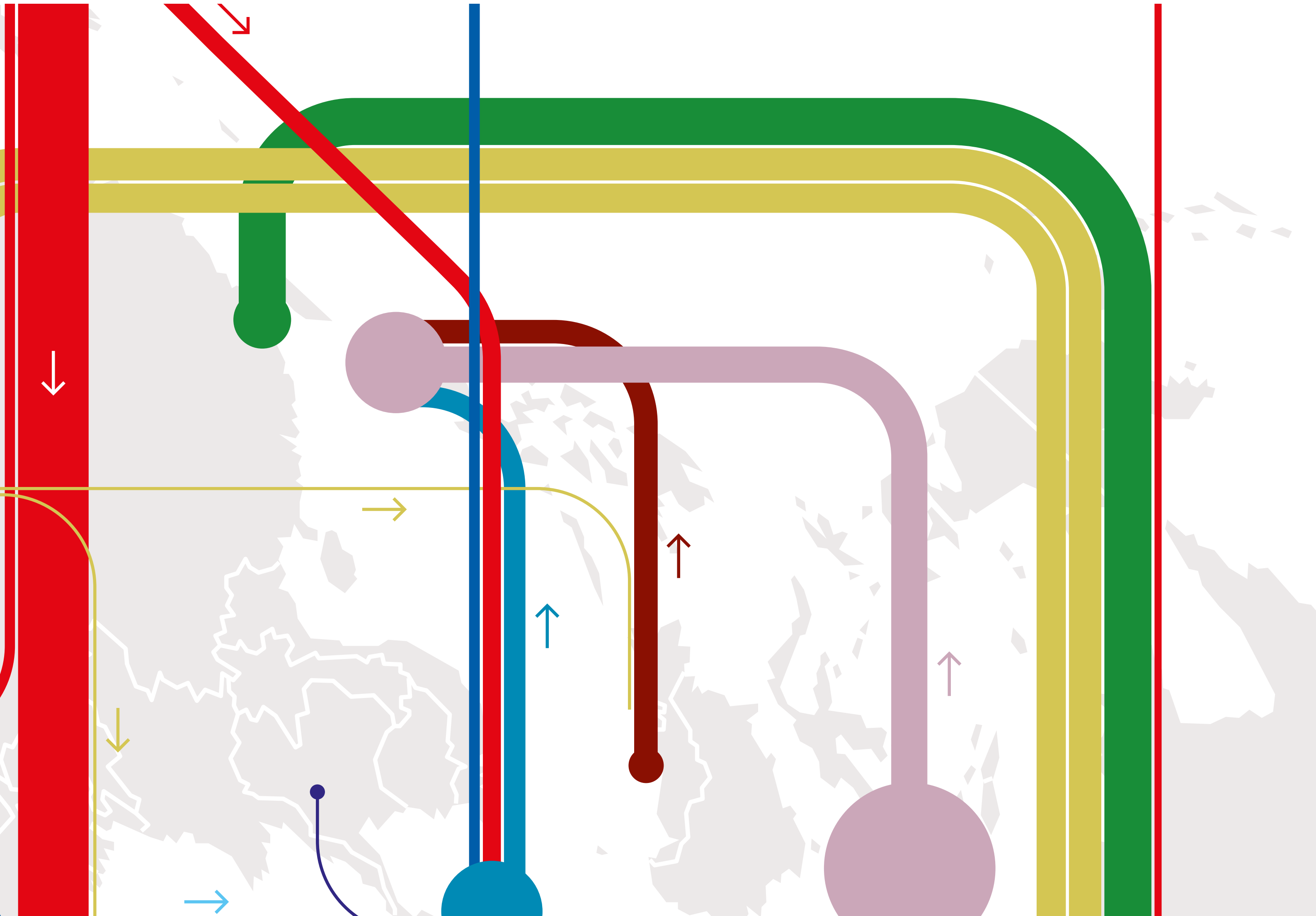
Country	Reported exports (tonnes)
Mexico	307
Indonesia	284
Netherlands	183
Singapore	140
Japan	102
Switzerland	102
India	64
United Arab Emirates	31

Source: Comtrade statistics accessed 21 December 2016 at <https:// comtrade.un.org/data/>

Note: A number of other countries in Latin America, Asia and sub-Saharan Africa would also be included in this list if their undocumented exports to neighbouring countries were known (World Bank 2016b).

4. Global, regional and sectoral consumption of mercury

This chapter provides global mercury consumption data for 2015 by geographic region and by major application or sector. In particular, this analysis summarizes intentional uses of mercury in different regions, first, by analyzing the latest available information on each major application of mercury in products and processes, and second, by using various methodologies to estimate mercury consumption for those uses and in those countries where information is inadequate. In spite of the fact that information on mercury consumption in all applications continues to improve, considerable uncertainty remains. All mercury consumption estimates are presented as ranges, acknowledging the fact that few countries are able to provide precise numbers for mercury consumption for any given application.



4.1. Background

This analysis makes a particular effort to conform to the methodology used in the Global Mercury Assessment (the 2018 edition of which is currently in preparation), in which mercury consumption by sector and region is used to inform product- and process-related mercury emissions and releases. Therefore, the term "consumption" is defined here in terms of the end-use of mercury-added products, as opposed to general "demand" for mercury. For example, although most energy-efficient lamps (such as CFLs) are produced in China and therefore represent basic Chinese "demand" for mercury, many of them are exported, used and disposed of in other countries, representing the actual place of consumption. When a product reaches the end of its life and goes to recycling or into a separate waste stream, it is important to understand the quantity of domestic mercury consumption that feeds into these pathways.[31] Of course, domestic production is also useful to know for the implementation of Convention obligations.

This analysis of mercury consumption in products and processes has revealed some new insights. Although there is ongoing reduction or substitution of mercury used in most products (batteries, lamps and others) and in one key process (chlor-alkali production), the improved reporting from a number of countries, many based on Mercury Inventory Toolkit guidance, revealed some higher levels of consumption than had previously been estimated. The category of "other" uses of mercury (cosmetics, pharmaceuticals, cultural and ritual uses), in particular, showed an increase in consumption in 2015 over 2010, largely due to the availability of somewhat better information and estimates regarding the many uses of mercury apart from the more familiar applications.

As mentioned above, this analysis focuses on the regional level, partly to provide a scope that is manageable, but also because the country-level data for many countries are not available or not sufficiently reliable. The country-level information that is available, however – while accepting that each country is unique in some respects – is valuable for providing possible guidance on industries and markets in other economies in the region. In this regard, the sources in Table 18 in the Appendix are very helpful not only in understanding the situation of the subject countries, but also in appreciating the situation of neighbouring countries for which such detailed information is not yet available.

4.1.1. Regional definitions

Regions as defined for this analysis, and to maintain consistency with the regions used for the Global Mercury Assessments, include:

- East and Southeast Asia
- South Asia
- European Union (28 countries in 2015)
- Commonwealth of Independent States (CIS) and other European countries
- Middle East
- North Africa
- Sub-Saharan Africa
- North America
- Central America and the Caribbean
- South America
- Australia, New Zealand and Oceania

The countries included in each region are listed in Table 19 in the Appendix.

These regional groupings reflect data availability and/or geographic proximity and/or economic relations between the countries, and have been defined to facilitate the presentation of mercury imports and exports for each region. Regional groupings proposed here have no political connotation; they are merely an attempt to be all-inclusive of the countries and regions that appear in the Comtrade statistics. While these regional groupings of countries are not official United Nations groupings, some of them are similar, but have been adapted to enhance the value of this specific analysis and, for the most part, the countries of each region show fairly similar mercury use profiles.

31 On the other hand, when dealing with global mercury demand, or demand by economic sector or application, the terms "mercury consumption" and "mercury demand" may be used interchangeably since there is no geographical orientation implied.

4.1.2. Historical context

Table 12, showing mercury demand by sector, provides an historical perspective on mercury demand for products and processes during the last 10 years. The numbers provided in the last column are drawn from later sections of this report.

Looking even farther back, global demand for mercury has declined from more than 9 000 tonnes annual average in the 1960s, to around 7 000 tonnes in the 1980s, and closer to 4 000 tonnes in the late 1990s (Hylander & Meili 2003). By 2005, as seen in Table 12, global demand was estimated at 3 000-3 900 tonnes per year. By 2010, mean mercury demand was once again over 4 000 tonnes.

Due to the uncertainties and to the fact that new information has become available in the interim, directly comparing the 2005 and 2010 estimates in this table is not advisable. Nevertheless, general trends are evident. Between 2005 and 2010 the use of mercury in ASGM and VCM increased, while for most other uses a general decline was apparent. One exception to that decline was the category for a great variety of "other" uses – always difficult to quantify – where research in 2007 and 2008 (European Commission 2008b) revealed new information on such applications as catalysts used for curing polyurethane elastomers. This development added to the knowledge base (and the estimates) of overall mercury consumption.

Global mercury consumption in 2005 and 2010 was also estimated by geographic region as presented in Table 13. Although the estimates for mercury consumption in 2015 are developed in the following sections of this report, a column has also been included to facilitate comparison.

Table 12. Global mercury consumption by sector

Sector mercury consumption (tonnes)	2005	2010	2015
Small-scale/artisanal gold mining	650 - 1 000	912 - 2 305	872 - 2 598
Vinyl chloride monomer (VCM) production	600 - 800	860 - 1 030	1 210 - 1 241
Chlor - alkali production	450 - 550	300 - 400	233 - 320
Batteries	300 - 600	230 - 350	159 - 304
Dental applications	240 - 300	270 - 341	226 - 322
Measuring and control devices	150 - 350	219 - 280	267 - 392
Lamps	100 - 150	105 - 135	112 - 173
Electrical and electronic devices	150 - 350	140 - 170	109 - 185
Other (paints, laboratory, pharmaceutical, cultural/traditional uses, etc.)	30 - 60	222 - 389	215 - 492
Total	**3 000 - 3 900**	**3 258 - 5 400**	**3 404 - 6 027**

Note: Rather than "demand," the term "consumption" is used here to indicate the mercury content of all mercury added products used in a given country or region during a given year, as well as the gross mercury inputs of any industrial processes. For example, although most energy-efficient lamps (such as compact fluorescent lamps) are produced in China and therefore represent basic Chinese "demand" for mercury, many of them are exported, used and disposed of in another country, which is the actual place of "consumption." If mercury-added products consumed in a country are also produced in the same country, then all of the mercury that goes into their production (and related production waste) is also included in the calculation of consumption. Likewise, all mercury used in dental practices should be included in the calculation of a country's mercury consumption. If mercury happens to be consumed, recycled and consumed again in the same year, it would be counted two times as consumption, consistent with the overall level of activity.

Sources: UNEP (2006), AMAP/UNEP (2013), this report.

Table 13. Global mercury consumption by geographic region

Regional mercury consumption (tonnes)	2005	2010	2015
East and Southeast Asia	1 600 - 1 900	1 697 - 2 638	1 931 - 2 882
South Asia	300 - 500	124 - 182	192 - 334
European Union	400 - 480	314 - 470	194 - 304
CIS and other European countries	150 - 230	115 - 189	113 - 230
Middle Eastern States	50 - 100	77 - 106	79 - 136
North Africa	30 - 50	22 - 29	29 - 52
Sub - Saharan Africa	50 - 120	216 - 506	234 - 660
North America	200 - 240	191 - 275	107 - 167
Central America and the Caribbean	40 - 80	54 - 88	51 - 104
South America	140 - 200	433 - 897	458 - 1 130
Australia, New Zealand and Oceania	20 - 40	15 - 20	16 - 27
Total	**3 000 - 3 900**	**3 258 - 5 400**	**3 404 - 6 027**

Note: Rather than "demand," the term "consumption" is used here to indicate the mercury content of all mercury added products used in a given country or region during a given year, as well as the gross mercury inputs of any industrial processes. For example, although most energy-efficient lamps (such as compact fluorescent lamps) are produced in China and therefore represent basic Chinese "demand" for mercury, many of them are exported, used and disposed of in another country, which is the actual place of "consumption." If mercury-added products consumed in a country are also produced in the same country, then all of the mercury that goes into their production (and related production waste) is also included in the calculation of consumption. Likewise, all mercury used in dental practices should be included in the calculation of a country's mercury consumption. If mercury happens to be consumed, recycled and consumed again in the same year, it would be counted two times as consumption, consistent with the overall level of activity.

Sources: UNEP (2006), AMAP/UNEP (2013), this report.

4.1.3. Evolution of mercury prices

In order to provide a more complete perspective and additional historical context, some discussion of the evolution of mercury prices is necessary. Since the imposition of mercury export bans in the EU and US, mercury traders have suggested that they now work with three discrete mercury markets. Each market reflects its own unique supply and demand situation in response to regulatory realities.

The United States prohibits the export of mercury while continuing to generate more mercury domestically than it consumes. As a result, mercury that can be sold domestically has a low value, while any remaining domestic mercury has a negative value since there is a cost for its storage or disposal.

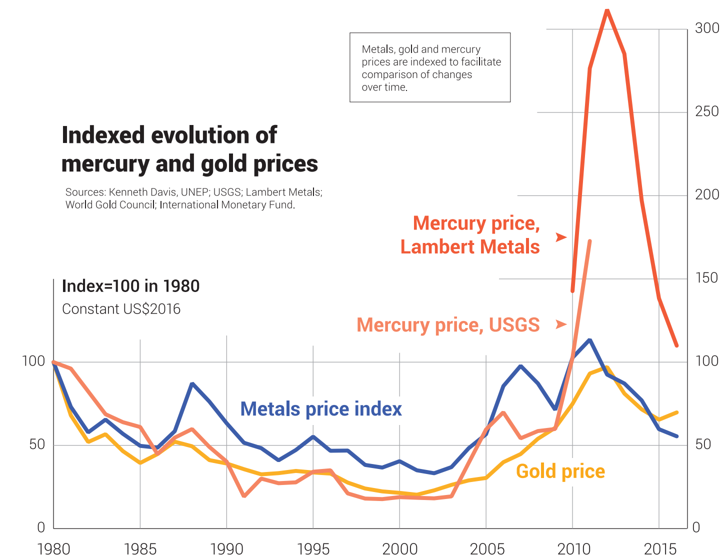
In the European Union there is a similar dynamic, although the domestic mercury market is somewhat larger, and mercury disposal costs tend to be lower than in the United States. Therefore mercury that can be sold domestically has a somewhat higher value, while any EU mercury that remains unsold has a "less negative" (reflecting a lower cost of disposal) value as compared to the United States. Similar to the situation in the United States, markets outside the European Union do not influence the mercury price within the European Union, and the internal market value of mercury tends to remain quite stable.

Finally, countries that have not banned mercury exports continue to exist in a relatively free-market environment, where the price of mercury may fluctuate greatly depending on the vagaries of supply and demand, but also on the quality of the mercury, the size of the overall shipment, the packaging of individual items such as plastic bottles, the distance from the supply source, and other factors.

Mercury and gold prices, 1980-2016

ASGM is a major component of mercury demand, especially in recent years. It is natural to assume a connection between demand for mercury from ASGM and mercury price. Because ASGM activity likely increases with higher gold prices, a correlation between mercury prices and gold prices might be expected.

This hypothesis is tested in the figure below, which presents mercury and gold prices, as well as a price index for commodity metals, from 1980 through 2016. Prices are normalized so that the 1980 value is 100, which allows for four time-series on a single graph.



Sources: K. Davis, 2017; mercury prices from USGS and Lambert Metals; gold prices from World Gold Council; metals price index from IMF.

Prices for mercury and gold are well correlated until about 2010, decreasing in real terms from 1980 until the turn of the century and then rising. A causal connection cannot necessarily be inferred, however, as the metals price index shows a similar trend during this period. Mercury prices then rise sharply between 2009 and 2012, diverging from the gold and metals series, before falling again through 2016.

With regard to the mercury price itself, before 2003 the reliable and freely traded sources included primary mining, residual mercury from the chlor-alkali industry, by-product from non-ferrous metal mining, stocks held by former Soviet states and recycled mercury. They were well established and they responded rapidly to normal swings in market demand, so that changes in demand rarely implied significant changes in the mercury price. Then mercury supplies began to be artificially restricted. The closing of the Almadén mine in 2003 represented a highly significant tightening of supply – the first in a chain of events that made it increasingly difficult for mercury supplies to respond quickly and cheaply to rising demand from the ASGM sector and the vinyl chloride industry. At this point the marginal cost of providing an additional unit of mercury to meet demand began to increase dramatically.

By the time the EU and US export bans took effect in 2011 and 2013, respectively, many mercury users had difficulty in securing the metal and the market experienced some panic. Supplies and inventories had to be secured at any price, and the 2011-2013 price reached nearly five times the price in 2009. Unsurprisingly, the ongoing demand and high price of mercury stimulated supply, which caught up with demand by 2012 and began driving the mercury price back down. The sources of supply included US and EU stocks that had been transferred out of those regions before the export bans took effect, mercury illegally exported by DELA as waste, and new primary mining in Mexico and Indonesia. By mid-2016 the mercury price was once again close to 2010 levels.

While there may appear to be a correlation between mercury and gold prices during most of this period, it should be noted that the gold price tracks the metals price index even more closely (though with less volatility) than it tracks mercury for the entire period, suggesting that movements in the gold price are rather consistent with those of other metals, and demonstrate no special relationship to movements in mercury prices.

4.1.4. Methodology for estimating sector mercury consumption

The methodologies for estimating mercury consumption in the ASGM, VCM and chlor-alkali sectors are described in those specific sections of the report below. For other sectors (batteries, lamps, dental, and others), a common methodology was used, including the following steps:

1. The review of published and unpublished estimates of mercury consumption in a given sector by country
2. The review of other relevant information provided by the Mercury Inventory Toolkit and other sources
3. Based on country economic well-being (in terms of GDP at PPP, as in Table 20 in the Appendix), the calculation of mean country mercury consumption factors (g Hg/million $INT of GDP at PPP) for the countries for which sufficient information is available
4. Similarly, based on country population (also presented in Table 20 in the Appendix), the calculation of the mean country mercury consumption per inhabitant (mg Hg/capita) for the countries for which sufficient information is available
5. Based on these two country-level economic and population-based indices, the estimation of mean regional mercury consumption factors (g Hg/million $INT) for each mercury use sector
6. Based on the mean regional mercury consumption factors previously estimated, the calculation of total mean regional mercury consumption (kg Hg) for each mercury use sector
7. Based on the availability and general quality of the information supporting these calculations, the estimation of the likely margin of error around the mean regional mercury consumption for each mercury application

This analysis is summarized in Table 17 for the various regions and mercury applications, which are discussed below in separate sections of the report.

4.2. Artisanal and small-scale gold mining

ASGM remains the largest global use of mercury, and the largest source of mercury releases. This type of mining relies on rudimentary methods and technologies, and is typically performed by miners with little or no economic capital, who most often operate in the informal economic sector, sometimes illegally and with little formal organizational or management structure (UNEP 2006). Table 21 in the Appendix provides an update of mercury use in all of the countries where ASGM activities have been observed. Typically occurring in regions where there are few economic alternatives for workers, ASGM tends to be even more attractive when the world gold price is elevated, as it has been since about 2009. Due to the way mercury is handled and used, the sector is associated with serious risks to human health and the environment. For this reason national and international initiatives have multiplied, seeking to reduce the use of mercury in ASGM, and to improve the operating practices and well-being of those working in this sector. The extent and informal nature of ASGM activities, however, raise serious long-term challenges to the success of such efforts.

Previous estimates (Telmer and Veiga 2009; Pirrone et al. 2010) that at least 100 million people – directly and indirectly – depend on ASGM for their livelihoods remain valid, mostly concentrated in lower income economies in Africa, Asia and South America.[32] This analysis confirms previous estimates that ASGM is now responsible for around 20 per cent (600-650 tonnes per annum) of the world's primary (mined) gold production.[33] It directly involves an estimated 10-15 million miners, including some 4.5 million women and 1 million children.

The two main processes used by artisanal gold miners are concentrate amalgamation, where the gold-bearing ore is concentrated by panning or sluicing prior to amalgamation with mercury; and whole-ore amalgamation, where a relatively greater quantity of mercury is added directly to the gold ore during the grinding or crushing process. Concentrate amalgamation uses an average of about

32 Not all artisanal/small scale gold miners use mercury. Some use cyanide, permitting more gold to be recovered than when using mercury. Others use gravimetric or other methods without mercury or cyanide.

33 Published estimates range as follows: 500-800 tonnes (Swain et al., 2007); 20–30% (UNEP, 2008); 20–30% (Telmer and Veiga 2008); 25% (Chouinard and Veiga, 2008); 25% (Cordy et al., 2013); 25% (Saldarriaga-Isaza et al., 2013); 20% (World Bank, 2013); 12–15% (Ismawati, 2014); 400 tonnes (Telmer, 2015).

1.3 g of mercury per gram of gold recovered. Whole-ore amalgamation, on the other hand – most common in Bolivia, China, Colombia, Ecuador, Indonesia, Peru, Philippines, Suriname and Venezuela – is less prevalent though estimated to use an average of about 5 g of mercury per gram of gold recovered (AGC 2017). However, practices vary greatly and the use of 20 g of mercury or more has been observed at some whole-ore amalgamation mining sites, with the result that this process is responsible for more than 50 per cent of all mercury consumed in ASGM. For this reason, whole ore amalgamation has been identified as a worst practice, to be eliminated under Annex C of the Convention. Although there may be considerable variation from one mining site to the next, if site-specific data are unavailable, the most logical way to calculate mercury consumption is by way of a reasonable estimate of the quantity of gold produced.

The methodology used to update to the present the previous estimates of mercury consumed in ASGM therefore started with the foundation provided by data published in the Technical Background Report for the 2013 Global Mercury Assessment (AMAP/UNEP 2013), much of which remains the most current information available. That information was mostly based on research estimating the number of ASGM miners, the earnings required to support themselves and their families, and the quantity of gold produced by ASGM. Gold production was then converted to mercury consumption using factors developed by field researchers for the quantity of mercury required to produce a unit of gold. As mentioned above, different factors apply to concentrate and whole ore amalgamation, while the quality of the data was reflected in the margin of error. The database was updated with information collected from a literature search for recent peer-reviewed articles and papers on ASGM activities, consultant reports and "grey literature" such as the draft World Bank (2016b) report on ASGM in sub-Saharan Africa, as well as information from other primary sources such as the Artisanal Gold Council. Experts with extensive field experience provided the final review.

The results of this analysis are presented in Table 21 in the Appendix, which summarizes the most recent estimates of global ASGM mercury consumption ranging from about 872 to 2 598 tonnes, with a mean of about 1 735 tonnes. This is an increase of more than 100 tonnes as compared with the 2010 mean. While the updated figures reflect a significant reduction especially in the estimate of ASGM activity in China, although still highly uncertain, this reduction is offset by significant increases in the estimates for Ecuador, Guinea, Myanmar, Peru, Sudan and Suriname. Some changes from previous estimates may reflect real observed increases or decreases in country, while other changes may simply be due to the availability of better information than previously available – for example with regard to gold production.

The difficulty in further improving these estimates and narrowing the uncertainties lies in the enormous number of countries and stakeholders involved (Fritz et al. 2016), the diversity of mining methods, the fact that some ASGM activities take place in conflict zones, the remote, informal and sometimes illegal (in a number of countries) nature of many of the mining activities, and the relative lack of resources needed to put more research and extension personnel in the field. It is important to keep in mind that there are many ASGM countries where researchers have not worked for many years, so that even some of the estimates used in 2010 were based on older research that had not been updated. The age of the information available is reflected in the range of uncertainty applied to the various estimates.

4.3. VCM production

Vinyl chloride monomer is mainly used to produce PVC (a plastic mostly used in construction, window frames, and other applications), and the global demand for PVC has grown rapidly, especially in developing economies. In countries where coal may be used as a cheap feedstock, the carbide-based process was widely used in the past, relying on a mercuric chloride catalyst to produce VCM. The main mercury-free process, based on ethylene, uses oil as a feedstock.

The carbide-based process for the production of VCM has been phased out in most countries, but still dominates in China, and limited production remains in Russia and India as well. The carbide-based process is a subject of particular concern as it is not clear how much mercury is released from this process, where and in what form (Hui et al. 2016). There are also concerns about the management of various mercury waste streams including the spent catalyst and activated carbon filters.

While other estimates have been published (Hui et al. 2016), the most recent and reliable information for China estimates carbide-based production of VCM at 14 million tonnes in 2014, and ethylene-based production at 2.3 million tonnes (UNIDO 2016), mainly concentrated in Inner Mongolia, Xinjiang, Shandong, Henan and Tianjin. UNIDO (2016) estimated that 40 per cent of Chinese capacity has shifted to a low-mercury catalyst,[34] and calculated total mercury consumption for VCM production in 2014 at 1 216 tonnes. In parallel a mercury-free catalyst has also been developed and is in the advanced testing stage.

According to UNIDO (2016) and Hui et al. (2016), 30-50 per cent of the mercury remains in the spent catalyst and most of that goes to recycling. Another 30-50 per cent is caught in activated carbon filters that mostly go to recycling as well; 4-6 per cent of the mercury ends up in various wastes. Nevertheless, these numbers suggest that the fate of up to 30 per cent of the mercury is still unknown.

Eco-Accord (2010) identified two facilities in Russia with a total production of about 120 000 tonnes of VCM using the carbide-based process. A recent update on the situation (Russia 2017) gave annual production of 64 500 tonnes of VCM, and mercury consumption of 6 197 kg.

Chakraborty et al. (2013) confirmed that carbide based VCM production capacity of 36 000 tonnes/year remains in India, using an estimated 4-5 tonnes of mercury per year, based on factors provided by the Mercury Inventory Toolkit.

Despite some uncertainty in the above sources, global mercury consumption for VCM production in 2015 was in the range of 1 210-1 240 tonnes, as summarized in Table 23 in the Appendix.

4.4. Chlor-alkali production

While global chlorine and caustic production capacity has been on the rise for many years, the capacity of plants using the mercury cell electrolytic process has been on the decline. In 2005 there were about 9 million tonnes of global chlorine capacity using mercury cell technology. In 2010 there were about 6.7 million tonnes (AMAP/UNEP 2013), and in 2015 some 4.8-5.0 million tonnes (UNEP 2016).

Depending on a host of factors including cost, plant capacity, local market realities, and construction site size, old mercury cell plants may be permanently closed, converted to a mercury-free process and/or replaced with a mercury-free facility constructed close by. Nearly all plant conversions in recent years have opted for the more energy-efficient and mercury-free membrane process. In many cases governments have worked with industry representatives and/or provided financial incentives to facilitate the phase-out of mercury technology. In addition, governments and international agencies have created partnerships with industry and others to encourage broader industry improvements with regard to the management and releases of mercury from those facilities that are still operating.

The intent of the Minamata Convention is for all chlor-alkali production to eventually become mercury-free. India closed its last mercury cell facility at the end of 2015. Mexico and the United States each had two plants still operating in 2015, but one of the Mexican plants has now stopped operating. Brazil is arranging for four plants to convert to the membrane process in the near future. Argentina closed its last mercury cell plant in 2016.

34 Nankai University successfully developed and tested a new low-mercury catalyst technology for PVC production, as reported 31 July 2014. See <http://www.asianmetal.com/news/getMoreProNewsEn.am?v=1&productThreeID=37&jspBarNewsType=News&ny=2014>

Uruguay has committed to convert its last mercury cell plant during the next five years. The European Union, which historically has relied quite heavily on mercury cell technology, has placed its member states under increasing regulatory pressure to develop plans to close or convert all 27 plants that were still operating at the end of 2015. Worldwide, at the end of 2015 there were still about 75 plants using the mercury cell process operating in 40 countries, plus two plants in Germany using the same basic process to produce sodium methylate.

There are significant variations – not only between countries but even between companies – in mercury releases generated during the chlor-alkali production process. Some plants have invested in substantially reducing mercury consumption and releases, while others consume 10-20 times more mercury per unit capacity than the best performing plants. This spread is reflected in the Mercury Inventory Toolkit's default values of annual mercury consumption of between 10 g and 200 g mercury per tonne of chlorine production capacity. The fact that few facilities have managed to balance known mercury consumption with measured emissions and releases complicates the work of quantifying mercury releases from this industry.

The 2005 estimate for global mercury consumption[35] was 450-550 tonnes, based on previous studies (UNEP 2006; EEB 2006; Euro Chlor 2007; WCC 2006; SRIC 2005). The 2010 estimate of 300-400 tonnes of mercury consumption was based on reduced capacity as well as the assumption of commitments to improvements in consumption factors. The estimate for 2015 is based largely on input from the World Chlorine Council (WCC 2016), the UN Environment Global Mercury Partnership (UNEP 2016a, 2016b) and Euro Chlor (2016). As detailed and summarized in Table 22 in the Appendix, the best estimate for total mercury consumed in the industry in 2015 is in the range of 233-320 tonnes.

35 The practice followed here with regard to this industry is to calculate mercury "consumption" before any recycling of wastes, with the knowledge that, as in many industries, some waste is recycled in order to recover the mercury, while most mercury waste is sent for disposal. This is not necessarily the same approach used by many of the operators, who may recycle mercury from their plants' wastes or sludge, and then subtract the quantity of recycled mercury from the amount of mercury otherwise consumed during plant operation.

4.5. Batteries

A number of countries have placed limits on the mercury content of batteries in an effort to deal with the problems related to diffuse mercury releases and inadequate levels of battery recycling. As a result, many suppliers have upgraded their facilities to produce batteries complying with these limits. Most recently, limits on the mercury content of some batteries have been incorporated into the Minamata Convention.

The Mercury Inventory Toolkit confirms that all of the battery types in Table 14 may contain mercury, although in recent years mercury-free substitutes – sometimes more expensive – have also become available for most of these batteries.

Globally the use of mercury in batteries, while still considerable, continues its long-term decline. It was estimated at 270-460 tonnes in 2005, and appeared to decline to 230-350 tonnes in 2010.

There has been, and remains, considerable uncertainty with regard to the contribution of mercuric oxide batteries, which have a particularly high mercury content, to that total. They have been used for many years in military, medical and maritime applications, among others. Trade statistics from 2015 appear to provide evidence of ongoing international commerce in mercuric oxide batteries. Comtrade statistics show that more than 100 countries imported mercuric oxide batteries in 2015, with net world imports of about 300 tonnes of these batteries. Some experts have raised doubts about the quality of the data, but there has been no detailed investigation. A preliminary review in Mexico recently concluded that in the Mexican trade data most of these entries appear to be mistaken (CEC 2017) and should refer to different types of batteries.[36] Comtrade statistics show that a large part of world production of mercuric oxide batteries may take place in Belgium, which sends considerable exports to Spain, Portugal and the UK, among others. A recent Product Safety Data Sheet for Energizer mercuric oxide batteries may be found online.[37] For this assessment, a global figure of 20-60 tonnes of mercury is estimated for mercuric oxide batteries, but pending further research, considerable uncertainty surrounds that estimate.

36 Comtrade statistics for 2015 show Mexican imports of over 77 tonnes of mercuric oxide batteries (representing a potential content of at least 25 tonnes of mercury) and no exports.

37 See <http://data.energizer.com/pdfs/mercuricoxidezinc_psds.pdf>, accessed 5 June 2017.

For the main battery type affected by the Minamata Convention (alkaline manganese button cells), China is the major producer. In 2015 China exported over 200 000 tonnes of batteries (of all sizes) identified in Comtrade as manganese dioxide cells and batteries, some of which were alkaline and some not. According to Comtrade, Belgium and Indonesia exported about 60 000 tonnes apiece, and Singapore and the United States exported over 30 000 tonnes each. China's plan to shift production to mercury-free alkaline manganese button cells by the end of 2015 was not achievable, but this objective appears to be realistic by 2020.

With regard to the mercury content of the batteries identified in Comtrade as manganese dioxide cells and batteries, the available Comtrade data is not sufficiently detailed to determine how much of the trade comprises mercury-free batteries, nor does it indicate what percentage of the total are alkaline button cells (normally less than 3 g in weight) and what percentage are larger batteries. A calculation of mercury content can be based only on reasonably informed assumptions. With regard to the exports of all manganese dioxide batteries mentioned above, if 10-20 per cent of the 400 000 tonnes of exports were still to contain mercury, and if the average mercury content were 2-3 kg per tonne of batteries, they could represent some 80-240 tonnes of mercury.

Table 14. Default mercury content, by battery type

Mercury-added batteries	Mercury content (kg Hg/tonne batteries)
Mercury oxide (also called mercury-zinc cells), all sizes	320
Zinc-air button cells	12
Silver oxide button cells	4
Alkaline button cells	5
Alkaline, other than button cell shapes	0.25*

* European Union regulations restrict the mercury content to no more than 0.005 kg of mercury per tonne of batteries.
Source: UNEP (2015), p207

For the two types of button cells (silver oxide, commonly used as watch batteries; and zinc-air, commonly used for hearing aids) required by the Convention to contain less than 2 per cent mercury, Japan, Europe and the United States have a larger share of production. The European Union in 2015 exported close to 13 000 tonnes of zinc-air batteries. The statistics suggest that less than 20 per cent of these were button cells, and if most of them contained mercury, that would account for up to 30 tonnes of mercury. The export statistics also show that about 1 200 tonnes of the exported silver oxide batteries were button cells, implying around 5 tonnes of mercury content.

Combining the above estimates, and leaving aside for the moment the mercuric oxide batteries, gives a total mean mercury content of around 195 tonnes.

Using an alternative approach to calculate global mercury consumption in batteries, one could look at Chinese reporting. China estimated using 80±50 tonnes of mercury in batteries in 2015 (Lin et al. 2016), of which some 30 per cent were said to be exported. Past experience suggests using the upper part of that range which, less 30 per cent, would suggest around 100 tonnes of mercury. Based on what we know of the key battery producing countries, it is reasonable to assume that Chinese production represents at least 50 per cent of global use of mercury in batteries, still excluding mercuric oxide batteries. This would suggest global demand on the order of 190 tonnes of mercury in batteries, to which would be added 40 tonnes for mercuric oxide batteries, for a total of about 230 tonnes of mercury plus or minus a substantial 70 tonnes of uncertainty, as summarized in Table 23 in the Appendix.

4.6. Dental amalgam

Dental amalgam fillings consist of an alloy of mercury (44-51 per cent mercury by weight, but generally very close to 50 per cent), silver, copper and tin, with the last three metals varying in percentage depending on the amalgam characteristics desired. The alloy may be supplied to dental practitioners as:

1. A mix of powdered metals to be combined with elemental mercury prior to placement of the filling; these may be weighed and mixed in an agitator in the clinic, or mixed by hand

2. Pre-weighed metal tablets that are crushed and mixed with mercury prior to placement of the filling

3. Small capsules of different sizes, to accommodate fillings of different sizes, where mercury and the metal powders are pre-measured in the right proportions and need only to be combined using an amalgamator in the clinic, prior to placement of the filling

In the dental clinic, part of the prepared amalgam is placed in the tooth cavity, but a significant amount remains unused (going to solid waste), and the filling surface is carved or ground to its final shape, which releases some amalgam to the trap, separator and/or wastewater system. Whatever waste amalgam is collected will typically go to waste disposal or recycling (especially for recovery of the silver content). In total, some 30-40 per cent of the amalgam material prepared for the filling typically ends up as waste (UNEP 2015; EEB 2007). Based on detailed Danish data (Maag et al. 1996, and Skårup et al. 2003), the average mercury consumption (including wastes) per filling was determined to be about 0.8 g.

As a human health concern, the World Health Organization is integrally involved in the phase down of dental amalgam. It has been determined that a small amount of mercury vapour routinely escapes from fillings in the mouth. The World Health Organization (WHO/IPCS 1991) and others (e.g., Skare and Engqvist 1994) estimated the average human daily mercury intake derived from amalgam restorations to be 10 µg (range 3-17 µg), which varies depending not only on the composition of the amalgam, but also on the skill of the dental practitioner and other factors. Some years later researchers (Richardson et al. 2011) calculated individual exposure in the range of 1-10 µg/day for the US population with amalgam fillings, depending on age, number of fillings, etc. For precautionary health reasons, the European Union has moved to restrict the use of amalgam for children and pregnant women.

The use of dental amalgam varies enormously from one country and region to another. The public health care system has a greater tendency to rely on amalgam due to lower cost and lesser need for training in the latest materials and techniques. Country and regional variations in dental care and amalgam use may be related to local customs and norms, the general level of prosperity, the availability of dental care and dental restoration materials, the cost of dental care in general as well as the cost of alternative filling materials in particular, the influence of the insurance industry on dental costs and alternatives, and the level of public awareness of possible health and environmental effects.

Largely due to the difficulty of keeping dental mercury from escaping to the environment, Sweden, Japan, Denmark and Norway, among others, have implemented measures to phase out or greatly reduce the use of dental amalgams containing mercury. These efforts have been further encouraged by the Minamata Convention calling for a phase down of mercury use in dentistry. In other countries as well (the United States, most of the European Union member states), dental use of mercury is generally declining. The main alternatives are composites (most common), glass ionomers and compomers (modified composites). The speed of change varies widely, however, so that while in a few countries amalgam has almost disappeared, amalgam fillings remain the majority in most countries. Meanwhile, in some lower income countries, changing diets and better access to dental care have probably spurred an increase in the number of amalgams placed in recent years.

Taking measures to reduce the use of amalgam

The Minamata Convention calls for a broad-based phase-down of mercury use in dentistry. Although different countries will adopt different strategies consistent with their circumstances, some measures already undertaken are mentioned here.

In Norway and Sweden, dental amalgam is no longer in use.

In Japan, Finland and the Netherlands, dental amalgam is being phased out.

In Mauritius and the European Union, dental amalgam is banned from use on children.

Denmark uses dental amalgam for only 5 per cent of restorations, and Germany for about 10 per cent.

In Bangladesh, dental amalgam is to be phased out in 2018.

In India, dental schools are required to eliminate amalgam in favor of mercury-free alternatives.

In Nigeria, the government has printed and distributed consumer information brochures promoting mercury-free alternatives to amalgam.

The government of Canada has recommended that dentists not use amalgam for children, pregnant women and persons with kidney disorders.

By a margin of 663 to 8, the European Parliament voted in March 2017 in favor of a comprehensive package to reduce mercury use, as required by the Minamata Convention on Mercury. Under this new European Union regulation, covering a population of more than 500 million persons:

—Amalgam use in children under age 15 will be banned on 1 July 2018.

—Amalgam use in pregnant women will be banned on 1 July 2018.

—Amalgam use in breastfeeding mothers will be banned on 1 July 2018.

—Each country in the European Union will be required to develop a national plan by 1 July 2019, laying out how it will reduce amalgam use.

—The European Commission must decide by mid-2020 whether to move forward with plans to phase out dental amalgam completely in the European Union.

The practices of one country are not necessarily a good indicator of the practices of the whole region; nor is the availability of dental care a good indicator of the number of amalgam fillings placed in a given country.[38] This analysis therefore use the results of 21 country/region studies to inform initial estimates of amalgam use. The quality of these country studies varies greatly. The estimate for the United States (USEPA 2017), for example, was based on Interstate Mercury Education and Reduction Clearinghouse (IMERC) figures that have been demonstrated in the past to be underestimates – not due to inaccurate reporting by the five industries submitting data, but rather due to the lack of reporting by other companies marketing amalgam in the United States. Likewise, one study of Indian dental practices (Bharti et al. 2010) estimated that in 2009 dental amalgam constituted approximately 75 per cent of all restorative materials used by dentists. On the contrary, Toxics Link (2011) estimated not long afterward that only 26 per cent of restorative materials used by dentists were amalgam.

These studies and other sources of information were evaluated, and when viable, used to inform estimates for other countries for which data were not available, using indicators of country prosperity (GDP at purchasing power parity) and per capita incidence of amalgam fillings.

The results are summarized in Table 23 in the Appendix, showing a level of dental mercury consumption that varies from less than 10 mg of mercury per capita in sub-Saharan Africa to 90 mg or more in Australia, the European Union and the United States. Except for sub-Saharan Africa and East and Southeast Asia, the average amount of mercury used per inhabitant per year is generally within the default range of 50-200 mg suggested by the Mercury Inventory Toolkit. Thus global mercury use in dental applications in 2015 is estimated to be in the range of 226-322 tonnes.

38 Rothenburg and Katz (2011) suggested correlating dental mercury consumption in different countries with the population and the reported "density" of dental personnel.

4.7. Measuring and control devices

This category includes a variety of instruments and devices using mercury that are not powered by batteries or mains electric current, including barometers, bougie tubes, esophageal dilators, feeding tubes, flow meters, gastrointestinal tubes, hydrometers, hygrometers, manometers, pyrometers, psychrometers and sphygmomanometers. Dairy manometers, general-purpose thermometers (laboratory, industrial) and fever thermometers are described briefly below as examples.

Table 15. Common mercury-added measuring and control devices

Device	Brief description
Dairy manometer	A specific type of mercury-added manometer that is used to measure the pressure in milk piping or in milking machines on dairy farms.
Thermometer	A mercury thermometer used for measuring temperature.
Fever thermometer	A specific type of mercury thermometer used for measuring body temperature.

There is a rather wide selection of mercury-containing measuring and control devices manufactured in various parts of the world, especially thermometers and sphygmomanometers, but also barometers, manometers and others. European legislation, among others, has been developed to phase out most of these devices and to promote mercury-free alternatives, which are available for nearly all applications. Most international suppliers now offer mercury-free alternatives.

For a number of years China has been the largest producer and consumer of mercury-added measuring devices. According to Lin et al. (2016), in 2011 China produced thermometers containing an estimated 150 tonnes of mercury, and exported about 50 per cent of them. In the same year China produced sphygmomanometers containing nearly 100 tonnes of mercury, and exported about 30 per cent of them. By 2015 China had not yet implemented measures to reduce the use of mercury in this business sector, so it is reasonable to assume that production has remained fairly stable.

To provide a slightly different perspective, Hui et al. (2016) wrote that in 2010 thermometers and sphygmomanometers were responsible for 260 tonnes of mercury input to the domestic waste stream in China. This implied substantially greater domestic use of these devices than suggested by Lin et al. (2016).

This analysis uses the results of 18 country and region studies of varying quality to develop regional estimates of amalgam use. As compared to dental uses of mercury, there is less variation between countries with regard to the per capita consumption of measuring and control devices. Special cases, however, are the European Union and North America, where regulations are now in place to ban these devices except for very limited exceptions. The 18 reference studies have been used to estimate the activity level of other countries using indicators of country prosperity (GDP at purchasing power parity) and per capita consumption.

The results of the analysis are summarized in Table 23 in the Appendix, showing a level of mercury consumption that varies from 5 mg per capita in the European Union and the United States to over 90 mg of mercury per capita in East and Southeast Asia. Global mercury use in measuring and control devices in 2015 is estimated to range from 267-392 tonnes. This total may be assumed to include the various less common measuring and control devices (U-shaped manometers, manometers for milking systems, manometers and barometers used for measuring air pressure, barometers, environmental manometers) identified by the Mercury Inventory Toolkit as consuming an estimated 5 mg of mercury per inhabitant. Overall, these less common measuring and control devices would amount to about 10 per cent of the total mercury consumed annually in this category.

4.8. Lamps

Mercury containing lamps, such as fluorescent tubes, compact fluorescent lamps, high-intensity discharge (HID) lamps, and neon lights, have long been the standard for energy-efficient lamps. Ongoing efforts to reduce the amount of mercury in these lamps have been countered, to some extent, by the ever-increasing number of energy-efficient lamps purchased and installed around the world. There is no doubt that mercury-free alternatives such as LEDs will become increasingly available, but for most applications and for most customers in 2015, the mercury-free alternatives were still limited and/or relatively expensive.

During the last five years the significant quantity of mercury used for backlighting of liquid crystal display (LCD) panels has greatly declined. Most mercury in lamps is now found in the types presented in Table 16, by customs code as found in international trade statistics, and with the mercury content as cited by the Mercury Inventory Toolkit.

China remains the world leader in production and consumption of mercury-added lamps. Lin et al. (2016) estimated the mercury content of fluorescent lamps produced in China in 2014 at 32 tonnes, and the mercury content of high-intensity discharge lamps produced in 2015 at 50 tonnes, with a combined uncertainty of ±24 tonnes. One could assume 40-50 per cent lamp exports (2010 exports were estimated at 38 per cent), as well as additional markets for other types of mercury-added lamps. In short, the available data suggests Chinese domestic consumption ranging around 50 tonnes of mercury in lamps.

Seventeen country and regional reports with estimates of mercury consumption in lamps were reviewed. The reports were quite variable in comprehensiveness and rigour, and domestic production and cross-border trade of various types of lamps are not readily available for many countries. Published trade statistics often lack the quantities of lamps shipped, and the trade is marked by frequent re-imports and re-exports.[39] The mercury content of different types of domestically produced lamps is not well known, and even less so in the case of imported lamps, although the ranges provided by the Mercury Inventory Toolkit are helpful. Using the country reports for guidance, the best estimates pointed to per capita mercury consumption generally in the range of 20-30 mg of mercury.

The results of the analysis are summarized in Table 23 in the Appendix, showing global mercury consumption in lamps in 2015 in the range of 112-173 tonnes. This total may be assumed to include the various less common lamps (metal halide, ultraviolet, infrared) as well as neon lights typically used for signs. Neon lights may comprise 3 per cent or more of the total mercury consumed annually in this category.

39 Export data in Comtrade combine the exports of domestic and foreign goods, but they also normally list separately the re-export data. Re-exports are exports of foreign goods in the same basic condition as previously imported. Re-imports are goods imported in the same basic condition as previously exported. There are several reasons why a previously exported good might return to the country of origin. The exported good might be defective, the importer might have defaulted on payments or cancelled the order, the authorities might have imposed an import barrier, or demand or prices in the country of origin might have made it worthwhile to bring the good back.

Table 16. Major mercury-added lamp categories

HS code	Description	Mercury content per lamp (mg)
8539 31 10	Discharge lamps, fluorescent, hot cathode, with double ended cap	10-40
8539 31 90	Discharge lamps, fluorescent, hot cathode (excl. with double ended cap)	5-15
8539 32	Mercury and sodium vapour lamps	10-30
8539 39	Discharge lamps (excl. fluorescent, hot cathode lamps, mercury/sodium vapour lamps, metal halide lamps and ultraviolet lamps)	25

Source: UNEP (2015)

4.9. Electrical and electronic devices

Mercury-added electrical and electronic devices consist mainly of switches and relays.

Switches are products or devices that open or close an electrical circuit that powers some piece of equipment, or that in turn opens or closes a liquid or gas valve. Mercury-added switches include float switches, actuated by a change in liquid levels; tilt switches, actuated by a change in the inclination of the switch; pressure switches, actuated by a change in pressure; and temperature switches and flame sensors (diostats), actuated by a change in temperature. Mercury switches have been used in a variety of consumer, commercial, and industrial products, including appliances, space heaters, ovens, air handling units, security systems, leveling devices, and pumps (NEWMOA 2014). Among other applications, these switches have been commonly used to operate convenience lights and anti-lock braking systems in automobiles, and thermostats in air conditioning units. Currently, mercury switches are less often used for such purposes.

Relays are products or devices that open or close electrical contacts to control the operation of other devices in the same or another electrical circuit. Relays are often used to turn on and off large current loads by supplying relatively small currents to a control circuit. Mercury-added relays include mercury displacement relays, mercury wetted reed relays and mercury contact relays. Relays have been used in telecommunication circuit boards, commercial and industrial electric ranges, and other cooking equipment (NEWMOA 2014).

Mercury-added switches and relays comprise a diverse product group due to the range of applications, the range of mercury content, and the differences in product life expectancy. Moreover, they usually reach the consumer integrated in a larger piece of equipment. Also, since there are mercury-free alternatives that are comparable or superior with regard to cost and functionality for virtually all of these applications, it is difficult to know whether switches and relays integrated in other equipment are actually mercury-added components. Due to the availability of mercury-free alternatives, the European Union, Canada, Japan, China and a number of states in the United States have enacted legislation prohibiting the sale of new mercury switches and relays, or they have implemented other measures to reduce the use of these mercury-added components.[40] Nevertheless, periodic reports to the IMERC database[41] confirm that mercury use in these devices remains significant.

A review of a variety of reports estimating mercury consumption in electrical and electronic devices for 15 countries and regions revealed the challenge of developing regional and national estimates for this application. With a considerable margin of error, the East and Southeast Asia regions remain the major consumers with around 50 tonnes of mercury in electrical and electronic devices, while the European Union claims to consume less than 1 tonne.

Mercury use in electrical and electronic devices in 2010 was estimated at 140-170 tonnes globally. Due to a gradually better understanding of the range of uses, together with guidance provided by country reporting and the Mercury Inventory Toolkit, the 2015 estimate of global mercury consumption in this sector is in the range of 109-185 tonnes, as summarized in Table 23 in the Appendix. This estimate lies within the lower part of the much broader range of 150-1 800 tonnes of mercury suggested by the default factors (0.02-0.25 g mercury per capita per year) given in the Mercury Inventory Toolkit.

40 For California, see <http://www.dtsc.ca.gov/HazardousWaste/EWaste/>.

For Korea's RoHS/WEEE/ELV-like legislation called «The Act for Resource Recycling of Electrical/Electronic Products and Automobiles," see <http://www.europeanleadfree.net/pooled/articles/BF_NEWSART/view.asp?Q=BF_NEWSART_195645>.

For Japan, see <http://www.jeita.or.jp/index.htm>;
also <http://uk.farnell.com/jsp/bespoke/bespoke8.jsp?bespokepage=farnell/en/rohs/rohs/facts.jsp>.

41 All suppliers of mercury containing products to the northeastern United States are required to file annual reports, as described in http://www.newmoa.org.

4.10. Mercury compounds and other applications

This category comprises diverse uses of mercury and mercury compounds in pesticides, fungicides, laboratory chemicals, catalysts, chemical intermediates, porosimeters, pycnometers, pharmaceuticals, mercury compounds in paints, traditional medicine, cultural and ritual uses, and cosmetics such as eye make-up and skin-lightening creams. There are also novelty items containing mercury including practical jokes, figurines, adornments, toys, games, cards, ornaments, statues, candles, jewelry, holiday decorations, footwear and other apparel.

For the vast majority of these applications viable mercury-free alternatives are widely available, but recent efforts to better understand some of these uses suggest that their consumption of mercury is more significant than previously thought.

One of the difficulties of estimating the mercury content of “other” applications is not only the diversity of uses, but also the variation between countries and regions. Most regional or national assessments provide little information on, or understanding of, these miscellaneous uses of mercury. Apart from a few of these applications that have been studied in some places (rotational balancing devices in the United States; mercury catalysts in polyurethane elastomers in the European Union), the best one can do, once again, is to extrapolate from what little information we have, and to assume that the markets for many of these items are roughly related to a country’s or region’s level of prosperity and purchasing power.

After considering the range of mercury uses described above, the Quicksilver Caucus recommended an initial focus on four product categories with the greatest potential for significant use, human exposure and/or environmental releases (ECOS 2013):

1. Polyurethane products
2. Rotational balancing products
3. Cosmetics and tattoo inks
4. Nanotechnology manufacturing processes and applications

The use of mercury catalysts in the production of polyurethane elastomers was discussed in a European Union report (European Commission 2008). A number of organic mercury compounds have been used to achieve a uniform, bubble-free product consistency during the curing of a two-part elastomer system, typically used in the production of polyurethane rollers, durable flooring, a rust-proof coating in marine environments, and other applications. The catalyst remains dispersed within the final product. Again, alternatives are available but, until recently, there was little incentive for manufacturers to identify them, or for users to ask for them. The European Commission report also discussed the considerable use of mercury in porosimetry and pycnometry, although it was determined that these uses are within a closed system and most of this mercury is collected and recycled.

In North America, an earlier Quicksilver Caucus report (ECOS 2012) singled out rotational balancing devices, especially wheel weights in which up to 28 ounces (784 g) of mercury are sealed in a tubular ring and installed behind the wheel assemblies of trucks, motor homes and motorcycles. Similar uses containing less mercury are promoted as well, such as to help balance motorcycle drive shafts or aircraft propeller shafts. Although the total use of mercury in these products in Canada and the United States very likely did not exceed 5 tonnes in 2015 (CEC 2017), the Quicksilver Caucus report noted that the relatively large quantity of mercury in individual units, as well as the nature of the application, invited an unacceptable risk of releases, especially as mercury-free alternatives are readily available.

The most important use of mercury in cosmetics is for skin-lightening creams, in which inorganic mercury is sometimes used as the active ingredient. Hamann et al. (2014) screened 549 products labeled as having been manufactured in 32 countries. The study confirmed a mercury content exceeding 1 000 ppm in 6 per cent of the 549 skin-lightening products tested. These mercury-added cosmetics were labeled as having been produced in China, Jamaica, Japan, Thailand, the Philippines and in other places not specified.

Many similar smaller studies have been carried out, some finding no mercury-added creams in certain countries, and others finding significantly more, although the presence of mercury in some of these products is by no means restricted to the developing world. All studies have confirmed the popularity of such creams among persons with darker skin (McKelvey et al. 2011; CDC 2012; Cristaudo et al. 2013; Adawe and Oberg 2013; Dlova et al. 2014; Ali and Khwaja 2016). In a study of Saudi women, Al-Saleh et al. (2015) also confirmed the availability and common use of skin-lightening creams, further noting that the contents are poorly controlled. Elsewhere, "by 2015, facial care was a US $1 billion market in India, and skin lighteners represented almost half that market size. The facial care market is expected to grow to US $1.96 billion – nearly doubling in size – by 2019" (Gerdeman 2017).

The Quicksilver Caucus has written that the need "to track and restrict the use of nanomercury is most likely the most challenging project … human and environmental health agencies may need to tackle." In this case the warning is not due to the quantities of mercury involved, but rather to the potential human and environmental health effects. Nanotechnology deals with the design and manufacture of extremely small materials and devices engineered at the molecular level. In some cases nanoparticles of a chemical substance may replace, at a very small scale, the function(s) of the substance's larger chemical form, thus reducing the quantity of chemical substance needed. In most cases, however, product developers use nanoparticles because they expect the particles to initiate reactions or enable functions unachievable by the larger chemical form. The effects of nanomercury on natural systems may therefore result in unique or enhanced exposure potential, biological uptake and/or toxicity (ECOS 2013).

With regard to applications such as those discussed above, the Mercury Inventory Toolkit is quite helpful in identifying many of these "other" uses of mercury so that researchers have a better understanding of what to look for, and in a few cases it suggests what quantities of mercury might be involved. For the most part, however, considerable legwork is required to quantify the mercury used in this category. As a result, the amounts of mercury used globally in most of these applications remain largely unknown, and for some of the less visible applications such as cultural/ritual uses in Latin America and the Caribbean, traditional uses in Chinese medicine, and cultural/religious uses in India, the amounts may never be well known.

The first extensive investigation of "other" applications in the European Union assessed the situation in 2005 (European Commission 2008), focusing on mercury consumption in compounds used as chemical intermediates and catalysts, mercury used in porosimeters and pycnometers, as well as lesser uses such as for routine maintenance of lighthouses. This remains the basis for our present understanding of the mercury used in a number of these applications. Based on that study and a wide variety of other sources, the comprehensive default factors developed for the Mercury Inventory Toolkit suggest global mercury consumption for these applications (excluding cosmetics) in the range of 440-735 tonnes per year. As the European Union has worked to phase out the use of mercury catalysts in polyurethane, however, and many other countries have raised awareness of, and placed increasing restrictions on, mercury uses, the broad range suggested by the Toolkit no longer appears valid.

For this analysis, a review of 17 regional and country reports of "other" uses of mercury revealed efforts to estimate a few of these uses, while ignoring many others due to the difficulty of obtaining good information. In the reports, the European Union, North America and Mexico showed the highest (150-170 mg per capita) consumption of mercury, largely on the basis of mercury compounds used in industrial processes. Overall, based on guidance provided by the country reports and the Mercury Inventory Toolkit, this analysis estimates global mercury consumption in this sector for 2015 to be in the range of 215-492 tonnes. The regional estimates are summarized in Table 23 in the Appendix. The 2015 mean of about 350 tonnes is about 15 per cent higher than that of the 2010 estimate, which gave a range of 220-390 tonnes (AMAP/UNEP 2013).

4.11. Summary of global mercury consumption

Despite ongoing improvements across the board in understanding the quantities of mercury used in products and processes, serious gaps in knowledge remain for most applications and countries. With that caveat, this analysis has been built on the most recent country and regional reports, peer-reviewed papers, consultant reports, the wealth of information and guidance in the Mercury Inventory Toolkit, international trade statistics, and other sources. Following the methodology outlined in section 4.1.4, the previous estimates were developed for all mercury applications, and then allocated among the various geographic regions on the basis of the valid data available and indicators of national prosperity and individual purchasing power, as described below.

4.11.1. Regional population and economic activity, 2015

Table 20 in the Appendix presents the population of the defined geographical regions in 2015, the GDP per region and per capita, and each region's share of global economic activity. As described in section 4.1.4, these indicators were used in support of mercury-added product consumption estimates for those countries and regions where viable estimates were not available. For ASGM and industrial processes using mercury, even though the uncertainties are significant in many cases, the data sources are such that regional allocations could readily be made without extrapolations.

Table 20 shows that more than two-thirds of the global population resides in East and Southeast Asia, South Asia and sub-Saharan Africa. In contrast with the population distribution, Table 20 also demonstrates that two-thirds of global economic activity takes place in East and Southeast Asia, North America and the European Union. While there are some geographic differences in per capita consumption as regards various mercury-containing products, it may be expected that these three regions are also responsible for the majority of mercury consumed in products and processes globally.

4.11.2. Regional mercury consumption

Table 17 summarizes the overall mean consumption of mercury in products and processes for the various geographical regions in 2015 based on the analysis and assumptions previously presented. The rough ranges of uncertainty in these estimates may be found in Table 23.

Table 17. Mean mercury consumed by region and by major application, 2015

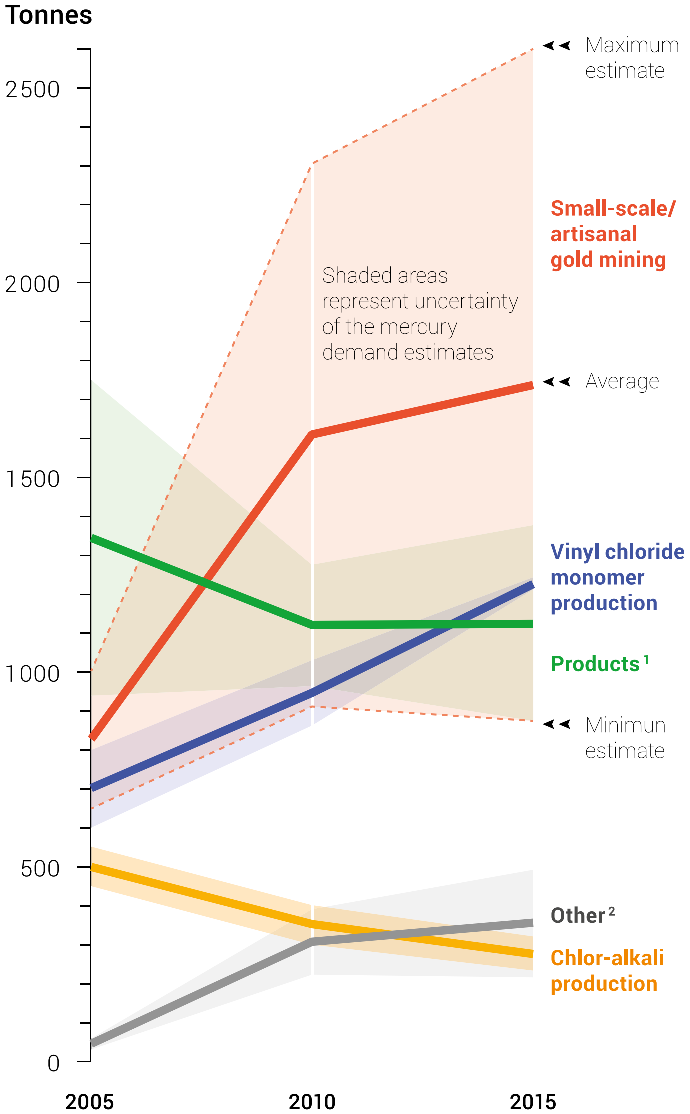
Region	ASGM	VCM production	Chlor-alkali production	Batteries	Dental applications	Measuring and control devices	Lamps	Electrical and electronic devices	Hg compounds and other applications[2]	Regional totals
	mean[3]	mean[3]	mean[3]	mean[3]	mean[3]	mean[3]	mean[3]	mean[3]	mean[3]	mean[3]
East and Southeast Asia	645	1 215	8	95	52	208	69	52	62	2 407
South Asia	4	5	27	33	72	39	12	12	59	263
European Union (28 countries)	0	0	85	8	56	3	13	1	84	249
CIS and other European countries	24	6	45	13	19	12	7	7	37	171
Middle Eastern States	0	0	38	13	13	18	7	9	9	107
North Africa	0	0	11	8	4	6	4	2	5	41
Sub-Saharan Africa	366	0	1	24	7	11	5	19	15	447
North America	0	0	8	9	32	2	8	19	61	137
Central America and the Caribbean	16	0	19	9	6	9	4	6	8	78
South America	680	0	35	18	12	20	9	8	13	794
Australia, New Zealand and Oceania	0	0	0	1	3	1	3	13	1	22
Total per application	**1 735**	**1 226**	**277**	**231**	**274**	**330**	**142**	**147**	**354**	**4 715**

Note 1—The term "consumption" is defined here in terms of the end-use of mercury-added products, as opposed to overall regional "demand" for mercury. For example, although most energy-efficient lamps (such as CFLs) are produced in China and therefore represent basic Chinese "demand" for mercury, many of them are exported, used and disposed of in other countries, representing the actual place of "consumption."

Note 2—"Mercury compounds and other applications" include uses of mercury in cosmetics, pesticides, fungicides, catalysts, chemical intermediates, porosimeters, pycnometers, pharmaceuticals, traditional medicine, cultural and ritual uses, etc.

Note 3—As discussed in the text, the values presented here are the means of wider ranges of estimates representing various levels of uncertainty, depending on the application. The uncertainty ranges may be seen in Table 23.

Figure 8. Global mercury demand by sector, including uncertainties



1. Batteries, dental applications, measuring and control devices, lamps, electrical and electronic devices
2. Paints, laboratory, pharmaceutical, cultural/traditional uses, etc.

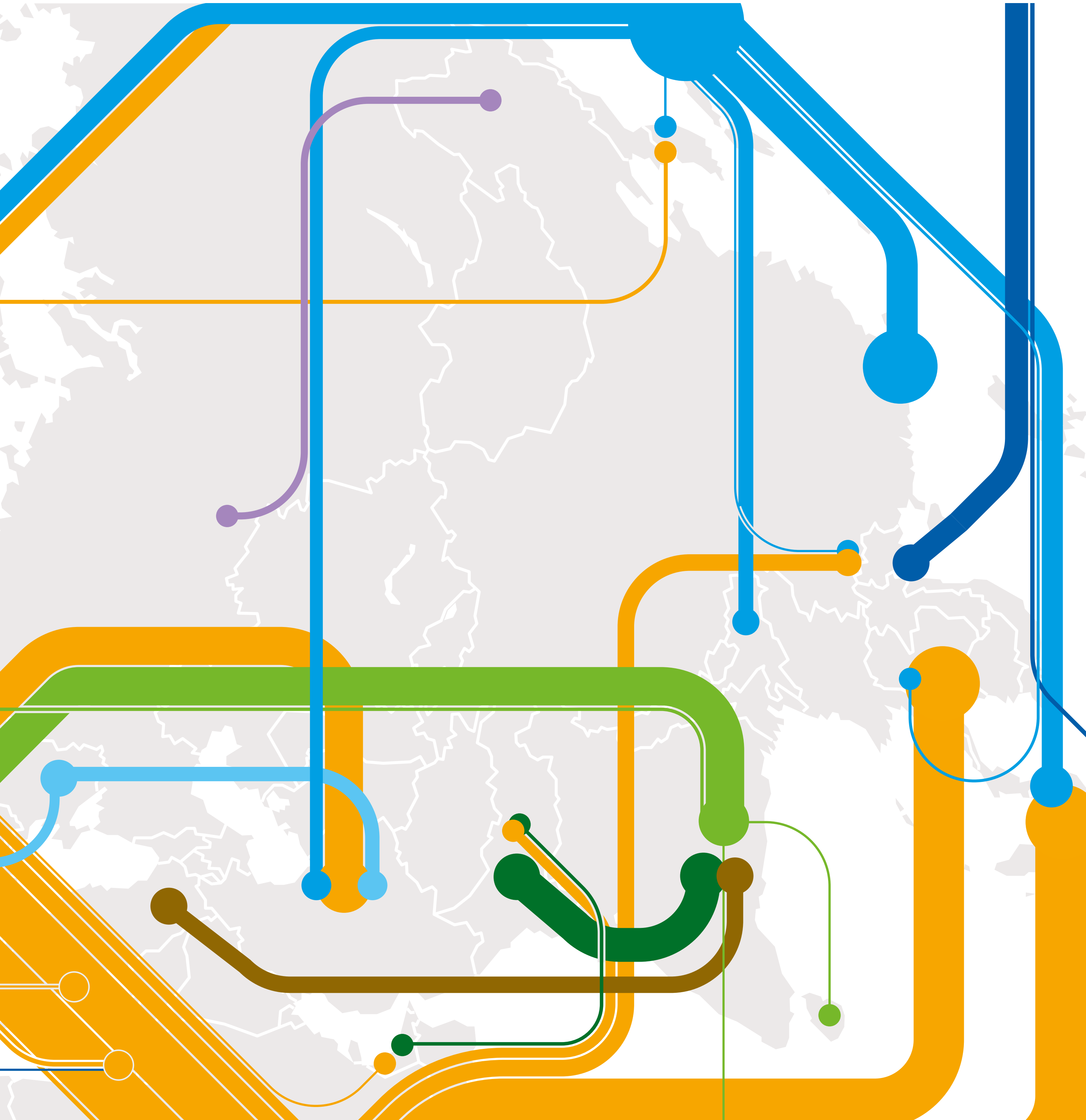
Sources: UNEP, 2006; AMAP, 2013; this report.

The East and Southeast Asia regions predominate in overall mercury consumption, and particularly in artisanal mining, VCM/PVC production, batteries and measuring and control devices.

Referring to the trends in sectoral mercury consumption presented in Table 12, Figure 8 summarizes the evolution of global mercury demand by sector from 2005-2015, and demonstrates at the same time the uncertainties implicit in these estimates. The shaded areas bordering each trend line in the figure represent the extent of the uncertainties.

The marked increase in the category of "other" uses should be viewed as a reflection of the increasing availability of better information about these uses, rather than as an indication of a significant increase in demand. The very large uncertainty around ASGM mercury demand is basically a summing up of the uncertainties associated with each individual country estimate, and may be a bit misleading. A more precise way to estimate the error envelope, though impractical in this case, would be to model each country estimate as a probability function and then to do a Monte Carlo simulation. This would result in a narrower overall error envelope. The same point could be made for the oversized error envelope around the trend line for mercury-added products.

5. Conclusions



Mercury supply

While the quantity of mercury available on the open market from the chlor-alkali industry has declined in recent years, primary mercury mining has increased overall in response to strong demand, such that the global mercury supply in 2015 was in the range of 3 850 to 4 400 tonnes per year. Better information to be provided under the Minamata Convention will permit a more precise estimate. It is evident that global mercury demand will have to be reduced in parallel with supply, or else supplies – formal or informal – will continue to be generated in one manner or another to meet demand.

Mercury trade

Since 2011 the former European Union (centering mostly on Spain and the Netherlands) and the US trading hubs have gradually ceded their roles to Singapore and Hong Kong, and to a lesser extent Turkey and Viet Nam, which have become the major storage and transit points for global mercury trade. Meanwhile, during the same period there is significantly reduced activity related to global imports and exports of mercury. Undocumented mercury trade in some parts of the world has increased somewhat during this period, however, so the documented trade reporting does not tell the whole story.

There are also questions with regard to mercury compounds. Certain countries, especially within the European Union, reported importing around 18 000 tonnes of mercury compounds in 2015. This figure is so inconsistent not only with these countries' exports but also with the trade levels reported by other countries, that it raises the question of whether industrial wastes may be included in these shipments reported as mercury compounds. Other mistakes may also have occurred.

Although databases such as Comtrade and Eurostat are populated by data furnished by national statistical agencies, they are imperfect resources for understanding demand for and trade of mercury-added products. For example, the reported trade data typically do not differentiate between mercury-added and mercury-free products; there is occasional difficulty in identifying the actual origins and final destinations of shipments; and there are sometimes mistakes (some of them intentional) in the tariff codes listed with shipments of certain commodities. Even with improvements, however, there are limits to the value of trade data, especially as many details of commercial transactions are considered to be sensitive and therefore not accessible to the public.

Mercury demand

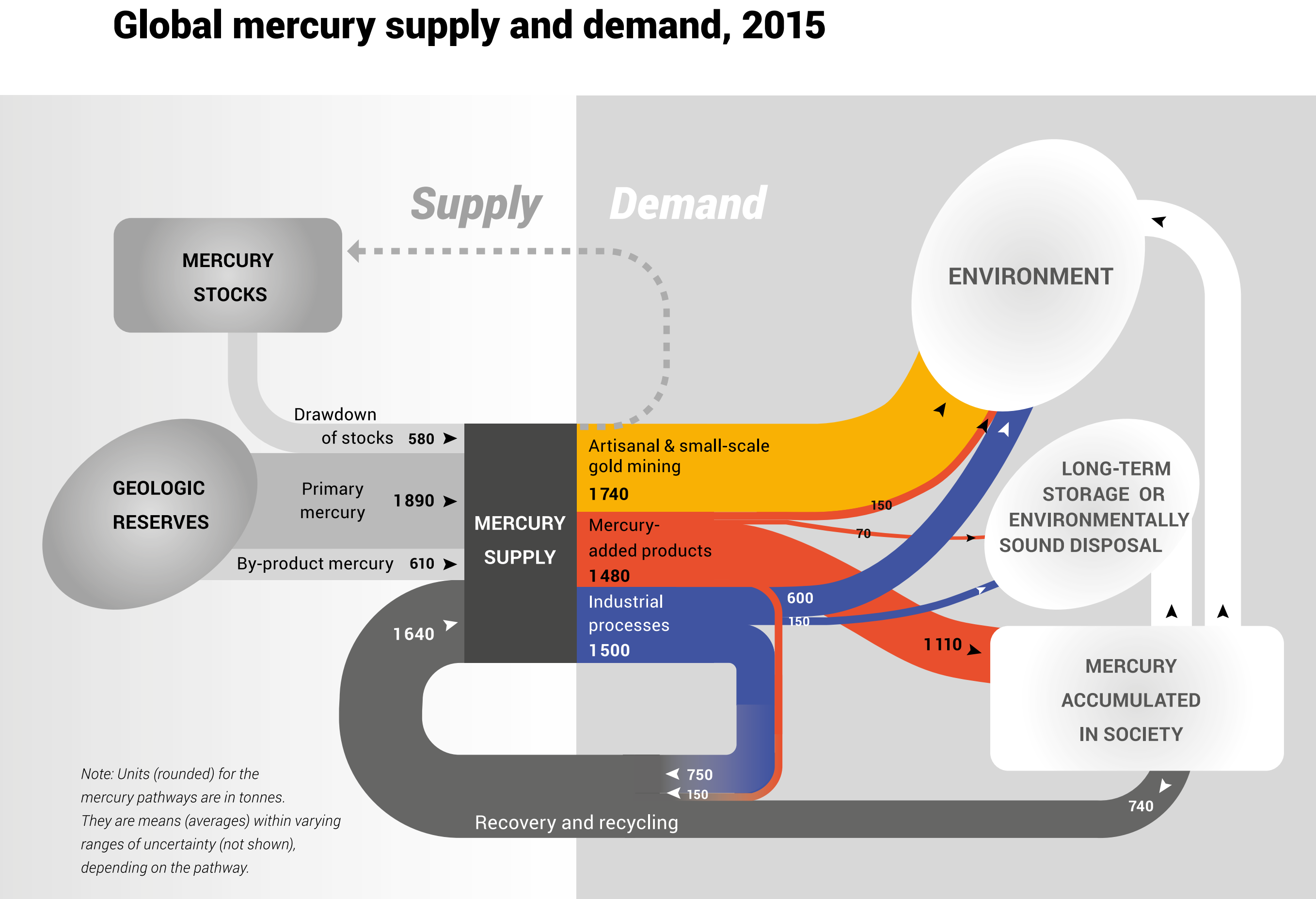
This assessment found that the demand for mercury in ASGM – as in 2005 and 2010 – continues to increase. Countries are required to address this issue directly under the Minamata Convention. Similarly, mercury use for vinyl chloride monomer production showed an overall increase in 2015 as compared with 2010, although China, the main country using the mercury process, has already taken steps to address this issue. Otherwise, mercury use in most product categories continues its long-term decline as a result of regulation, enhanced awareness of environmental impacts and a range of other measures, although some countries are far ahead of others in this regard.

The demand for mercury remains relatively robust in South and East Asian countries, which consume significant quantities of mercury in products, vinyl chloride monomer production and ASGM; and in Central and South American countries, which consume large amounts of mercury especially in ASGM.

Global overview

Figure 9 provides a graphic overview of the global mercury supply, from sources to uses and sinks. The widths of the pathways representing the flows are proportional to the magnitude of the flow. The global mercury supply to products and processes is simply the sum of all of the flows coming from the left side of the diagram which, over a given period of time, should be equivalent to the mercury uses shown on the right side of the diagram. Mercury inventories are shown as boxes representing either physical stocks or mercury accumulated in society, prior to entering the waste stream. Sources and sinks are shown as ovals representing geological reserves, or endpoints identified as the environment or long-term storage/disposal.

Figure 9. Mass balance for mercury products and processes, 2015



While there is an obvious interest in balancing the supply side and the demand side in the figure, there are several reasons that the estimated global supply of mercury in a given year may not be precisely the same as the estimated demand. In this case it has been assumed that the net drawdown of mercury stocks (a quantity that is otherwise impossible to know from the information currently available) during the year made up the difference between supply and demand. Apart from this "source" of mercury, however, there are the uncertainties implicit in all of these flows.

There is also a potential for double counting of mercury demand in certain cases. For example, while there is significant variation from one facility to another, mercury may be used in the production of vinyl chloride monomer, retrieved and recycled after 10 or 11 months, and returned to the same or another use. In such a case a given supply of mercury could effectively be used more than once during a 12-month period.

It should be emphasized that mercury demand apparently exceeds the basic supply by 10-15 per cent, and the difference in 2015 was most likely made up through a drawdown of mercury stocks or inventories. Considering that available stocks are rather limited, unless mercury demand can be reduced rapidly, this imbalance will maintain pressure on increased formal and informal mercury mining, which will add to the difficulty of changing course under the Minamata Convention.

On a more general but important note, the Intergovernmental Negotiating Committee (INC) process leading up to the Minamata Convention, which included multiple regional meetings and working groups, paid a sizable dividend in raising awareness of the issues, and in increasing the technical and policy understanding of the Parties. This level of awareness and understanding has become evident not only in the structure and content of the Convention, but may have ultimately been instrumental in the success of the negotiations themselves, not to mention the quantity and quality of information made available for this report.

Acronyms & abbreviations

$INT	International dollar
ABS	Anti-lock brake system
ASGM	Artisanal and small-scale gold mining
CDAT	Chemical Data Access Tool (at USEPA)
CFL	Compact fluorescent lamp
CIMT	Canadian International Merchandise Trade
CIS	Commonwealth of Independent States
CNIA	Chinese Nonferrous Metals Industry Association
DoD	United States Department of Defense
DoE	United States Department of Energy
g	gram(s)
GDP	Gross Domestic Product
GEF	Global Environment Facility
HID	High-intensity discharge
HS	Harmonized Commodity Description and Coding System
IEA	International Energy Agency
IMERC	Interstate Mercury Education and Reduction Clearinghouse
INC	Intergovernmental Negotiating Committee
kg	kilogram(s)
LED	Light-emitting diode
MAYASA	Minas de Almadén y Arrayanes, S.A.
mg	milligram(s)
PPP	Purchasing Power Parity
PVC	Polyvinyl chloride
SIAVI	Sistema de Informacion Comercial Via Internet
tonne	metric ton
UN Comtrade	United Nations International Trade Statistics Database
UNEP	United Nations Environment Programme (now UN Environment)
UNIDO	United Nations Industrial Development Organization
UNSD	United Nations Statistics Division
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USITC	United States International Trade Commission
VCM	Vinyl chloride monomer

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Appendix

Table 18. Key sources for country-specific information on mercury-added products

Country	Reference
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Bangladesh	ESDO 2012. Mercury Sources: Products and Hotspots in Bangladesh, Environment and Social Development Organization (ESDO), May 2012.
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Burkina Faso	DGACV 2007. Rapport de l'inventaire national des sources de production, d'utilisations et de rejets du mercure dans l'environnement au Burkina Faso, Ministère de l'Environnement et du Cadre de Vie, Direction Générale de l'Amélioration du Cadre de Vie, November 2007.
Canada	ToxEcology 2009. Socioeconomic and mass balance study for mercury-containing products. ToxEcology for Environment Canada, as cited in Canada Gazette Part II, Vol. 18, No. 24 (2014-11-19).
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China	Zhang et al. 2015. Zhang L, Wang SX, Wang L, Wu Y, Duan L, Wu QR, Wang FY, Yang M, Yang H, Hao JM, Liu X. Updated emission inventories for speciated atmospheric mercury from anthropogenic sources in China. Environ. Sci. Technol. 49 (5), 3185–3194.
	Lin et al. 2016. Lin Y, Wang SX, Wu QR and Larssen T. Material flow for the intentional use of mercury in China. Environ. Sci. Technol. 50 (5), 2337–2344.
	Hui et al. 2017. Hui M, Wu Q, Wang S, Liang S, Zhang L, Wang F, Lenzen M, Wang Y, Xu L, Lin Z, Yang H, Lin Y, Larssen T, Ming X and Jiming H. Mercury Flows in China and Global Drivers, Environ. Sci. Technol. 51 (1), pp 222–231. DOI: 10.1021/acs.est.6b04094 (and Supporting Information).
Ethiopia	Ethiopia 2017. ToolKit Inventory Level 2 (preliminary), 2017.
European Union	European Commission 2008. Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society, COWI A/S and Concorde East/West Sprl for the Directorate General for the Environment, Commission of the European Communities, Brussels, September 2008.
	UNEP 2008. The challenge of meeting mercury demand without mercury mining: An assessment requested by the Ad Hoc Open-Ended Working Group on Mercury. Concorde East/West Sprl for the United Nations Environment Programme—Chemicals. Geneva, November 2008.
	European Commission 2012. Study on the Potential for Reducing Mercury Pollution from Dental Amalgam and Batteries. BIO Intelligence Service for the Directorate General for the Environment, Commission of the European Communities, Brussels, 2012

	European Commission 2015a. Study on EU Implementation of the Minamata Convention on Mercury, Final Report. ICF, Cowi, BiPro and Garrigues for the Directorate General for the Environment, Commission of the European Communities. Contract ENV.C.3/FRA/2011/0030/11 under Framework Contract ENV.C.3/FRA/2011/0030, Brussels, 30 March 2015.
	European Commission 2015b. Ratification of the Minamata Convention by the EU: Complementary assessment of the mercury export ban, Cowi and Bipro for the Directorate General for the Environment, Commission of the European Communities, Brussels, 9 June 2015.
	European Parliament 2016. Briefing: EU Legislation in Progress, European Parliament, March 2016.
India	Chakraborty et al. 2013. (Supporting information for) Burger Chakraborty L, Qureshi A, Vadenbo C, Hellweg S. Anthropogenic Mercury Flows in India and Impacts of Emission Controls. Environ. Sci. Technol. 47, 130726132711009.
	Toxics Link 2014. Mercury Free India: Right choices, Toxics Link, New Delhi, 2014.
Indonesia	BaliFokus 2012. Indonesia: Inventory of mercury releases in Indonesia, BaliFokus Foundation, 30 October 2012.
Japan	Japan 2016. Japan's Commitment on the Minamata Convention on Mercury, Environmental Health and Safety Division, Environmental Health Department, Ministry of the Environment, Japan, 2016.
Korea	KME 2016. Republic of Korea Hg consumption, Korean Ministry of Environment, 2016.
	Seo 2016. Seo YC, UNEP/AMAP Mercury Inventory: Template for Waste Management Information, Yonsei University, South Korea, 2012.
Madagascar	DGE 2015. Replacing Mercury-Added Products and Promoting Improved Management of Mercury-Added Product Waste In Madagascar (final report), Directorate-General for Environment, March 2015.
Mauritius	PANeM 2017. Study On Mercury-Free Products In Mauritius, PANeM for European Environmental Bureau and Zero Mercury Working Group (preliminary), Jan. 2017.
Mexico	CEC 2008. Castro-Diaz J, Mexican Mercury Market Report, Commission for Environmental Cooperation, Montreal, 2008.
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Nigeria	SRADev 2014. Mercury Use In Products In Nigeria, Sustainable Research and Action for Environmental Development (SRADev Nigeria), September 2014.
Pakistan	UNEP 2000. Preliminary report on Mercury Inventory in Pakistan. UN Environment Chemicals Branch and Ministry of Environment, Islamabad. 2000. Available at: <http://www.atsdr.cdc.gov/emergency_response/Action_Levels_for_Elemental_Mercury_Spills_2012.pdf>.
Russia	Eco-Accord 2010. Mercury Emission Sources In Russia: The situation survey in six cities of the country, Eco-Accord Centre for the European Environmental Bureau—Zero Mercury, June 2010.
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Saudi Arabia	Al-Saleh et al. 2015. Al-Saleh I, Abduljabbar M, Al-Rouqi R, Eltabache C, Al-Rajudi T, Elkhatib R and Nester M, The extent of mercury (Hg) exposure among Saudi mothers and their respective infants, Environ Monit Assess 187: 678

Tanzania	Tanzania 2016. ToolKit Inventory Level 2 (preliminary), Vice President's Office, December 2016.
Thailand	Wongsoonthornchai 2016. Wongsoonthornchai M, Kwonpongsagoon S and Scheidegger R. Modeling Mercury Flows in Thailand on the Basis of Mathematical Material Flow Analysis. CLEAN - Soil, Air, Water 44, 16–24. doi:10.1002/clen.201400670 (and Supporting Information).
Uganda	NEMA 2017. ToolKit Inventory Level 2 (preliminary), National Environment Management Authority, February 2017.
United States	NEWMOA 2014. IMERC Fact Sheet on Mercury Use in Switches and Relays. Available at <http://www.newmoa.org/prevention/mercury/imerc/factsheets>.
	NEWMOA 2015. IMERC Fact Sheets on Mercury Use in Thermostats, Mercury Use in Measuring Devices, Mercury Use in Dental Amalgam, Mercury Use in Batteries, Mercury Use in Lighting, and Formulated Mercury-Added Products, updated December 2015. Available at <http://www.newmoa.org/prevention/mercury/imerc/factsheets>.
	USEPA 2016. Report to Congress on the Global Supply and Trade of Elemental Mercury, prepared for the Committee on Energy and Commerce of the United States House of Representatives and the Committee on Environment and Public Works of the United States Senate, Office of Chemical Safety and Pollution Prevention, United States Environmental Protection Agency, Washington, D.C., December 2016.
	USEPA 2017. Mercury—US Inventory Report: Supply, Use, and Trade, Office of Chemical Safety and Pollution Prevention, United States Environmental Protection Agency, Washington, D.C., 2017.
Vietnam	MOIT 2017. Summary of mercury inventory results (preliminary), Vietnam Chemicals Agency (VINACHEMIA), Ministry of Industry and Trade (MOIT), Hanoi, Vietnam, 2017.

Table 19. Geographic regions as defined for this study

East and Southeast Asia

Brunei Darussalam
Cambodia
China
China-Hong Kong SAR
China-Macao SAR
Indonesia
Japan
Korea, DPR of
Korea, Republic of
Lao People's DR
Malaysia
Mongolia
Myanmar
Papua New Guinea
Philippines
Singapore
Thailand
Timor-Leste
Vietnam

South Asia

Afghanistan
Bangladesh
Bhutan
India
Maldives
Nepal
Pakistan
Sri Lanka

European Union (28 countries)

Austria
Belgium
Bulgaria
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxembourg
Malta
Netherlands
Poland
Portugal
Romania
Slovak Republic
Slovenia
Spain
Sweden
United Kingdom

CIS and other European countries

Albania
Andorra
Armenia
Azerbaijan
Belarus
Bosnia and Herzegovina
Georgia
Gibraltar
Iceland
Kazakhstan
Kosovo
Kyrgyz Republic
Liechtenstein
Macedonia, FYR
Moldova, Republic of
Montenegro
Norway
Russian Federation
Serbia
Switzerland
Tajikistan
Turkmenistan
Ukraine
Uzbekistan

Middle East

Bahrain
Iran
Iraq
Israel
Jordan
Kuwait
Lebanon
Oman
Qatar
Saudi Arabia
Syria
Turkey
United Arab Emirates
West Bank and Gaza
Yemen

North Africa

Algeria
Egypt
Libya
Morocco
Tunisia

Sub-Saharan Africa

Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Rep.
Chad
Comoros
Congo, Rep.
Congo, DR of
Côte d'Ivoire
Djibouti
Equatorial Guinea
Eritrea
Ethiopia
Gabon
Gambia
Ghana
Guinea-Bissau
Guinea
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Namibia
Niger
Nigeria
Rwanda
Saint Helena, Ascension and Tristan da Cunha
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
South Sudan
Sudan
Swaziland
Tanzania
Togo
Uganda
Zambia
Zimbabwe

North America

Canada
Greenland
United States of America

Central America and the Caribbean

Anguilla
Antigua and Barbuda
Aruba
Bahamas
Barbados
Belize
Bermuda
British Virgin Islands
Cayman Islands
Costa Rica
Cuba
Dominica
Dominican Republic
El Salvador
Grenada
Guatemala
Haiti
Honduras
Jamaica
Mexico
Montserrat
Nicaragua
Panama
Puerto Rico
Saint Kitts and Nevis
Saint Lucia
St. Vincent and the Grenadines
Trinidad and Tobago
Turks and Caicos Is.
Virgin Islands (US)

South America

Argentina
Bolivia
Brazil
Chile
Colombia
Ecuador
Falkland Is. (Malvinas)
Guyana
Paraguay
Peru
Suriname
Uruguay
Venezuela

Australia, New Zealand and Oceania

Australia
Cook Islands
Fiji
French Polynesia
Kiribati
Marshall Islands
Micronesia, Fed. States of
Northern Mariana Islands
Nauru
New Caledonia
New Zealand
Niue
Palau
Samoa
Solomon Islands
Tokelau
Tonga
Tuvalu
Vanuatu
Wallis and Futuna Islands

Table 20. Regional population and economic activity, 2015

Region	Population (thousand)	GDP at PPP ($INT million)	GDP/capita at PPP ($INT)	Share of global GDP at PPP
East and Southeast Asia	2 247 652	34 659 869	15 420	31%
South Asia	1 744 161	9 862 149	5 654	9%
European Union (25 countries)	509 668	19 153 482	37 580	17%
CIS and other European countries	319 616	6 180 421	19 337	5%
Middle Eastern States	318 474	7 242 395	22 741	6%
North Africa	182 938	2 068 059	11 305	2%
Sub-Saharan Africa	1 001 877	3 700 262	3 693	3%
North America	357 327	19 537 765	54 678	17%
Central America and the Caribbean	214 640	3 137 665	14 618	3%
South America	418 179	6 524 670	15 603	6%
Australia, New Zealand and Oceania	31 376	1 284 790	40 949	1%
Total	**7 345 907**	**113 351 528**	**15 431**	**100%**

Note: An international dollar ($INT) would buy in the cited region a comparable amount of goods and services that a US dollar would buy in the United States. This term is often used in conjunction with Purchasing Power Parity (PPP) data.
Sources: World Bank (2016a); CIA (2016).

Table 21. Mercury use in artisanal and small-scale gold mining

	Country	Data quality[a]	Margin of error (±%)	ASGM mercury use (tonnes)			Percentage concentrate amalgamation	Percentage whole ore amalgamation
				min	mean	max		
1	Bolivia	4	30%	84.0	120.0	156.0	25%	75%
2	Guinea	4	30%	13.4	19.1	24.8	100%	0%
3	Nicaragua	4	30%	2.5	3.5	4.6	0%	100%
4	Senegal	4	30%	2.1	3.0	3.9	100%	0%
5	Suriname	4	30%	44.1	63.0	81.9	5%	95%
1	Brazil	3	50%	22.5	45.0	67.5	50%	50%
2	Burkina Faso	3	50%	17.6	35.1	52.7	100%	0%
3	Cambodia	3	50%	3.8	7.5	11.3	50%	50%
4	Colombia	3	50%	90.0	180.0	270.0	17%	83%
5	Ecuador	3	50%	42.5	85.0	127.5	20%	80%
6	French Guiana	3	50%	3.8	7.5	11.3	100%	0%
7	Ghana	3	50%	35.0	70.0	105.0	100%	0%
8	Guyana	3	50%	7.5	15.0	22.5	100%	0%
9	India	3	50%	0.3	6.0	8.0	100%	0%
10	Indonesia	3	50%	210.0	420.0	630.0	17%	83%
11	Lao Peoples Dem. Rep.	3	50%	0.7	1.3	2.0	100%	0%
12	Mali	3	50%	5.0	12.5	20.0	100%	0%
13	Mongolia	3	50%	5.8	11.5	17.3	50%	50%
14	Mozambique	3	50%	2.0	4.0	6.0	100%	0%
15	Nigeria	3	50%	10.0	20.0	30.0	100%	0%
16	Peru	3	50%	72.5	145.0	217.5	25%	75%
17	Philippines	3	50%	35.0	70.0	105.0	25%	75%
18	Sierra Leone	3	50%	2.0	11.0	20.0	100%	0%
19	Venezuela	3	50%	7.5	15.0	22.5	25%	75%
20	Zimbabwe	3	50%	12.5	25.0	37.5	20%	80%
1	Botswana	2	75%	0.2	0.8	1.4	50%	50%
2	Cameroon	2	75%	0.4	1.5	2.6	100%	0%
3	Central African Rep.	2	75%	2.0	8.0	14.0	100%	0%
4	Chile	2	75%	1.0	4.0	7.0	50%	50%
5	China	2	75%	25.0	100.0	175.0	25%	75%
6	Congo	2	75%	0.4	1.5	2.6	100%	0%
7	DRC	2	75%	3.8	15.0	26.3	100%	0%
8	Guatemala	2	75%	0.4	1.5	2.6	50%	50%
9	Honduras	2	75%	0.3	1.2	2.1	50%	50%
10	Kenya	2	75%	1.0	3.5	6.0	100%	0%
11	Kyrgyzstan	2	75%	1.9	7.5	13.1	50%	50%
12	Madagascar	2	75%	0.4	1.5	2.6	100%	0%
13	Malaysia	2	75%	0.9	3.5	6.1	50%	50%
14	Mexico	2	75%	1.9	7.5	13.1	50%	50%
15	Myanmar	2	75%	3.8	15.0	26.3	100%	0%
16	Panama	2	75%	0.4	1.5	2.6	50%	50%
17	Papua New Guinea	2	75%	1.8	7.0	12.3	50%	50%
18	Russia	2	75%	2.8	11.0	19.3	50%	50%
19	South Africa	2	75%	1.0	3.5	6.0	50%	50%
20	South Sudan	2	75%	0.0	0.0	0.0	n.a.	n.a.
21	Sudan	2	75%	63.0	83.0	103.0	100%	0%
22	Tajikistan	2	75%	1.0	4.0	7.0	100%	0%
23	Tanzania	2	75%	20.0	35.0	50.0	100%	0%
24	Thailand	2	75%	0.4	1.5	2.6	100%	0%
25	Togo	2	75%	1.0	4.0	7.0	100%	0%
26	Uganda	2	75%	2.0	4.0	6.0	100%	0%
27	Viet Nam	2	75%	1.9	7.5	13.1	50%	50%

Country		Data quality[a]	Margin of error (±%)	ASGM mercury use (tonnes)			Percentage concentrate amalgamation	Percentage whole ore amalgamation
				min	mean	max		
1	Angola	1	100%	0.1	0.3	0.5	100%	0%
2	Argentina	1	100%	0.1	0.3	0.5	100%	0%
3	Azerbaijan	1	100%	0.1	0.3	0.5	100%	0%
4	Benin	1	100%	0.1	0.3	0.5	100%	0%
5	Burundi	1	100%	0.1	0.3	0.5	100%	0%
6	Chad	1	100%	0.1	0.3	0.5	100%	0%
7	Costa Rica	1	100%	0.1	0.3	0.5	50%	50%
8	Cote d'Ivoire	1	100%	0.1	0.3	0.5	100%	0%
9	Dominican Rep.	1	100%	0.1	0.3	0.5	100%	0%
10	El Salvador	1	100%	0.1	0.3	0.5	100%	0%
11	Equitorial Guinea	1	100%	0.1	0.3	0.5	100%	0%
12	Eritrea	1	100%	0.1	0.3	0.5	100%	0%
13	Ethiopia	1	100%	0.1	0.3	0.5	100%	0%
14	Gabon	1	100%	0.1	0.3	0.5	100%	0%
15	Gambia	1	100%	0.1	0.3	0.5	100%	0%
16	Guinea-Bissau	1	100%	0.1	0.3	0.5	100%	0%
17	Iran	1	100%	0.1	0.3	0.5	100%	0%
18	Kazakhstan	1	100%	0.1	0.3	0.5	100%	0%
19	Lesotho	1	100%	0.0	0.0	0.0	100%	0%
20	Liberia	1	100%	0.1	0.3	0.5	100%	0%
21	Malawi	1	100%	0.0	0.0	0.0	100%	0%
22	Mauritania	1	100%	0.1	0.3	0.5	100%	0%
23	Niger	1	100%	0.1	0.3	0.5	100%	0%
24	Paraguay	1	100%	0.1	0.3	0.5	100%	0%
25	Rwanda	1	100%	0.1	0.3	0.5	100%	0%
26	Swaziland	1	100%	0.1	0.3	0.5	100%	0%
27	Ukraine	1	100%	0.1	0.3	0.5	100%	0%
28	Uzbekistan	1	100%	0.1	0.3	0.5	100%	0%
29	Zambia	1	100%	0.1	0.3	0.5	100%	0%
TOTAL			**50%**	**872**	**1 735**	**2 598**		

Note a: In most cases, the following margins of uncertainty are applied to the "mean" estimates above:

- class 1 = simply an indication of the presence or absence of mercury use in ASGM, no quantitative information is available, error may be greater than ±100%;
- class 2 = sources have provided some indication of the quantity of mercury used, rough margin of error ±75%;
- class 3 = quantitative data exists but it has not been significantly updated within past 5 years, rough margin of error ±50%;
- class 4 = recent quantitative data is available, rough margin of error ±30%.

Source: Artisanal Gold Council (2017). Draft dated 31 July 2017, subject to revision in the near term as new information becomes available.

Table 22. Mercury consumed in the chlor-alkali industry, 2015

Country	CHLORINE PRODUCTION CAPACITY (THOUSAND TONNES)											
	No. of mercury cell plants	East and Southeast Asia	South Asia	European Union (28 countries)	CIS and other European countries	Middle Eastern States	Middle Eastern States	Sub-Saharan Africa	North America	Central America and the Caribbean	South America	Australia New Zealand and Oceania
Algeria	2						14					
Angola	1							10				
Argentina	2										120	
Bangladesh	2		175									
Belgium	2			315								
Bosnia Herzegovina	?				0							
Brazil	4										226	
Colombia	1										24	
Cuba	1									17		
Czech Rep.	2			196								
Finland	1			40								
France	5			277								
Germany	4			699								
Greece	0			closed								
Hungary	1			131								
India	2		46									
Indonesia	5	25										
Iran	1					220						
Iraq	3					68						
Israel	1					33						
Italy	1			42								
Libyan Arab Jamahiriya	1						45					
Mexico	2									154		
Morocco	1						45					
Myanmar	1	7										
North Korea	2	25										
Pakistan	1		24									
Peru	1										117	
Philippines	1	14										
Poland	1			77								
Romania	0			closed								

Country	CHLORINE PRODUCTION CAPACITY (THOUSAND TONNES)											
	No. of mercury cell plants	East and Southeast Asia	South Asia	European Union (28 countries)	CIS and other European countries	Middle Eastern States	Middle Eastern States	Sub-Saharan Africa	North America	Central America and the Caribbean	South America	Australia New Zealand and Oceania
Russian Federation	3				414							
Serbia	2				10.5							
Slovakia	1			76								
Spain	7			576								
Sweden	1			120								
Switzerland	1				27							
Syria	1					14						
Turkmenistan	1				??							
United Arab Emirates	2					9						
United Kingdom	1			277								
United States	2								109			
Uruguay	1										14	
TOTALS	**75**	**71**	**245**	**2 826**	**451.5**	**344**	**104**	**10**	**109**	**171**	**501**	**0**
Est. mercury consumption (g per tonne chlorine capacity):												
min		90	90	25	90	90	90	90	60	90	60	0
MAX		130	130	35	110	130	130	130	80	130	80	0
Est. mercury consumption (tonnes):												
min		**6.4**	**22.1**	**70.7**	**40.6**	**31.0**	**9.4**	**0.9**	**6.5**	**15.4**	**30.1**	**0.0**
MAX		**9.2**	**31.9**	**98.9**	**49.7**	**44.7**	**13.5**	**1.3**	**8.7**	**22.2**	**40.1**	**0.0**

Sources: WCC Mercury Consumption and Emissions report for 2015; Euro Chlor Chlorine Industry Review, 2014-2015; UNEP Global Mercury Partnership Chlor-Alkali Area estimates of MCCA chlorine capacity in 2012, updated to 2013.

Table 23. Mercury consumed[1] worldwide by region and by major application, 2015

	ASGM			VCM production			Chlor-alkali production			Batteries			Dental applications			Measuring and control devices			Lamps			Electrical and electronic devices			Mercury compounds and other applications[2]			Regional totals		
Region	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean	min	MAX	mean
East and Southeast Asia	289	1 001	645	1 200	1 230	1 215	6	9	8	72	119	95	47	57	52	177	239	208	55	83	69	42	62	52	44	81	62	1 931	2 882	2 407
South Asia	0	8	4	4	5	5	22	32	27	23	43	33	61	83	72	32	47	39	10	14	12	10	14	12	30	89	59	192	334	263
European Union (28 countries)	0	0	0	0	0	0	71	99	85	6	9	8	44	67	56	2	3	3	11	15	13	0	1	1	59	110	84	194	304	249
CIS and other European countries	6	42	24	6	6	6	41	50	45	9	17	13	13	24	19	9	16	12	5	10	7	5	10	7	19	56	37	113	230	171
Middle Eastern States	0	1	0	0	0	0	31	45	38	9	17	13	10	16	13	13	24	18	5	9	7	6	11	9	4	13	9	79	136	107
North Africa	0	0	0	0	0	0	9	14	11	5	10	8	3	5	4	4	8	6	3	5	4	2	3	2	3	8	5	29	52	41
Sub-Saharan Africa	196	536	366	0	0	0	1	1	1	7	40	24	5	9	7	8	14	11	4	7	5	9	28	19	4	25	15	234	660	447
North America	0	0	0	0	0	0	7	9	8	7	10	9	27	37	32	2	2	2	7	9	8	16	21	19	42	79	61	107	167	137
Central America and the Caribbean	6	27	16	0	0	0	15	22	19	6	12	9	5	7	6	8	11	9	4	5	4	4	8	6	4	12	8	51	104	78
South America	376	985	680	0	0	0	30	40	35	13	23	18	8	15	12	14	25	20	6	12	9	5	10	8	7	20	13	458	1 130	794
Australia, N. Zealand and Oceania	0	0	0	0	0	0	0	0	0	1	1	1	3	4	3	1	1	1	2	4	3	9	17	13	0	1	1	16	27	22
Total per application (tonnes)	**872**	**2 598**	**1 735**	**1 210**	**1 241**	**1 226**	**233**	**320**	**277**	**159**	**304**	**231**	**226**	**322**	**274**	**267**	**392**	**330**	**112**	**173**	**142**	**109**	**185**	**147**	**215**	**492**	**354**	**3 404**	**6 027**	**4 715**

Note 1—The "consumption" of mercury is defined here in terms of the end-use of mercury-added products, as opposed to overall regional "demand" for mercury. For example, although most energy-efficient lamps (such as CFLs) are produced in China and therefore represent basic Chinese "demand" for mercury, many of them are exported, used and disposed of in other countries, representing the actual place of "consumption."
Note 2—"Mercury compounds and other applications" include uses of mercury in cosmetics, pesticides, fungicides, catalysts, chemical intermediates, porosimeters, pycnometers, pharmaceuticals, traditional medicine, cultural and ritual uses, etc.

The world's nations adopted the Minamata Convention on Mercury to protect human health and the environment from mercury pollution. A good understanding of mercury supply, trade and demand is critical to effective implementation of the Convention. This report provides detailed and timely information on where mercury comes from, how it moves in commerce, and how it is used in products and industrial processes. To further facilitate informed decision-making, the report also evaluates data sources, discusses trends and identifies knowledge gaps.

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