# Mercury Issues and How Mercury Flow Analysis Can Contribute

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# Mercury Problems - Needs for Global Actions

# Mercury as a Global Pollutant

## Widely used chemical with toxic property

- Chemical element with toxic forms
- Human activities increased mercury levels in the environment
- Elevated human exposure to some populations
- Global action are needed

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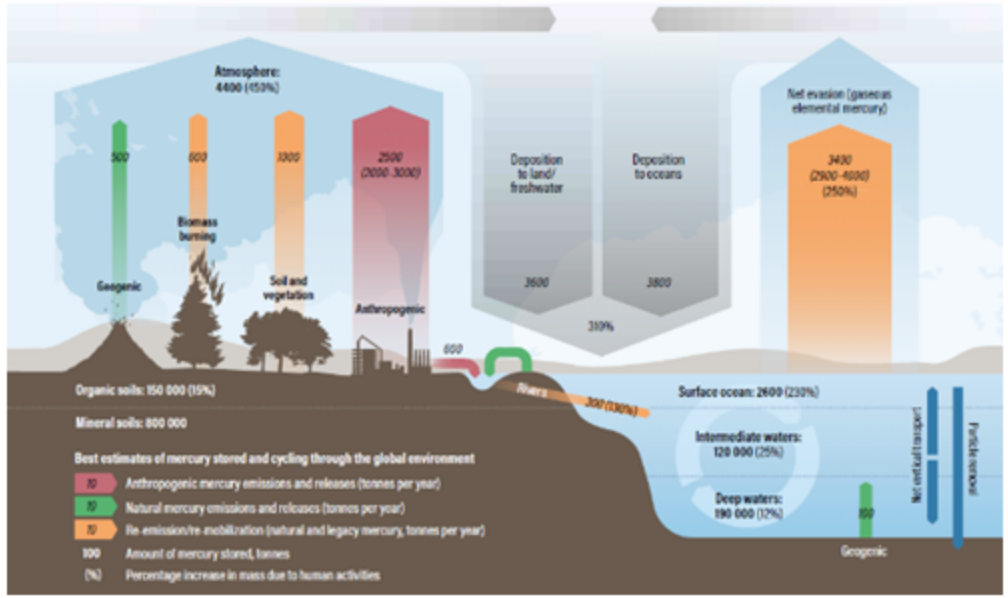
Mercury Problems - Need for Global Actions

# Environmental Behaviour

## Persistent in the environment




Source: UNEP (2019). Global Mercury Assessment 2018.

Stays in circulation for a long time and cycles globally

Anthropogenic emissions increased atmospheric level by 450%

Bioaccumulates in wildlife via food chain

Natural sink is insufficient to eliminate increased emission

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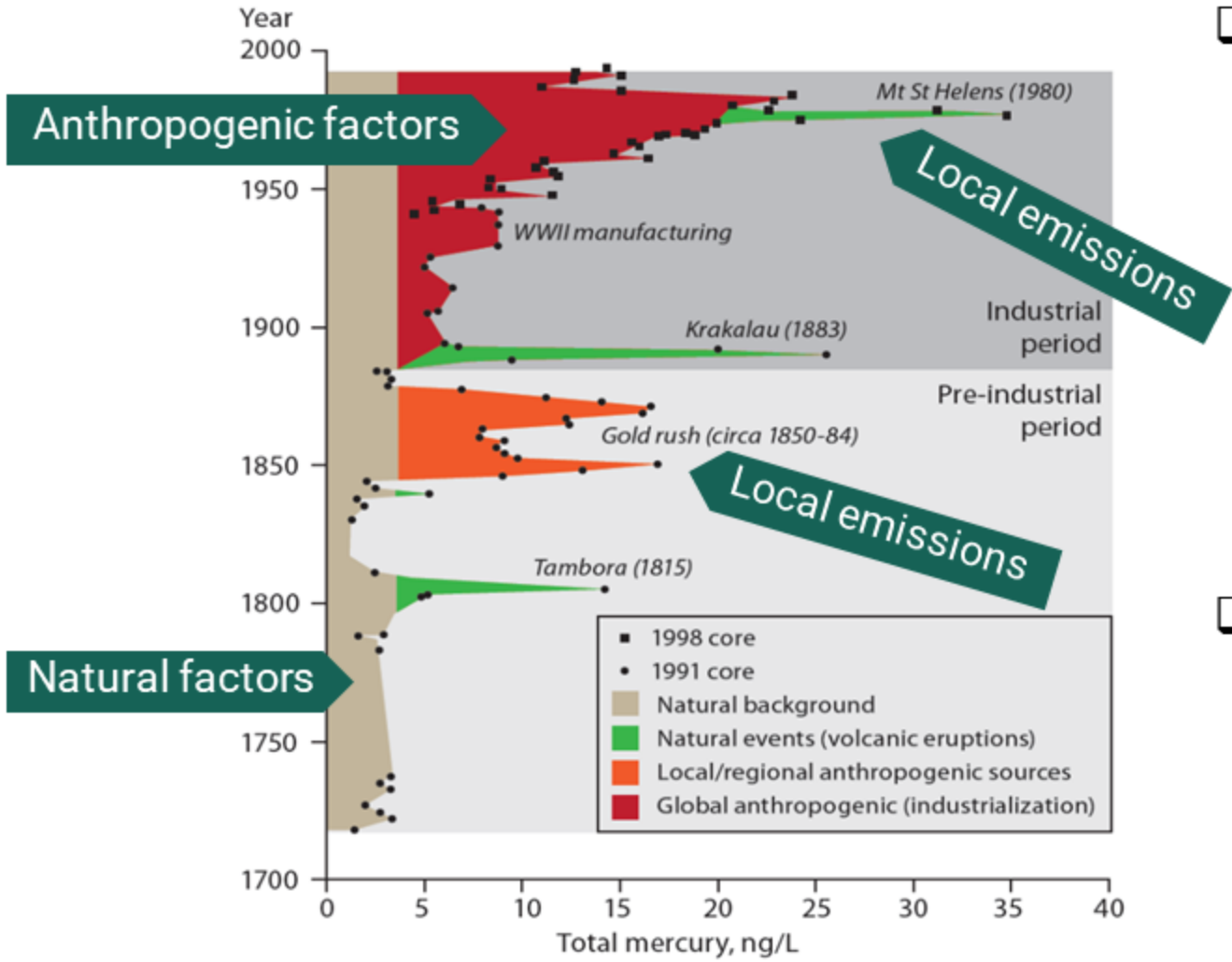
# Historical Mercury Levels




Source: UNEP (2013). Global Mercury Assessment, source, emissions, releases and environmental transport.

- The ice core record of deposition from Wyoming, USA. The elevated levels associated with the US gold rush probably reflect local/regional sources rather than a global signature.
- Increasing environmental levels of mercury associated with industrialization are found in environmental archives like this ice core around the globe.

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# Chemical Properties of Mercury

## Toxicities of mercury exhibits in two ways

| | | |
|---|---|---|
| Divalent mercury ions are corrosive in contact with body tissue | Alkyl-mercury combines with amino acid to form protein | Slow metabolic activity results in accumulation in human body |

## Mercury changes its chemical form and property

| | | |
|---|---|---|
| Elemental mercury is innocent but gradually oxidized to become corrosive | Organic mercury is assimilated into protein and alters its function | Soluble inorganic mercury is corrosive but rapidly excreted |

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# Biological Properties of Mercury

## Inorganic mercury is methylated by microorganisms

| | | |
|---|---|---|
| Majority of mercury in air and water exists in elementary or inorganic form | Some sulphate-reducing bacteria produce methylmercury | Methylation mainly occurs in seabed sediments |

## Bioaccumulates and biomagnifies though food chain

| | | |
|---|---|---|
| Absorption rate of inorganic mercury is low | Species with large sizes and long lifetimes tend to accumulate methylmercury | Some species also store insoluble inorganic mercury |

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# Addressing Mercury Problems

# Anthropogenic Emissions and Releases

## Mercury emissions and releases spread globally

| | |
|---|---|
| Fast in the atmosphere | Slowly in rivers and ocean currents |

## Overall source categories of emissions/releases:

| | | |
|---|---|---|
| Industrial extraction and processing of raw materials that have natural contents of mercury | Production processes that use mercury intentionally, including ASGM | Mercury-added products |

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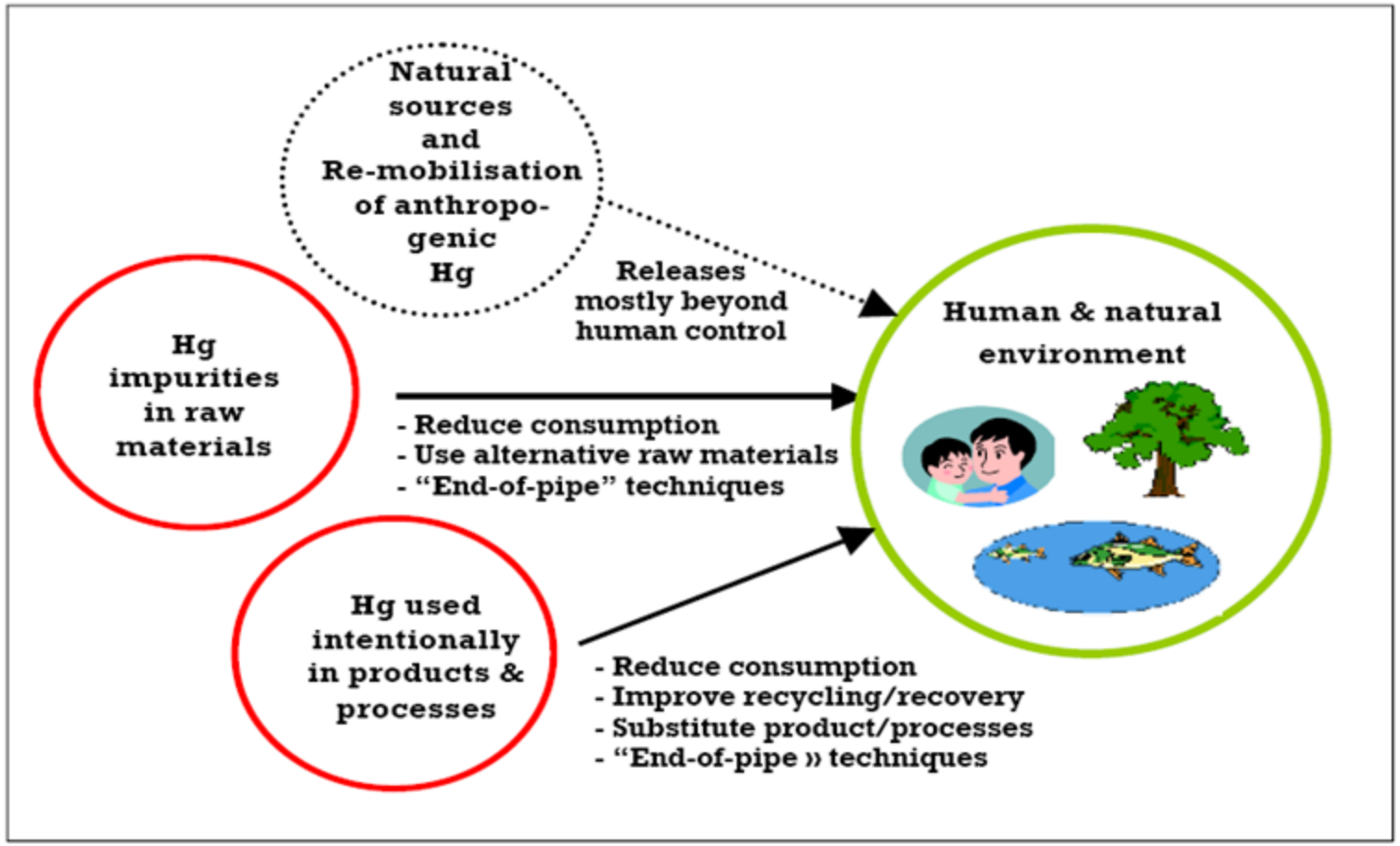
# Alternatives and Management Solutions

Key sources of mercury releases to the environment, and main control options.




Source: UNEP (2002). Global Mercury Assessment.

# Sources of Mercury to Global Economy

- Mercury mining
  - Ore rich in mercury and with mercury as the primary product of interest
- Other non-ferrous metal mining, zinc, lead, gold (industrial scale) and copper
  - Mercury present in the ores used. Not commercially extracted (as metals or minerals), is either deposited as waste or released (emissions to air and releases to land and water)
- Previously accumulated stocks of mercury metal and it's compounds
- Circulation within the global economy happens through recycling of mercury and with marketing of mercury-carrying products and materials

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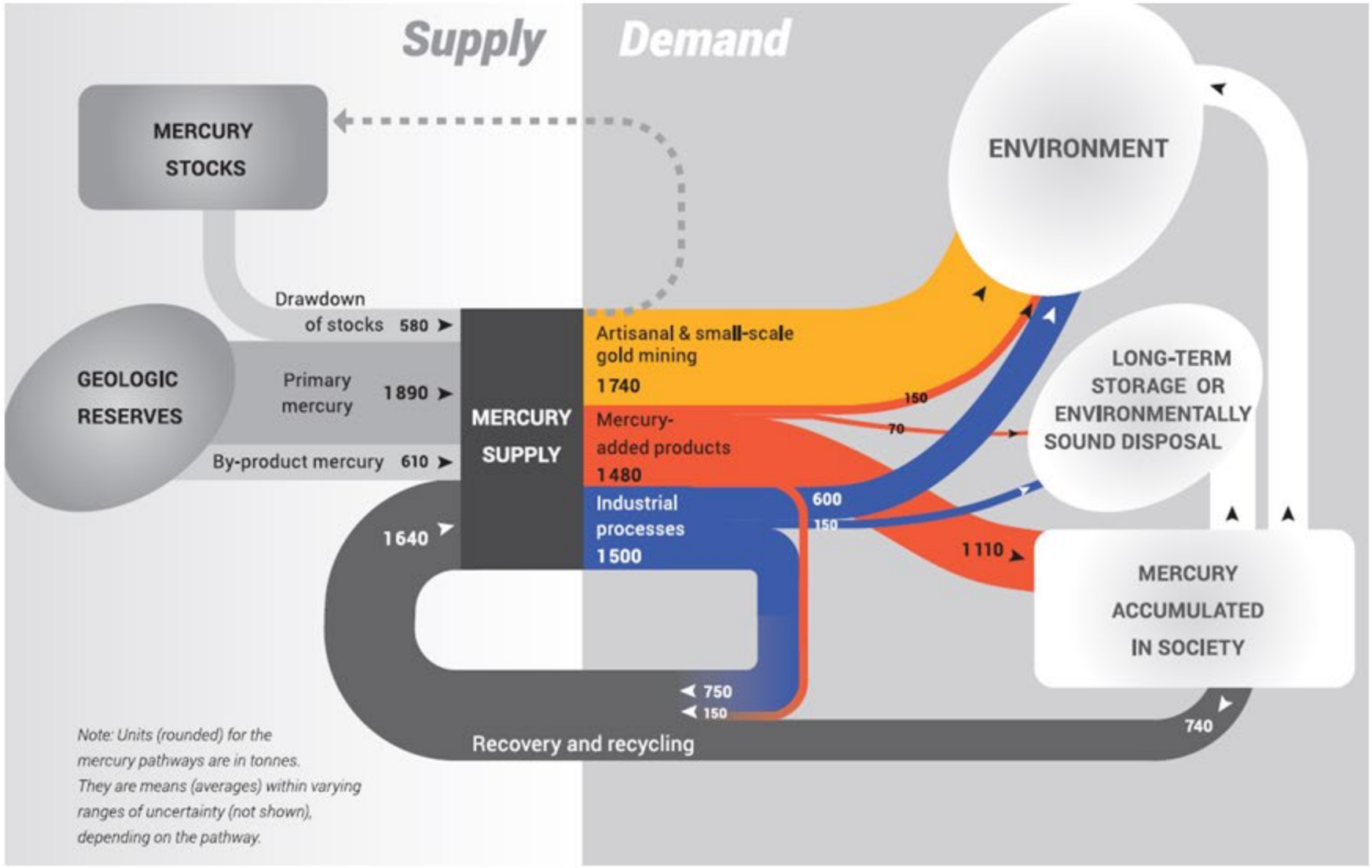
# Global Mercury Inputs and Outputs




Source: UNEP (2017). Global mercury supply, trade and demand.

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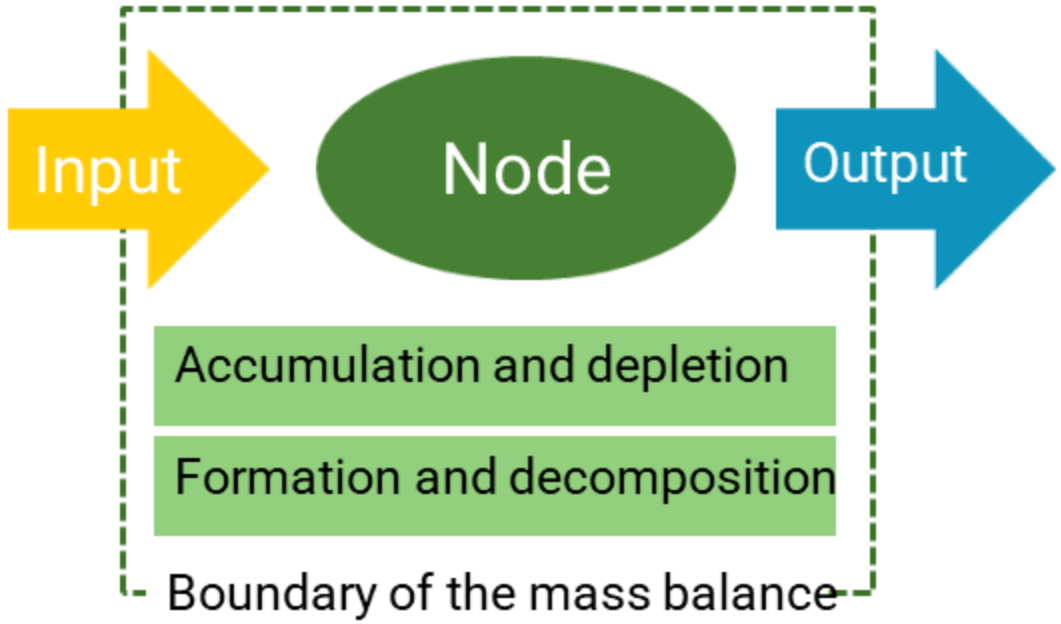
Addressing Mercury Problems

# How Mercury Flow Analysis Can Contribute

# Material Flow Analysis

- Methods to quantify flows and stocks of materials.
- Study for physical / social aspects of human activities.
- Principles:
  - System boundary
  - Process balance model
- Applications:
  - National accounting
  - Industrial process
  - Life cycle of a substance/product

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How Mercury Flow Analysis Can Contribute

# Flow Analysis to Overview Mercury Status

The origin and pathways of the mercury releases that need to be reduced are sometimes complex.

Mass balances help to see the intricate links between sources and releases in the lifecycle of mercury.

Mass balances help in policy development by setting target mercury sources where they are most effective.

# Relevance of the Minamata Convention

- Many developed countries have significantly reduced their internal mercury releases and emissions since as early as the1970s.
- The creation of the Minamata Convention triggered many activities globally to investigate mercury, and to implement measures to reduce mercury exposure in most countries of the world.

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# Roles of Flow Analysis

Minamata Convention sets out a range of measures throughout the **entire life cycle of mercury** to meet its objective.

For the effective implementation of the Convention, it is crucial to **identify the priority areas** as a basis for effective and efficient domestic policy.

Mercury inventory and flow analysis can serve as **fundamental tools** in the identification of key mercury source types and mercury's fate in society.

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# Contribution to the Minamata Convention

- Measures for entire lifecycle stages of mercury covered by different articles of the Convention:
- Identifying trade, stocks and sources of mercury (Article 3)
- Phasing-out and -down for mercury use in products and processes (Articles 4 and 5)
- Reviewing measures taken under national action plans of artisanal and small-scale gold mining (Article 7)
- Developing inventories on emissions to air and releases to land and water (Articles 8 and 9)
- Information provision, awareness raising, and scientific activities (Article 17, 18 and 19)

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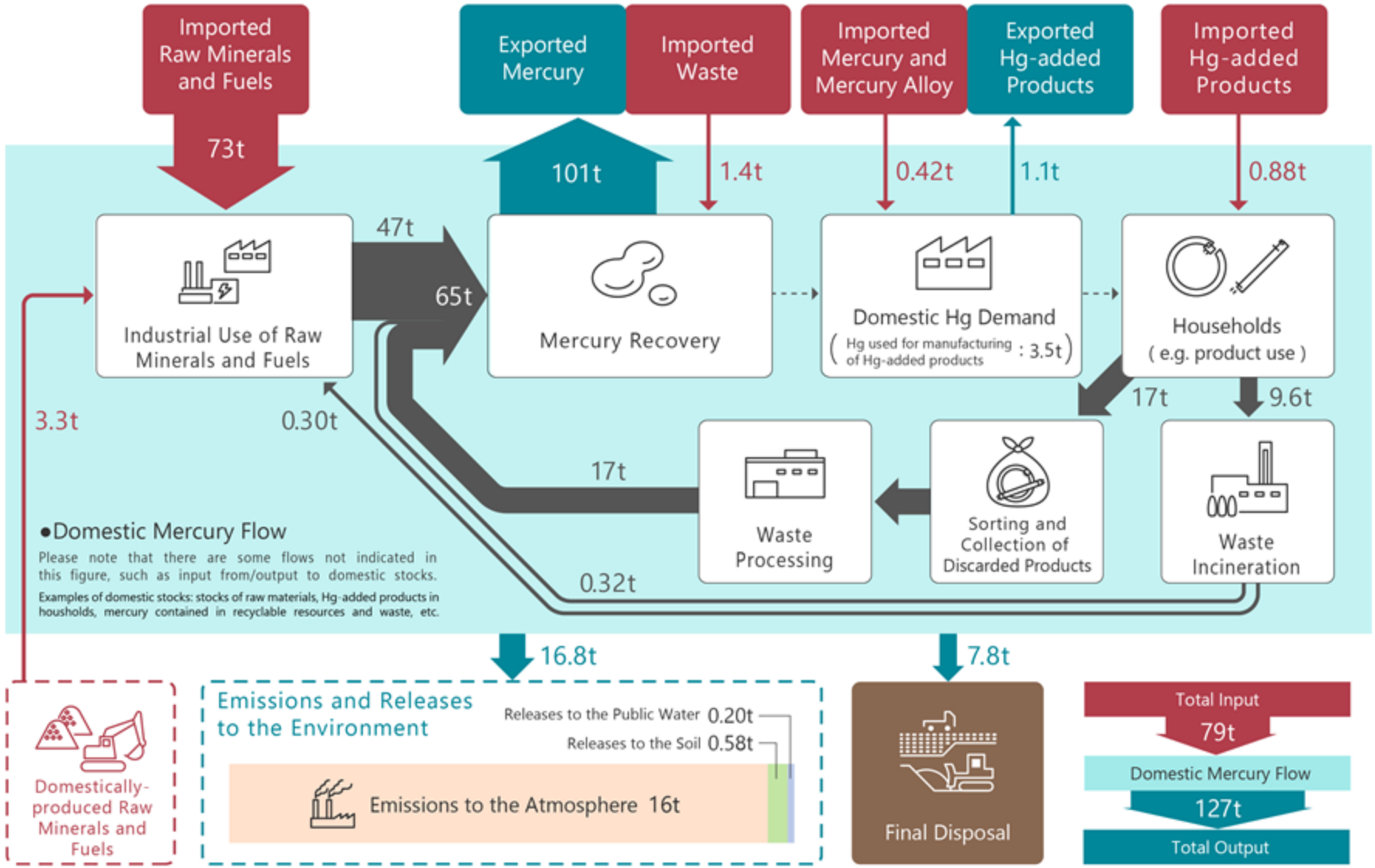
# Policy Implication (Case in Japan)

# Mercury Flow Analysis in Japan




Source: MOEJ (2016). Overview of mercury material flow in Japan.

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Policy Implication (Case in Japan)

# How Mercury Flow is Used

- To review the related act and the implementation plan on mercury management.
  - Japan has established a new “Act on Preventing Environmental Pollution of Mercury” and “The National Implementation Plan for Preventing for Preventing Environmental Pollution of Mercury” to implement the Minamata Convention
  - The new Act is planned to review 5 years after entering into force.
  - Collect data through the development can be utilized for the review of the act and implementation plan.
- The information on mercury free alternatives and new technologies can help to develop new policies.

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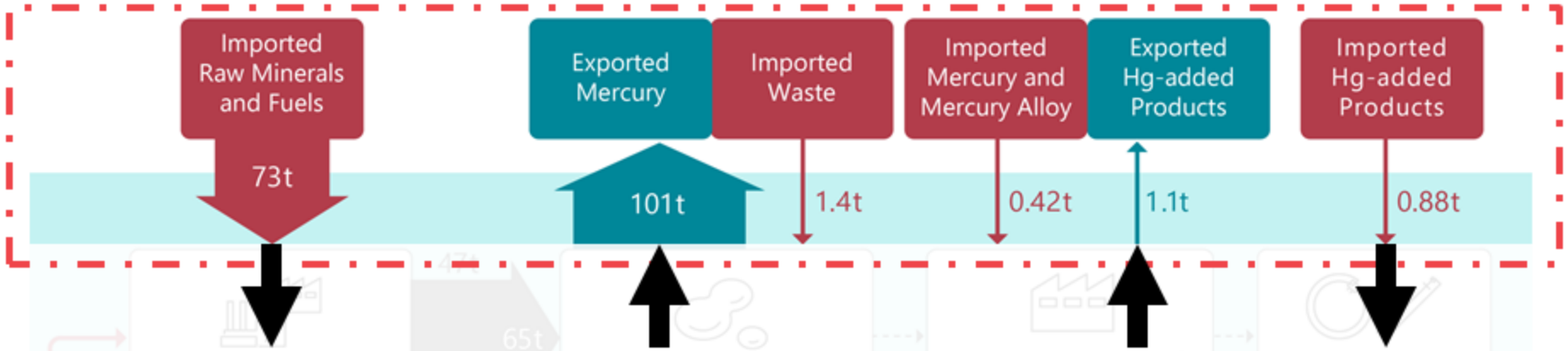
# Analysis: Import and Export




| | FY 2014 | FY 2016 |
|---|---|---|
| Import of raw minerals and fuels | 74 t | 73 t |
| Export of mercury | 84 t | 101 t |
| Import of mercury-added products | 1.0 t | 0.88 t |
| Export of mercury-added products | 2.0 t | 1.1 t |

| FY 2015 | FY 2016 | FY 2017 |
|---|---|---|
| 115.0 t | 145.1 t | 43.6 t |
| | Average 101 t | |

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Policy Implication (Case in Japan)

# Implication: Import and Export

- The amount of mercury exports greatly exceeds the amount of mercury imports.
- The implementation of mercury export regulations is essential, considering the impact of exported mercury.
- Reporting is crucial to prevent inappropriate use of mercury in the importing country (Foreign Exchange and Foreign Trade Act).
- Flow analysis is useful to understand the long-term trend of mercury as well as the short term to take appropriate measures to address the findings.

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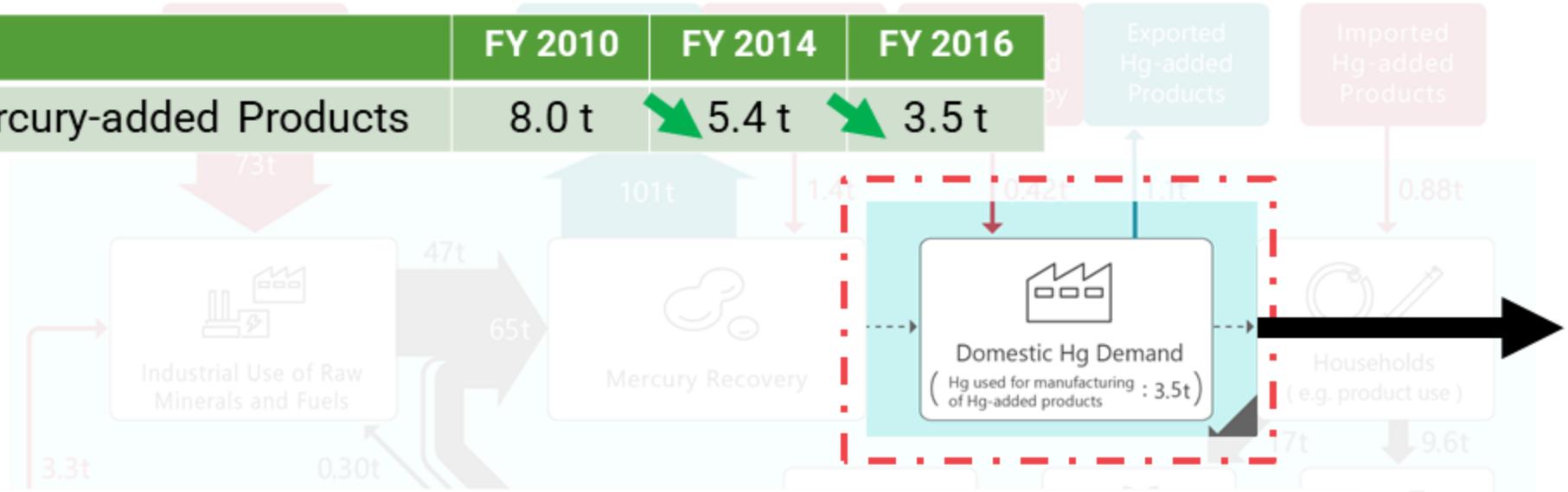
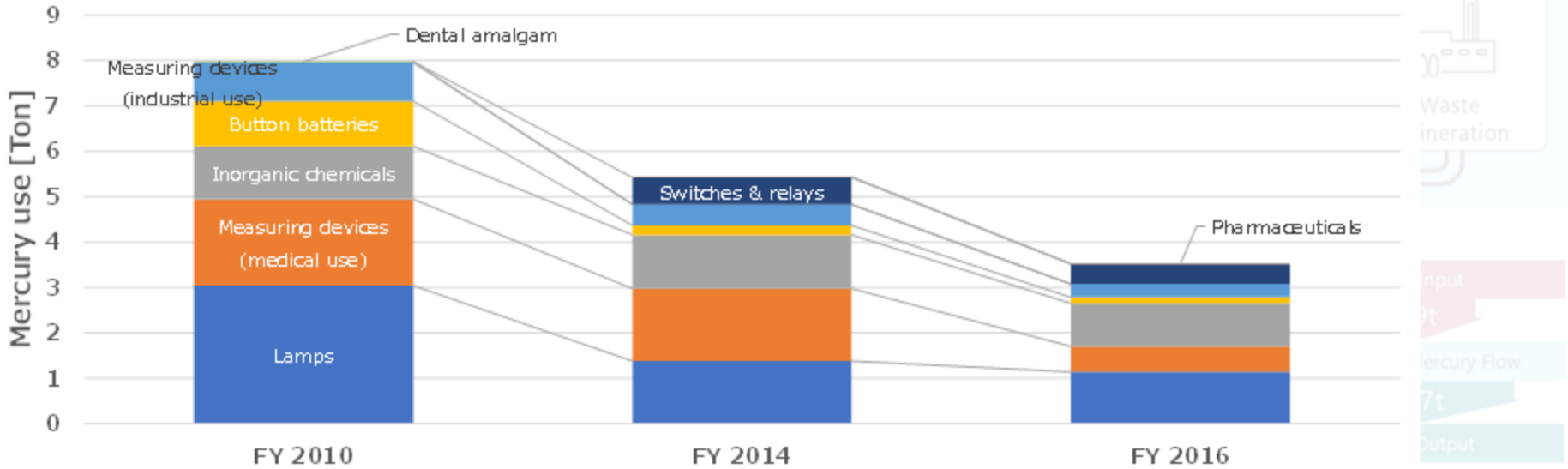
# Analysis: Mercury-added Products

| | FY 2010 | FY 2014 | FY 2016 |
|---|---|---|---|
| Mercury-added Products | 8.0 t | ↘ 5.4 t | ↘ 3.5 t |

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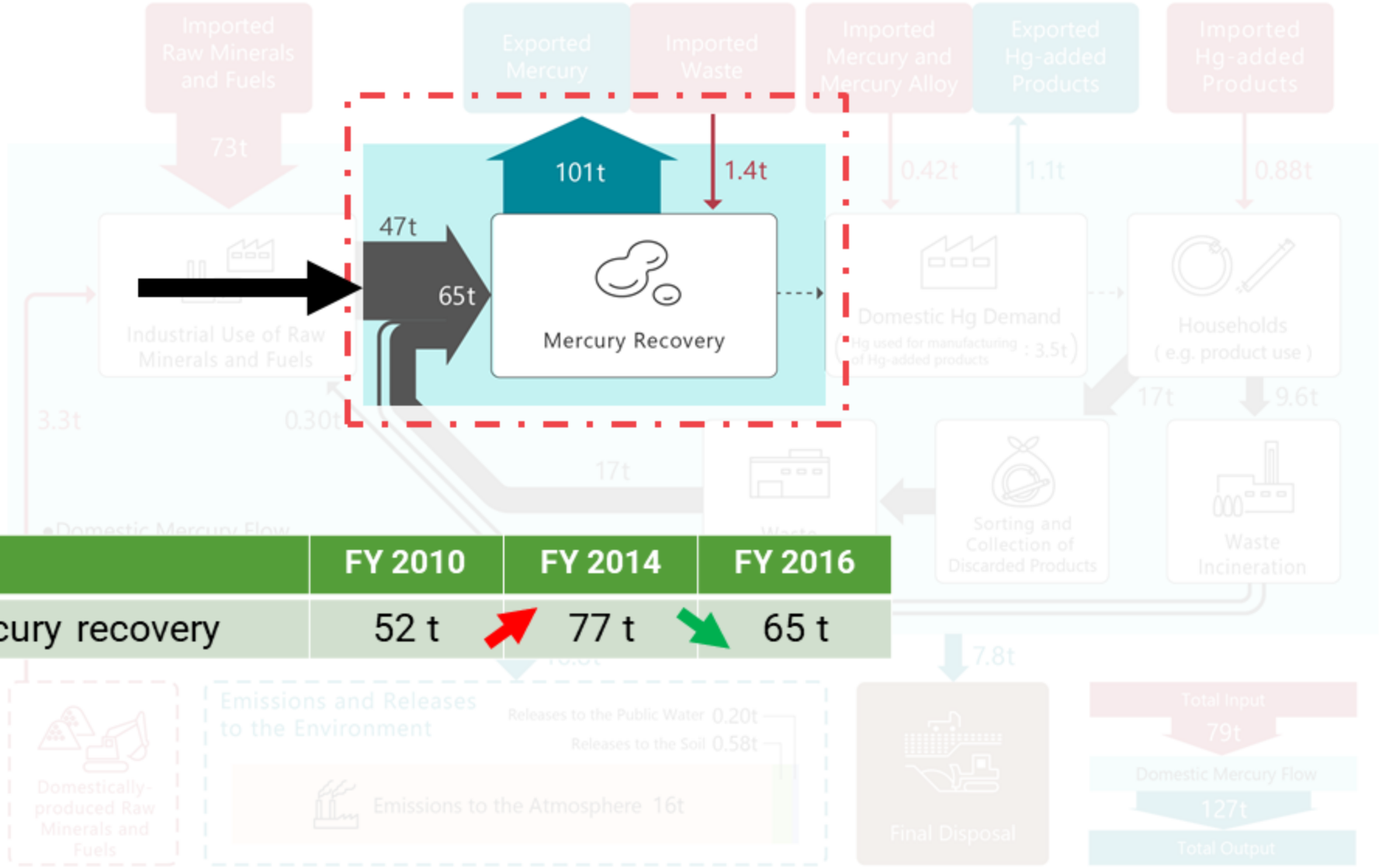
Policy Implication (Case in Japan)

# Implication: Mercury-added Products

- The decreasing trend seems to continue as manufacturers are moving towards mercury-free alternatives.
- Even though mercury-free is not possible, technology development enables mercury reduction per unit of product.
- It is important to raise citizens' awareness to promote mercury-free alternatives.

# Analysis: Mercury Recovery from Waste




| | FY 2010 | FY 2014 | FY 2016 |
|---|---|---|---|
| Mercury recovery | 52 t ↗ | 77 t ↘ | 65 t |

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Policy Implication (Case in Japan)

# Implication: Mercury Recovery from Waste

- It is likely that waste would continue to be generated in the future, even after the manufacture of some types of mercury-added products are phased out.
  - Effective collection of discarded products should be further promoted by stakeholders, such as municipalities and industries.
- The domestic mercury demand can be fulfilled by mercury recovered from waste, only a small amount of mercury and mercury alloys is imported.
  - After the Minamata Convention entered into force, the mercury demand was expected to decline, resulting in disincentives to recover mercury from waste.
  - As sound mercury waste management is an important factor for long-term mercury management, a framework for controlling high concentration mercury waste is deliberately discussed.

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# Future Refinement

| Type of data and expected policy implications | Data source |
|---|---|
| Stock of mercury-added products in households and offices (hoarded stock)<br>• Identify and evaluate responsible entities in each sector for the proper separation, discharge and collection of the products. | Estimated by modelling |
| Mercury stocks in manufacturers<br>• Trend on stocks after the Observe the changes in the mercury stocks after the law enforcement. | Report on mercury stocks more than 30 kg |
| The amount of materials traded as recyclable resources containing mercury generated and disposed of<br>• Evaluate the market value of such material after demand-supply balance changes doe to the strict mercury regulations. | Report on the management of recyclable resources containing mercury |
| | Based on the Act on Preventing the Environmental Pollution of Mercury |

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Mercury Issues and How Mercury Flow Analysis Can Contribute

Policy Implication (Case in Japan)

# Introduction of UNEP Mercury Inventory Toolkit

# How the Toolkit Relates to Mass Flow (1/2)

The UNEP Mercury Inventory Toolkit is based on the mass balance principle

Simplifications necessitated breaking some mass balance flows

The Toolkit currently focuses on the quantification of mercury emissions and releases

Adding the additional layer of linking the quantifications to a mass balance gives the full overview of how mercury release sources are linked and contribute to the overall mercury exposure pattern

# How the Toolkit Relates to Mass Flow (2/2)

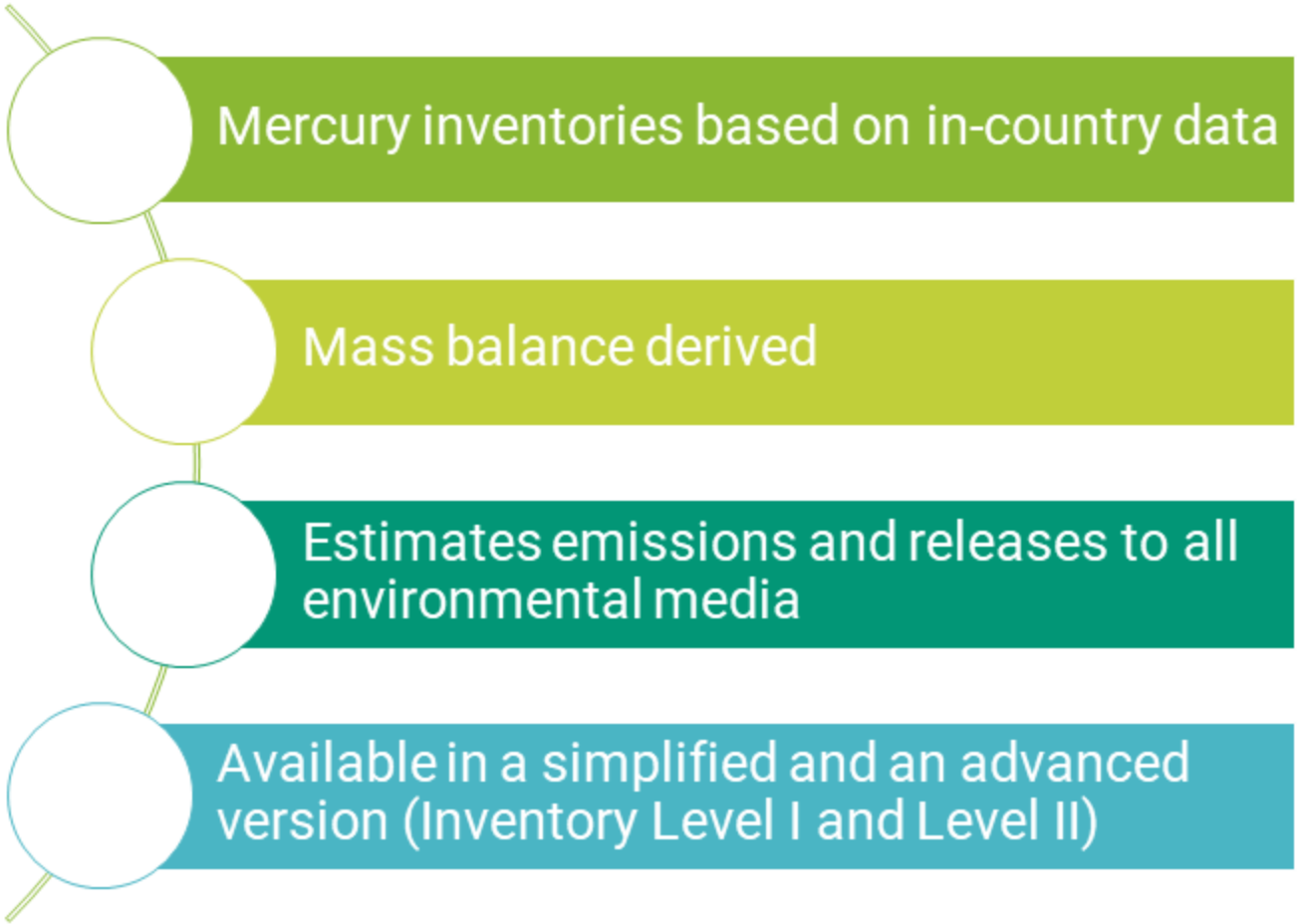
Understanding the Toolkit is highly beneficial for making correct mass flows for mercury

- All the key guidance is provided in easy overview
- Methodologies and system boundaries are defined
- Put simply: You waste your time if you do not use it

(Other emission inventory systems can be used as appropriate )

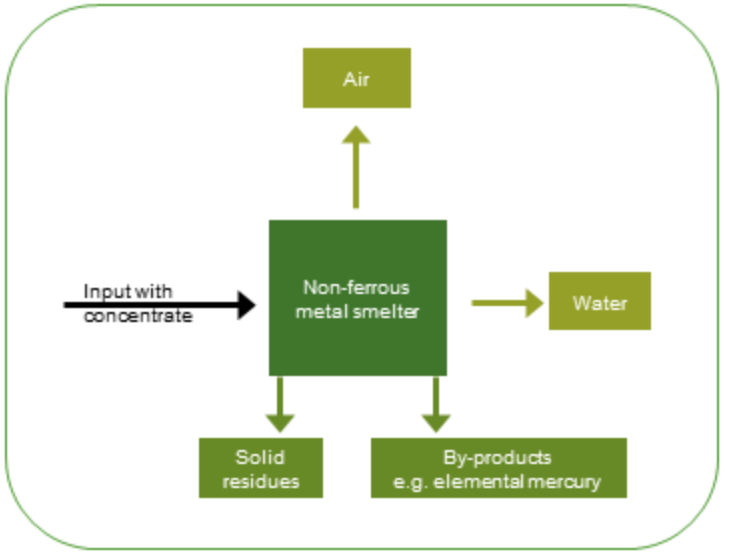
More than 95 countries, mostly developing and in economical transition, use the Toolkit for their mercury quantifications currently

# Toolkit Design



# Toolkit Works with

- Mass balance approach – "what comes in must come out"
  - Highlights cross media effects
- Input factors
  - Mercury concentration in products and input materials
- Output distribution factors
  - Unit-less fractions of total inputs to each environmental media
- Default back-up factors based on literature
- Specific factors encouraged where available (Level 2)

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Introduction of UNEP Mercury Inventory Toolkit

# Mass Balance Based Key Equation

**Mercury release to pathway (*e.g.* "air") =**
**activity rate × input factor × output distribution factor (air)**

Amount of feed material or product (*e.g.* tonnes or pieces per year)

Mercury content (*e.g.* in grams of Hg) per unit of feed material processed or product produced

Fraction of the mercury input that is released through a particular pathway: Air, water, land, product, general waste, or "sector-specific waste treatment"

# Simple Inventory Toolkit Level 1 (IL1)

Very simple to use, needing only activity rate data

Optional: Data on filters, etc. used

Aided data entry (protected formulas, feedback to potentially incorrect data)

Automatic calculations producing very standardised “model” inventories

# Limitation of Toolkit Level 1

"Model inventory" optimised for basic national inventory

Results do not reflect local variations in mercury contents of products, materials and wastes

Can reflect improved pollution control systems but with default factors only

Results do not reflect associated uncertainties

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# Detailed Inventory Toolkit Level 2 (IL2)

Default factors suggested (optional)

Includes (most) relevant release control regimes

Can fully reflect local settings and mercury management

Open for user enhancements

**Only data availability is the limitation**

# Default Factors

- Used automatically in Inventory Level 1 calculations (intermediate values)
- Given as intervals and an intermediate value (pre-entered) in Inventory Level 2 calculations
- For some factors, published data are still scarce (potential for improvement)

# Derivation of Default Factors

- All data used in the derivation of default factors are presented in the Toolkit Reference Report
- The derivation is transparent and open for constructive feedback
- Principles for derivation of input factors:
  - Low end of range: Lowest observations cut off
  - High end of range: Highest observations cut off
  - Intermediate: "Mean" (or mid range, if limited data)
- The Toolkit is updated regularly when needed and funding is available
- Factors are harmonized with "Global Mercury Assessment" (for stationary source sub-categories)



# Toolkit Guidance Elements

# Current Tools in the Toolkit Level 1

- Guideline for Inventory Level 1
- Inventory Level 1 calculation spreadsheet
- Reporting template (MS Word format)
- Examples of data request letters
- e-learning tool MercuryLearn

# Current Tools in the Toolkit Level 2

Toolkit Reference Report

Inventory Level 2 calculation spreadsheet



e-learning tool MercuryLearn

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# Learning Materials about the Toolkit

- ‘Toolkit for identification and quantification of mercury releases’, or UNEP Mercury Inventory Toolkit can be found on

https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-inventory-toolkit

- An e-learning course on the UNEP Mercury Inventory Toolkit is available at MercuryLearn, available at

https://mercurylearn.unitar.org/