Mercury emission inventory enhancement for the coal sector

PROF LESLEY SLOSS

June 2024
Improving data quality and applicability in the coal sector

Using emission factors to estimate emissions

Improving data

Focussing on the important differences
Thanks to the US Department of State, the International Centre for Sustainable Carbon, BCRC-Asia, and the Indonesian Government for this project of work.

Full report freely available from www.sustainable-carbon.org
Vietnam has ratified the Minamata Convention on Mercury

“EACH PARTY SHALL ESTABLISH, AS SOON AS PRACTICABLE AND NO LATER THAN FIVE YEARS AFTER THE DATE OF ENTRY INTO FORCE OF THE CONVENTION FOR IT, AND MAINTAIN THEREAFTER, AN INVENTORY OF EMISSIONS FROM RELEVANT SOURCES”

A PARTY WITH RELEVANT SOURCES SHALL TAKE MEASURES TO CONTROL EMISSIONS AND MAY PREPARE A NATIONAL PLAN SETTING OUT THE MEASURES TO BE TAKEN TO CONTROL EMISSIONS AND ITS EXPECTED TARGETS, GOALS AND OUTCOMES
Creating an emission inventory

A detailed approach

Most inventories are produced using a “top-down” approach:

Total coal burned x emission factor x retention factor

A far more appropriate approach is “bottom-up”:

Data for each unit x specific emission factor x specific retention factor
# Emission factors for coal

\[ \text{EMISSION} = \text{EF} \times \text{RF} \times \text{AV} \]

<table>
<thead>
<tr>
<th>Approach</th>
<th>Emission Factor, EF</th>
<th>Retention factor, RF</th>
<th>EF x RF</th>
<th>Activity value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNEP Toolkit*</td>
<td>Generic – 0.05 g/kg</td>
<td>Generic - minus 10%</td>
<td>0.045 g/kg</td>
<td>Coal burn, t</td>
<td>Assumes all plants and coals are identical. Targets busier units, often unfairly</td>
</tr>
<tr>
<td>2017 UNEP Project</td>
<td>Coal analyses Results averaged across the fleet</td>
<td>iPOG# model of generic national plant</td>
<td>Convert to g/TJ Applies to all plants and takes average plant efficiency into account</td>
<td>Coal burn, t</td>
<td>EF and RF are now more accurate for the national coal fleet BUT still assumes all plants and coals are identical</td>
</tr>
<tr>
<td>Advanced projects (eg Indonesia)</td>
<td>Coal analysis on a unit-by-unit basis</td>
<td>iPOG analysis on a unit-by-unit basis</td>
<td>Unit-specific emission factor</td>
<td>Unit-specific plant activity</td>
<td>Produces a unit-specific emission estimate</td>
</tr>
</tbody>
</table>


# [https://web.unep.org/globalmercurypartnership/interactive-process-optimization-guidance-ipog%E2%84%A2](https://web.unep.org/globalmercurypartnership/interactive-process-optimization-guidance-ipog%E2%84%A2)
Plant sampling for EF and RF

SAMPLES TAKEN AT PLANTS IN INDONESIA

- Sampling of coal as delivered and as fed into the boiler
- Coal samples from numerous mines were analysed and results collated
- Monitoring and mass balances are challenging but are still more useful than generic emission factors
## Creating the dataset

### REAL DATA FROM PLANTS
### MISSING DATA ESTIMATED THROUGH PROXY CALCULATIONS

<table>
<thead>
<tr>
<th>Unit/plant details</th>
<th>Unit performance</th>
<th>Emission controls</th>
<th>Fuel quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit and plant name</td>
<td>Operational load</td>
<td>Flue gas desulphurisation</td>
<td>Calorific value</td>
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<tr>
<td>Location</td>
<td>Utilisation/capacity factor</td>
<td>In boiler additives</td>
<td>Mercury content</td>
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<tr>
<td>Generating capacity</td>
<td>Specific energy consumption</td>
<td>NOx burners or SCR</td>
<td>Sulphur content</td>
</tr>
<tr>
<td>Certified operating and commissioning date</td>
<td>Annual coal consumption</td>
<td>PM controls</td>
<td>Chlorine content</td>
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</tbody>
</table>
Using the iPOG

INTERACTIVE PROCESS OPTIMISATION GUIDANCE TOOL

- Input unit-specific data
- RF estimated from plant configuration, coal chemistry and control technologies in place
- Results based on extrapolation and modelling of data from thousands of real data sets
- Used to focus on RELATIVE emission rates, not “actual”
- Image

Demonstration to follow
Creation of the dataset

LIVING DOCUMENT TO BE UPDATED REGULARLY
PROVENANCE OF DATA TO BE RECORDED

<table>
<thead>
<tr>
<th>No</th>
<th>Power unit</th>
<th>WEPP UNIT NAME</th>
<th>Capacity (MW)</th>
<th>2020</th>
<th>2020</th>
<th>Total electricity production/gross (MWh)*</th>
<th>Installed</th>
<th>Remaining life as of 2020 (40yr life)</th>
<th>Total electricity production/gross (MWh)*</th>
<th>Annual utilisation</th>
<th>Operational load</th>
<th>Fuel Consumptio (ton/year)</th>
<th>Fuel Consumptio (ton/MWh)</th>
<th>Specific Fuel Consumptio (ton/MWh)</th>
<th>2020 Purnomo</th>
<th>Stack Mercury Emission</th>
<th>SOx control (WEPP)</th>
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<th>Annual Hg Emission, kg</th>
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<th>Remaining Plant Life, kg</th>
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<td>35</td>
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<td>22.09</td>
<td>98.20</td>
<td>150,000.00</td>
<td>0.546</td>
<td>7,970</td>
<td>SWFGD</td>
<td>44.6</td>
<td>0.19</td>
<td>0.023</td>
<td>2.4</td>
<td>6,690</td>
<td>24</td>
<td>360</td>
<td>12,600</td>
<td>178,017</td>
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<td>91.59</td>
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<td>0.52</td>
<td>0.026</td>
<td>3.4</td>
<td>40,185</td>
<td>11</td>
<td>5,710</td>
<td>182,723</td>
<td>4,473</td>
<td>5</td>
</tr>
</tbody>
</table>
Conclusions and comments

Minamata inventories

- The Convention requires at least a Level 1 calculation for coal sector emissions

- A Level 2 or 3 approach, (bottom-up, using more coal and plant-specific data) will make cost-effective compliance easier
Thank you

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Using enhanced data to rank sources and create a cost-effective targeting strategy

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June 2024
Informed ranking of data

Informing a strategic approach to emission reduction
Requirements for coal plants

Under the UN Minamata Convention

“New sources” must apply, within 5 years of ratification:

• BAT/BEP (best available technology/best environmental practice)

“Existing source” must apply, within ten years of ratification:

• A qualified goal
• Emission limit values
• BAT/BEP
• Multipollutant strategy
• “Alternative measures”
How to turn emission data into an emission reduction strategy

• Create an accurate emission inventory for the fleet, with as much plant-specific data as possible

• Rank the sources/units and focus on high-emitters and inefficient plants first

• Create policy or legislation which is appropriate – affordable and achievable – maximising “co-benefit” and multipollutant strategies
Changing the input

MOVING FROM ASSUMPTIONS TO REAL DATA

All plants are assumed equal

<table>
<thead>
<tr>
<th>Plant</th>
<th>Emissions, g</th>
<th>EF, g/kg</th>
<th>RF, %</th>
<th>AV, t</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>90</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>90</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>90</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

Plant B has higher mercury coal

<table>
<thead>
<tr>
<th>Plant</th>
<th>Emissions, g</th>
<th>EF, g/kg</th>
<th>RF, %</th>
<th>AV, t</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>90</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>180</td>
<td>2</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>90</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

Plant C has higher ash retention

<table>
<thead>
<tr>
<th>Plant</th>
<th>Emissions, g</th>
<th>EF, g/kg</th>
<th>RF, %</th>
<th>AV, t</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>90</td>
<td>1</td>
<td>10</td>
<td>100</td>
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<tr>
<td>B</td>
<td>180</td>
<td>2</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>50</td>
<td>1</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

The total coal burned is the same in all assumptions

All plants are NOT the same

Focus on plant efficiency by converting the emission factor to g Hg/GWh
Fleet emission intensity

Changing the emission factor from g/kg to g/GJ – Indonesian example

Amount of Hg (g) emitted per GWh of electricity produced – indication of “cleaner” burning plants.
No indication of size-related intensity of Hg emissions for units >100 MW
SOME UNITS EMIT AN ORDER OF MAGNITUDE MORE MERCURY PER GWh OF POWER PRODUCED THAN OTHERS
Predicted annual emissions from Indonesian coal plants
# Bringing in plant lifetime

**IMMEDIATELY BRINGS IN COST-EFFECTIVENESS**

<table>
<thead>
<tr>
<th>Current method</th>
<th>Add in capacity factor/remaining lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies plants which emitted the most mercury in the last operating year</td>
<td>Removes older plants which will slow down or close soon.</td>
</tr>
<tr>
<td>BUT assumes all plants are the same age</td>
<td>Allows focus for intervention on plants where control technologies may be effective in the long-term</td>
</tr>
</tbody>
</table>
Units which will emit >1t Hg over their remaining lifetime (Indonesia)

ASSUMING PLANTS RUN UNTIL THEY ARE 40 YEARS OLD
The top 10 units in Indonesia (out of 111 units) emit around 50% of the total emissions from the entire fleet
Mercury emissions over remaining fleet lifetime

- Over 110 units analysed
- The top 10 units emit around 50% of the total emissions from the entire fleet

*This provides valid science for an informed and strategic emission reduction strategy*
Simple method to rank data

<table>
<thead>
<tr>
<th>UNIT NUMBER</th>
<th>CAPACITY (MW)</th>
<th>Remaining life as of 2020 (40yr)</th>
<th>Operational load</th>
<th>Fuel Consumption (calculated)</th>
<th>Gross unit efficiency</th>
<th>SOx control (WEPP)</th>
<th>Coal Hg content</th>
<th>Coal S content</th>
<th>Coal Cl content</th>
<th>Annual Hg Emissions, coal input, kg</th>
<th>Hg Emission Intensity, g/MWh</th>
<th>Annual Hg Emission (iPOG prediction), kg</th>
<th>Remaining Plant Life Hg Emissions, kg</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
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<td>4.0</td>
<td>5.0</td>
<td>3.0</td>
<td>4</td>
<td>3.0</td>
<td>5</td>
<td>4</td>
<td>52.0</td>
</tr>
</tbody>
</table>
Creating a reduction strategy for coal

BAT/BEP options

Maximising co-benefit
Two major forms of mercury

THE CHEMISTRY IS AFFECTED BY COAL TYPE, ASH CONTENT, CHLORINE CONTENT ETC – IT IS COMPLEX!

<table>
<thead>
<tr>
<th>Oxidised mercury</th>
<th>Elemental mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soluble and sticky</td>
<td>Not soluble and not sticky</td>
</tr>
<tr>
<td>Easy to capture in solutions, ash or sorbents</td>
<td>Hard to capture</td>
</tr>
<tr>
<td></td>
<td>Can be oxidised by chemicals such as chlorine and bromine</td>
</tr>
</tbody>
</table>

Hg2+  Hg0
Mercury flow through a coal plant

Hg speciation changes from pure Hg\textsuperscript{0} vapour at the furnace exit to changing mixtures of Hg\textsuperscript{0}, Hg\textsuperscript{2+} and Hg-P as the flue gas moves through the APCDs depending on the levels of Cl, Br and unburnt carbon, whether a SCR is present and many other cleaning conditions.
“Co-benefit effects”

MAXIMISING “FREE” MERCURY CONTROL

If you can control mercury, you can also control acid gases and particulates and if you control acid gases and particulates, you also control mercury
Flow chart for technology selection

INCLUDED IN THE UNEP BAT/BEP GUIDANCE FOR COAL
# Coal cleaning* and blending

*CHEMICAL COAL CLEANING HAS YET TO PROVE COST-EFFECTIVE FOR MERCURY CONTROL

## Selecting coal type
- US sub-bituminous coals tend to contain less chlorine and can be high in calcium
- Many US plants firing sub-bituminous coals found mercury reduction a challenge as most mercury is produced in the elemental form
- Oxidation with halogen addition was proven to work, but so was coal-blending

## Blending
- Coal plants blend coals to maintain the characteristics required for efficient combustion
  - Low-quality coals can be mixed with higher-quality coals to keep costs down
  - Low sulphur coals can be mixed with high sulphur coals to keep emissions down
  - Coal blending for emission control of anything other than sulphur is not a common strategy but theoretically it is possible

## Strategic blending
- Study in a US plant firing sub-bituminous coal – mercury emissions remained high, even though the plant was fitted with a flue gas desulphurisation system
  - Blending with bituminous coal helped to oxidise the mercury
  - By blending in 15% bituminous coal in with the sub-bituminous coal, mercury emissions could be reduced by up to 80%
Co-firing biomass

- Most vegetation for co-firing will be low in mercury content. Reducing the mercury input in the total fuel will reduce the mercury input to the plant and thus reduce overall emissions.
- The chlorine and ash contents of biomass can be higher than coal. This can help mercury oxidation and capture.

Figure 15 Variation of mercury emission during co-firing of subbituminous coal and biomass (Cao and others, 2008)
Particulate controls and mercury

Particulate control systems can reduce PM emissions by >99.99%

Particulate control systems can capture mercury – oxidised mercury will stick to unburnt fly ash (sorbents can be added)

Mercury capture in ESP is generally lower (10-30%) than in fabric filters/baghouses (40-70%)

Emission values must be established for each site, due to potential variations in coal chemistry
NOx controls and mercury

VARIES WITH COAL AND PLANT TYPE

NOx burners do not have a significant effect on mercury emissions

Selective catalytic reduction technologies fitted upstream of particulate controls can oxidise mercury and lead to increased mercury capture in the ash

BUT: Mercury can contaminate and shorten the life of catalysts.

Sulphur controls and mercury

VARIATES WITH COAL AND PLANT TYPE

IF mercury is in the oxidised form, it will be trapped in most FGD systems:

- Wet FGD systems will dissolve oxidised mercury
- Dry FGD systems will capture oxidised mercury in the dry sorbent
- Seawater FGD systems will dissolve oxidised mercury but may release it into the local water body

Mercury capture in any FGD system can be enhanced by converting elemental mercury to oxidised mercury by adding an oxidant such as bromine

Mercury reduction can be up to and even over 70% in an FGD system but is very site-specific.
Mercury-specific control options

Many mercury-specific control systems have been developed and some are commercialised.

Most plants see these systems as a “last-resort” to reducing emissions due to the cost.

### Table 7: Multi-pollutant control technologies

<table>
<thead>
<tr>
<th>System</th>
<th>Format</th>
<th>Demonstration status</th>
<th>Marketed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>WESP</td>
<td>Wet ESP</td>
<td>Full scale at many plants</td>
<td>Various</td>
</tr>
<tr>
<td>COHPAC™</td>
<td>ESP plus fabric filter or pulse-jet fabric filter</td>
<td>1700 MW installed on coal plant and waste-to-energy incinerators</td>
<td>EPRI, via Babcock and Wilcox, Hamon Research-Cottrell</td>
</tr>
<tr>
<td>TOXCON™</td>
<td>Sorbent, and pulsed-jet fabric filter (COHPAC plus sorbent)</td>
<td>Fitted in 8 plants in USA</td>
<td>EPRI, via Babcock and Wilcox, Hamon Research-Cottrell</td>
</tr>
<tr>
<td>EFC, electrostatic fabric integrated collector</td>
<td>Similar to COPAC with pulse-jet fabric filter</td>
<td>50 units currently in operation</td>
<td>China Fujian Longking</td>
</tr>
<tr>
<td>ESFF, ESP-FF hybrid system</td>
<td>Split level filters either integrated or separated</td>
<td>3 plants in China and 1 in India</td>
<td>Zhejiang Feida Environmental Science and Technology Co</td>
</tr>
<tr>
<td>ECO™ Technology</td>
<td>Dielectric barrier discharge, ammonia based scrubber, and WESP</td>
<td>Slip-stream demonstration</td>
<td>Powerspan</td>
</tr>
<tr>
<td>ReACT™</td>
<td>Regenerative activated coke technology</td>
<td>Full scale — Iogo, Japan; Weston, USA; industrial plants in Germany</td>
<td>J-Power, Haldor Topsoe</td>
</tr>
<tr>
<td>SNOX™</td>
<td>Dry catalyst/reactors with ammonia addition</td>
<td>Full scale, Nordjyllandsværket, Denmark, plus industrial sites</td>
<td>Haldor Topsoe</td>
</tr>
<tr>
<td>SNRE™ (SOX-NOx-Rox-Box)</td>
<td>Alkali sorbent injection and high temperature fabric filter</td>
<td>Demonstration</td>
<td>Babcock and Wilcox</td>
</tr>
<tr>
<td>Airborne™ Process</td>
<td>Sodium bicarbonate injection with wet sodium scrubbing and oxidation</td>
<td>Pilot and small scale</td>
<td>Airborne Clean Energy</td>
</tr>
<tr>
<td>Neustream™ Technology</td>
<td>Dual-alkali FGD with upstream ozone injection</td>
<td>Pilot scale</td>
<td>Neumann Systems Group</td>
</tr>
<tr>
<td>Ione mercury and SO₂ control modules</td>
<td>Passive, modular, fixed absorption media modules</td>
<td>2100 MW installed in coal-fired power plants in the USA and demonstration pilots in European plants</td>
<td>Goren</td>
</tr>
<tr>
<td>Skyline™ Process</td>
<td>Electrochemical sodium hydroxide scrubbing</td>
<td>Pilot scale</td>
<td>Skyonic Corporation</td>
</tr>
<tr>
<td>Tri-Mer™</td>
<td>Modular ceramic catalyst and oxidant units</td>
<td>Pilot scale</td>
<td>Tri-Mer</td>
</tr>
</tbody>
</table>
This is a simple flow diagram which allows the user to work through the BAT/BEP (best available technology(best environmental practice) to choose an option which will work best with different plant configurations.
Using the iPOG as a predictor

THE IPOG CAN HELP DETERMINE THE APPROACHES MOST LIKELY TO SUCCEED
Conclusions

Information and data = power

• The Minamata convention only requires a total sectoral inventory. However, an enhanced inventory could inform a significantly more cost-effective reduction strategy.

• Creating an enhanced inventory takes time but, once established can simply be updated annually to monitor trends in emissions.

• Use a ranking approach, considering plant-specific factors including remaining operating lifetime, to determine where action will achieve the greatest results.

• It is possible and even likely that acting on a few plants could achieve faster and more cost-effective emission reduction than a blanket requirement for action across all plants.
Thank you

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www.mq.edu.au
MERCURY FROM THE NON-FERROUS SECTOR

Peter Nelson

School of Natural Sciences
Macquarie University
Sydney, Australia

Co-lead UN Environment Mercury in Coal Combustion Partnership

Image: https://www.mining.com/wp-content/themes/miningdotcom/images/favicon/apple-icon-57x57.png
Non Ferrous Metals in Article 8 Minamata Convention

- Smelting and Roasting only
- Metals:
  - Copper
  - Lead
  - Zinc
  - Industrial Gold
<table>
<thead>
<tr>
<th>Sector</th>
<th>Mercury Emissions (range), tonnes</th>
<th>Sector % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artisanal and small-scale gold mining (ASGM)</td>
<td>838 (675-1000)</td>
<td>37.7</td>
</tr>
<tr>
<td>Biomass burning (domestic, industrial and power plant)</td>
<td>51.9 (44.3-62.1)</td>
<td>2.33</td>
</tr>
<tr>
<td>Cement production (raw materials and fuel, excluding coal)</td>
<td>233 (117-782)</td>
<td>10.5</td>
</tr>
<tr>
<td>Chlor-alkali production (mercury process)</td>
<td>15.1 (12.2-18.3)</td>
<td>0.68</td>
</tr>
<tr>
<td>Non-ferrous metal production (primary Al, Cu, Pb, Zn)</td>
<td>228 (154-338)</td>
<td>10.3</td>
</tr>
<tr>
<td>Large-scale gold production</td>
<td>84.5 (72.3-97.4)</td>
<td>3.8</td>
</tr>
<tr>
<td>Mercury production</td>
<td>13.8</td>
<td>0.62</td>
</tr>
<tr>
<td>Stationary combustion of coal (domestic/residential, transportation)</td>
<td>55.8 (36.7-69.4)</td>
<td>2.51</td>
</tr>
<tr>
<td>Stationary combustion of coal (power plants)</td>
<td>292 (255-346)</td>
<td>13.1</td>
</tr>
<tr>
<td>Vinyl-chloride monomer (mercury catalyst)</td>
<td>58.2 (28.0-88.8)</td>
<td>2.6</td>
</tr>
<tr>
<td>Waste (incineration and other emissions from all waste streams)</td>
<td>162 (129-255)</td>
<td>7.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2220 (2000-2820)</strong></td>
<td></td>
</tr>
</tbody>
</table>
Mercury variability in ores

Number of mines and the reported Hg concentrations in
a) Cu concentrates
b) Pb concentrates
c) Zn concentrates

High Temperature Processing releases Hg
Non-ferrous metal sector in Vietnam (based on MIA, 2016)

Vietnam has “significant quantities of copper, gold, tin, lead, zinc, gem stones, nickel, industrial and non-ferrous metals, clay and phosphate” (Reuters)
Non Ferrous Metals – Strong Growth
Emission Estimation
Tools for inventory development

UNEP Mercury Toolkit

Inventory Level 1 (IL1)
- a simplified model - easy to use; useful for first-time inventories
- less reading to get started, less data, calculations are fully automatic, and it includes in-cell guidance within the spreadsheet
- uses national activity rate data
- assess mercury controls (BAT/BEP)
Tools for Inventory Development

Inventory Level 2 (IL2)
• a detailed mercury inventory tool
• all factors adjustable to national or local conditions.
• default estimation factors are pre-entered
• requires more reading and experience
• high level of accuracy, provided that the data needed for this are available
Other resources – Study Report on Non Ferrous Metals

Identified uncertainties and knowledge gaps

- Hg content in ores and concentrates, at plant and country level
- Hg air emissions test data
- Hg concentrations in reject material
- Hg distributions between emissions and other releases
- Activity data (amounts of ores and concentrates processed)
- Effects of pollution control technologies, incl. on distribution of Hg between emissions to air, and capture in solid and liquid waste
- Additional quantitative information on how mercury deports to emissions and releases to air, land, water, waste and by-products

DATA REQUIRED FOR BETTER EMISSION ESTIMATES
Mercury concentrations as a function of gold concentrations; samples from the Kalgoorlie deposit (Eviron 2006)
Improving emissions estimations

- Improved data (mercury in ore and concentrates, activity data, control technologies and their effectiveness,...)
- Individual plant data (often a large task)
- Prospects for future development of mineral resources?
  Mine production of copper in concentrates (Cu content) and smelter and refinery copper production all increased by approximately 9% in 2021 (USGS, 2022)
Better understanding of ore characteristics

Gold is typically recovered from ores containing only traces of the metal - main challenge is concentrating

- **Techniques:**
  - Cyanide leaching; gold must be available for leaching
  - Mercury amalgamation – largely now only used in ASGM
  - Refractory ores – hard to leach ultra-fine mercury; requires pre-treatment (roasting, oxidation, ... )
Reducing mercury emissions
BAT/BEP
Reduction of Hg emissions

• Boliden-Norzink process
  – Hg + HgCl₂ → Hg₂Cl₂ (calomel)
• Selenium filter
  – Se + Hg → SeHg
• Activated carbon
• Co-benefits of air pollution abatement technologies
  – Particulate matter, SO₂, NOₓ
Case Study: Nevada Gold Plant

- Controls employed:
  - Cyclone separation
  - Gas Quench
  - Venturi gas scrubbing
  - Gas condenser
  - Wet electrostatic precipitator (ESP)
  - Calomel scrubber
<table>
<thead>
<tr>
<th>Mercury Removal Technology</th>
<th>Process Conditions</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Filter beds</td>
<td>Efficiency = 99%</td>
<td>• Effectively removes mercury chloride</td>
<td>• Untreated carbon ineffective in removing elemental mercury</td>
</tr>
<tr>
<td>Fixed activated carbon filter beds</td>
<td>Efficiency = 90%</td>
<td>• Sulfur-impregnated activated carbon is commercially available</td>
<td>• Spent carbon requires disposal in landfill</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Removes Hg⁰ and other species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low potential for leaching of mercury from spent carbon</td>
<td></td>
</tr>
<tr>
<td>Activated carbon injection</td>
<td>Efficiency = 90-95%</td>
<td>• Sulfur-impregnated activated carbon is commercially available</td>
<td>• Spent carbon requires disposal in landfill</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Removes Hg⁰ and other species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low potential for leaching of mercury from spent carbon</td>
<td></td>
</tr>
<tr>
<td>Lime/limestone scrubbing</td>
<td>Efficiency = 10-84%</td>
<td>• Effective for water soluble species</td>
<td>• Ineffective for elemental mercury</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Wastewater requires treatment prior to disposal</td>
</tr>
<tr>
<td>Selenium filters</td>
<td>Efficiency = 99.6%</td>
<td>• Successful installation at metallurgical plants</td>
<td>• Limited inlet mercury concentration</td>
</tr>
<tr>
<td></td>
<td>Max Hg_{IN} = 9 mg/m³ Max Hg_{OUT} = 40 µg/m³</td>
<td></td>
<td>• Ineffective for species other than elemental mercury</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Spent filter requires disposal in landfill</td>
</tr>
<tr>
<td>Boliden-Norzink process</td>
<td>Efficiency = 99%</td>
<td>• Widely demonstrated</td>
<td>• Removes only elemental mercury</td>
</tr>
<tr>
<td></td>
<td>Max Hg_{IN} = 5-80 mg/m³ Max Hg_{OUT} = 20-50 µg/m³</td>
<td></td>
<td>• Complicated flowsheet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mercury removed as marketable product</td>
<td>• Chlorine gas handling</td>
</tr>
</tbody>
</table>
Introduction: Minamata Convention on Mercury, Article 8, emissions inventories

Workshop to enhance inventories and strategies under Article 8 of the Minamata Convention in Vietnam, 10 June 2024

Alexander Romanov, UNEP-GEF Chemicals and Waste Unit (alexander.romanov@un.org) on behalf of the Secretariat of the Minamata Convention on Mercury
Mercury around us

Mercury mine in Idrija, Slovenia, 1679, by Johann Weikhard von Valvasor (1641-1693). Wikimedia Commons. Public domain.

Mercury around us

How mercury can enter our environment

- Degasification from atmosphere
- Coal-fired power plant
- Cement plant
- Chlor-alkali plant
- Vinyl chloride monomer plant
- Non-ferrous metal plant
- Artisanal and small-scale gold mining
- Soil contamination
- Landfill
- Leaking into groundwater
- Urban sewage system
- Mercury evaporation, deposition, and suspension
- Contaminated surface water evaporation
- Biomagnification


Produced for the European Commission, DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy
Mercury around us

How mercury can enter our bodies

- Volcanoes and other natural sources
- Coal power plants and industries
- Artisinal and small scale gold mining
- Urban sewage systems
- Soil contamination
- Contaminated food system from deposition to water
- Landfills
Mercury – pollutant of the global concern
GMA 2018 - Update on global Hg pools and cycles
Minamata Convention on Mercury

- **Objective:** to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.

- **Adopted in October 2013, entered into force in August 2017.**

- **Mercury is a chemical of global concern owing to its:**
  - Long-range atmospheric transport,
  - Persistence in the environment once anthropogenically introduced,
  - Ability to bioaccumulate in ecosystems, and
  - Significant negative effects and human health and the environment.

- **Recognizes the lessons of Minamata Disease, in particular the serious health and environmental effects from mercury pollution.**

See [Minamata Convention at a Glance](minamata-convention.org)
Parties to the Minamata Convention

► 148 parties as of May 2024

For most recent list of parties, see UN Treaties Section website
Control measures and support measures

Control Measures

- Reduce the use and presence of mercury in the economy, industry and society
  - Art. 3.5 (a): Stocks
  - Art. 3.5 (b): Excess mercury from decommissioned chlor-alkali facilities
  - Art. 3.6 – 3.10: Trade of mercury
  - Art. 4: Mercury-added Products
  - Art. 5: Manufacturing Processes
  - Art. 7: ASGM
  - Art. 10: Interim Storage
  - Art. 11: Mercury wastes
  - Art. 12: Contaminated sites

Reduce mercury to the environment

- Art. 7: ASGM
- Art. 8: Emissions
- Art. 9: Releases

Enabling / Supportive Context

- Art. 13: Financial Resources and Mechanism
- Art. 14: Capacity-building, technical assistance and technical transfer
- Art. 15: Implementation and Compliance Committee
- Art. 16: Health aspects
- Art. 17: Information Exchange
- Art. 18: Public information, awareness and education
- Art. 19: Research, development and monitoring
- Art. 20: Implementation plans
- Art. 21: Reporting
- Art. 22: Effectiveness evaluation
- Art. 23: Conference of the Parties
- Art. 24: Secretariat
- Arts. 25-35: Various procedural articles
Major obligations of the parties to the Minamata Convention

- Article 3: Not allow new mercury mines and close old ones in 15 years
- Article 3: Only export mercury with written consent of importing countries
- Article 4: Phase out listed mercury-added products by 2020 (2025 for newly-added product categories).
- Article 4: Take measures to phase down dental amalgam
- Article 5: Phase out listed mercury-using processes by 2018 or 2025, and take measures to restrict other listed processes
- Article 7: Develop and implement national action plans on artisanal and small-scale gold mining in 3 years
- Article 8: Take measures on new emission sources in 5 years and existing sources in 10 years. Establish emission inventory in 5 years
- Article 9: Identify relevant sources and take measures. Establish release inventory in 5 years
- Article 10: Take measures on interim storage
- Article 11: Manage mercury waste in an environmentally sound manner
- Article 12: Endeavour to develop strategies
- Article 21: Report on the implementation of the Convention

See Overview of Key Operational Articles
Global Mercury Assessment 2018

• The predominant source sector is artisanal and small-scale gold mining (about 38%).

• It is followed by stationary combustion of coal (about 21%), non-ferrous metal production (about 15%) and cement production (about 11%).
Article 8 of the Minamata Convention

- Controls the emissions of total mercury to air from the following sources listed in Annex D:
  - Coal-fired power plants
  - Coal-fired industrial boilers
  - Smelting and roasting processes used in the production of non-ferrous metals (lead, zinc, copper and industrial gold)
  - Waste incineration facilities
  - Cement clinker production facilities.

- Parties with relevant sources shall take measures to control emissions and may prepare a national plan, which is to be submitted within 4 years after the entry into force if prepared.

- For new sources, each Party shall require the use of BAT/BEP to control and reduce emissions, as soon as practicable but no later than 5 years after the date of entry into force.

- For existing sources, each Party shall include in any national plan, and shall implement, one or more of the following measures, as soon as practicable but no more than 10 years after the date of entry into force:
  - A quantified goal
  - Emission limit values
  - The use of BAT/BEP
  - A multi-pollutant control strategy that would deliver co-benefits
  - Alternative measures to reduce emissions from relevant sources

- Each Party shall establish, as soon as practicable and no later than 5 years after the date of entry into force of the Convention for it, and maintain thereafter, an inventory of emissions from relevant sources.
Guidance under Article 8 of the Minamata Convention

► Decision MC-1/4
- Adopted the guidance on BAT/BEP and on support for parties in implementing the measures
- Recognized that some of the measures described in the guidance may not be available to all parties for technical or economic reasons,
- Requested parties with experience in using such guidance to provide the secretariat with information on that experience, and the secretariat to compile such information and to update the guidance as necessary.

► Decision MC-1/16
- Adopted the guidance on criteria that parties may develop to identify emission sources, and on the methodology for emission inventories.
UNEP’s Toolkit for identification and quantification of mercury releases

► UNEP’s *Toolkit for identification and quantification of mercury releases* –aka UNEP Mercury Toolkit – is intended to assist countries to identify and quantify the sources of mercury emissions and releases, set priorities and reduction targets, enhance international co-operation, knowledge sharing, and enable targeted technical assistance.

► Inventories from countries contribute to the Global Mercury Assessment, the hub of the scientific knowledge of worldwide mercury emissions and releases.

► The Toolkit provides clear guidance on different stages of inventory development: identifying mercury sources, quantifying the consumption and calculating the final emissions and releases.

► The Toolkit includes detailed manual, calculation spreadsheet and a standard template for reporting.

► The Toolkit is one of the methods recommended in guidance from the Minamata Convention on preparing inventories of emissions pursuant to Article 8.
UNEP’s Toolkit for identification and quantification of mercury releases

**Inventory Level 1 (IL1)** – simplified model based on default factors, requires national sectoral activity rate data; useful for first-time inventories, yet less accuracy of emission/release estimates should be expected.

**Inventory Level 2 (IL2)** – detailed mercury inventory tool, all emission/release factors can be adjusted to national/local conditions (default factors are included), requires detailed national sectoral data to fully reflect mercury cycles.

**Inventory Level 3 (IL3)** - integrates all mercury sources into their entire mass flow through and out of society to the environment linking different mercury sources and provides increased accuracy in estimations; most data- and expertise-intensive.

+ Excel calculations sheets for Level 1, Level 2, and Level 3 inventories

Summary of mercury emissions and releases

<table>
<thead>
<tr>
<th>No.</th>
<th>Mercury sources (sectors/fields)</th>
<th>Total emissions kg Hg/year</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Energy consumption</td>
<td>6,541</td>
<td>13.3</td>
</tr>
<tr>
<td>2</td>
<td>Fuel production</td>
<td>1,041</td>
<td>2.1</td>
</tr>
<tr>
<td>3</td>
<td>Crude metal production</td>
<td>4,259</td>
<td>8.7</td>
</tr>
<tr>
<td>4</td>
<td>Production of other crude materials</td>
<td>7,783</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>Producing of containing-mercury products</td>
<td>504</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Use and disposal of products containing mercury</td>
<td>9,606</td>
<td>19.6</td>
</tr>
<tr>
<td>7</td>
<td>Waste incineration</td>
<td>12,383</td>
<td>25.2</td>
</tr>
<tr>
<td>8</td>
<td>Waste burning and wastewater treatment</td>
<td>5,440</td>
<td>11.1</td>
</tr>
<tr>
<td>9</td>
<td>Cremation and burial</td>
<td>1,565</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>49,131</td>
<td>100</td>
</tr>
</tbody>
</table>

List of priority sources identified in the MIA Vietnam report

<table>
<thead>
<tr>
<th>No.</th>
<th>Mercury sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Coal combustion in large power plants</td>
</tr>
<tr>
<td>2.1</td>
<td>Oil refinery: extraction and processing of natural gas</td>
</tr>
<tr>
<td>3.1</td>
<td>Metallurgy (tin, zinc, copper) from refined ore</td>
</tr>
<tr>
<td>3.2</td>
<td>Gold production by method using mercury amalgams</td>
</tr>
<tr>
<td>4.1</td>
<td>Cement production</td>
</tr>
<tr>
<td>5.1</td>
<td>Production of lamps containing mercury (fluorescent lamps, compacts and others)</td>
</tr>
<tr>
<td>6.1</td>
<td>Use and disposal of dental amalgam containing mercury</td>
</tr>
<tr>
<td>6.2</td>
<td>Thermometer</td>
</tr>
<tr>
<td>6.3</td>
<td>Circuit breakers/switches and relays containing mercury</td>
</tr>
<tr>
<td>6.4</td>
<td>Use and disposal of mercury containing lamps</td>
</tr>
<tr>
<td>7.1</td>
<td>Incineration of waste in incineration plants</td>
</tr>
</tbody>
</table>

Mercury releases to air (kg Hg/year)

List of priority sources identified in the MIA Vietnam report

## Minamata Initial Assessment Report for South Africa (2021)

### Mercury Releases to Air (Kg Hg/y)

<table>
<thead>
<tr>
<th>Category</th>
<th>Source category</th>
<th>Calculated Hg Input to Society (Kg/y)</th>
<th>Percentages of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Extraction and use of fuels/energy sources</td>
<td></td>
<td>38080</td>
<td>53.8</td>
</tr>
<tr>
<td>5.2 Primary (virgin) metal production</td>
<td></td>
<td>12894</td>
<td>18.2</td>
</tr>
<tr>
<td>5.3 Production of other minerals and materials with mercury impurities</td>
<td></td>
<td>803</td>
<td>1.1</td>
</tr>
<tr>
<td>5.4 Intentional use of mercury in industrial processes</td>
<td></td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>5.5 Consumer products with intentional use of mercury</td>
<td></td>
<td>11726</td>
<td>16.6</td>
</tr>
<tr>
<td>5.6 Other intentional product/process use</td>
<td></td>
<td>4346</td>
<td>6.1</td>
</tr>
<tr>
<td>5.7 Production of recycled metals (&quot;secondary&quot; metal production)</td>
<td></td>
<td>1594</td>
<td>2.3</td>
</tr>
<tr>
<td>5.8 Waste incineration*3</td>
<td></td>
<td>905</td>
<td>1.3</td>
</tr>
<tr>
<td>5.9 Waste deposition/landfilling and wastewater treatment</td>
<td></td>
<td>408</td>
<td>0.6</td>
</tr>
<tr>
<td>5.10 Crematoria and cemeteries</td>
<td></td>
<td>1250</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*Figure showing the mercury releases to air for different categories.*

UNEPA’s Toolkit for identification and quantification of mercury releases

MercuryLearn Training

- In response to the increasing interest of countries to develop mercury emissions inventories and the subsequent high demand of guidance and training on this topic, UNEP and UNITAR decided to collaborate on developing an online training platform: MercuryLearn. The main component is the UNEP Toolkit for Identification and Quantification of Mercury Releases.
- This initiative has been funded by the European Commission and the government of Switzerland.

► https://mercurylearn.unitar.org/

► Online training modules on the UNEP’s Toolkit for identification and quantification of mercury releases Inventory Level 1 and 2

► Self-paced, available in English and Spanish
Minamata Convention Initial Assessments

Minamata Initial Assessments Mercury Inventories
Summary of results from UNEP’s Toolkit for identification and quantification of mercury releases

Select a region using the regional drop down menu to update the Hg inputs in each figure and statistic.

© 2024 Michael O Donnellmap

Hg Inputs by Category (kg Hg yr⁻¹)

Gold extraction / processing other than amalgamation

Gold (silver) extraction with amalgamation processes

Copper extraction and initial processing

Batteries with mercury

Electricity switches and relays with mercury

Informal waste burning

Cosmetics and related products with mercury

Biocides and pesticides

Inorganic dumping of industrial waste

Waste water

Zinc

https://public.tableau.com/app/profile/mark.burton.bri/viz/MIAMercuryInventoryDashboard/Main_Dashboard?publish=yes
Minamata (training) Tools

Developed with the generous support of the European Union as part of project "Support to the capacity-building and technical assistance programme of the Secretariat of the Minamata Convention on Mercury"
Minamata Convention on Mercury
Learning Path for National Focal Points
Self-paced

https://www.unssc.org/courses/minamata-tools-0
Minamata Online series of virtual webinars on various topics related to the Minamata Convention on mercury since 2020

https://minamataconvention.org/en/meetings/upcoming-list-view?field_event_type_target_id=287
Thank you for your attention

Secretariat of the Minamata Convention on Mercury
United Nations Environment Programme
11-13, Chemin des Anémones - 1219 Châtelaine, Switzerland

WEB: https://minamataconvention.org/
MAIL: MEA-MinamataSecretariat@un.org
TWITTER: @minamataMEA
#MakeMercuryHistory
Using Inventory Data and Planned Policies to Inform Future Emission Scenarios in Vietnam

One-day working event on inventory production and compliance strategies for the Vietnam Coal fleet under the Minamata Convention
10 June 2024
Project Outcomes

Activities

• Review scientific data on mercury emissions from CFPPs

• Evaluate the impact of commitments and targets by UN Conventions on Hg/GHG/POP emissions from the coal sector

• Potential mercury reduction figures & scenarios from CFPPs produced
  ➢ Expand to Coal-Fired Industrial Boilers (CFIB)

OUTCOME 1: Comprehensive coal sectoral analysis
Electricity Generation from Coal – SE Asia

IEA WORLD ENERGY OUTLOOK 2022/23

- Rapid economic growth in SE Asia
  - Increased energy demand

- Continued increase in coal-fired power generation and new projects in SE Asia during a time of increased international pressures to phase-out coal globally.

- Heightened announced pledges in cleaner energy development in SE Asia comparing WEO2021 and WEO2022 report
Vietnam Electricity Generation from Coal

IN CONTEXT WITH OTHER ASEAN COUNTRIES

EMBER Electricity Data Explorer
https://ember-climate.org/data/data-tools/data-explorer/

Global Energy Monitor
Global Coal Plant Tracker database

• Young CFPP fleet in Indonesia, Vietnam, Malaysia, Philippines and Thailand combined
Vietnam Electricity and Primary Energy Mix

Japan Electricity Mix

https://ourworldindata.org/energy/country/vietnam

Share of electricity production by source, Vietnam

Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2023)

Our World in Data

Share of energy consumption by source, Vietnam

Measured as a percentage of primary energy, using the substitution method.

Data source: Energy Institute - Statistical Review of World Energy (2023)

1. Primary energy: Primary energy is the energy available in resources – such as the fuels burnt in power plants – before it has been transformed. This relates to the coal before it has been burned, the uranium, or the barrels of oil. Primary energy includes energy that the end user needs, in the form of electricity, transport and heating, plus inefficiencies and energy that is lost when raw resources are transformed into usable form. You can read more on the different ways of measuring energy in our article.

2. Substitution method: The substitution method is used by researchers to correct primary energy consumption for efficiency losses experienced by fossil fuels. It tries to adjust non-fossil energy sources to the inputs that would be needed if it was generated from fossil fuels. It presumes that wind and solar electricity is as efficient as coal or gas. To do this, energy generation from non-fossil sources are divided by a standard "thermal efficiency factor" – typically around 0.4. Nuclear power is also adjusted despite it also experiencing thermal losses in a power plant. Since it's reported in terms of electricity outputs, we need to do this adjustment to calculate its equivalent input value. You can read more about this adjustment in our article.
Vietnam’s Energy Future
WITH REFERENCE THE PDP-VII

• In December 2022, Vietnam became the third country to agree on a JETP with its International Partners Group (IPG).
  ▪ Initial USD 15.5 billion investment up to the period of 2026 to 2028 towards reaching energy transition targets.
  ▪ Vietnam’s reported annual investment needed - USD 8 to 14 billion per year up to 2030
    o Expansion of the national grid system & develop new power generation infrastructure.

• Eighth Power Development Plan (PDP-VIII) - released in May 2023
  o Total CFPP capacity of 30.1 GW is expected to be reached by 2030
  o Cessation of all CFPPs by 2050 through either retirement and/or repurposing with biomass and ammonia fuel sources.

• The application and feasibility of biomass/ammonia co-firing for Vietnam’s CFPP fleet, along with the development of cost-effective battery storage and transmission improvements for renewable energy sources are thus priority areas to be explored for the country.
Vietnam Coal-Fired Power Plants

LARGE INCREASE SINCE 2015 – EST. 7.6GW (2023)

**CFPP capacity – 2023**
- 27 GW operating
- 7.9 GW under development

**Coal consumption in power plants (MIA 2016):**
- 26.4 million tonnes / year

* Coal type influence mercury removal efficiency as mentioned in Minamata toolkit & POG
VIETNAM IN THE GLOBAL CONTEXT

Stationary Combustion of Coal at Power Plants
292 tons/year

Stationary Combustion of Coal at Industrial Boilers
126 tons/year

China, India & South Africa = 47% - 59% global coverage
Vietnam average emission estimate = 2.65 tonnes per year

China & India = 73% - 83% global coverage
### Table 3-1  Summary of mercury releases

<table>
<thead>
<tr>
<th>Source category</th>
<th>Estimated Hg releases, standard estimates, Kg Hg/y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air</td>
</tr>
<tr>
<td>Energy consumption</td>
<td></td>
</tr>
<tr>
<td>Coal combustion in large power plants</td>
<td>3,484.8</td>
</tr>
<tr>
<td>Other coal uses</td>
<td>1,413.3</td>
</tr>
<tr>
<td>Combustion/use of petroleum coke and heavy oil</td>
<td>-</td>
</tr>
<tr>
<td>Combustion/use of diesel, gasoil, petroleum, kerosene</td>
<td>75.4</td>
</tr>
<tr>
<td>Biomass fired power and heat production</td>
<td>996.9</td>
</tr>
<tr>
<td>Use of gas in pipelines (consumption)</td>
<td>-</td>
</tr>
<tr>
<td>Production of electrical and thermal energy from biomass</td>
<td>90.0</td>
</tr>
<tr>
<td>Charcoal combustion</td>
<td>5.8</td>
</tr>
</tbody>
</table>

### CFPPs:
- **Emission to air:**
  - 3.5 tonnes / year

Mercury release to water at CFPPs through seawater FGD technologies?

### GMA 2018

<table>
<thead>
<tr>
<th></th>
<th>Sum of Emission estimate, kg</th>
<th>Sum of Low range estimate, kg</th>
<th>Sum of High range estimate, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM</td>
<td>5770.9</td>
<td>2038.3</td>
<td>30421.4</td>
</tr>
<tr>
<td>SC-IND-coal</td>
<td>2447.5</td>
<td>1321.6</td>
<td>5833.2</td>
</tr>
<tr>
<td>SC-PP-coal</td>
<td>2651.7</td>
<td>1431.9</td>
<td>10928.6</td>
</tr>
<tr>
<td>Grand Total</td>
<td>10870.1</td>
<td>4791.9</td>
<td>47183.2</td>
</tr>
</tbody>
</table>
Methodology – CFPP emissions

BASELINE DATA FROM THE GLOBAL ENERGY MONITOR


Country- & Unit-level information

• Capacity (MW)
• Start/Planned retirement year
• Combustion technology
• Coal type
• Heat rate (Btu/kWh) - https://www.gem.v
• Capacity factor - Global average from Inte
• Remaining plant lifetime

E.g., Heat Rate
– Vietnam CFPP units

Low – 7,528 Btu / kWh
High – 12,618 Btu / kWh
Methodology – CFPP emissions

BASELINE DATA FROM THE GLOBAL ENERGY MONITOR

Assumptions/uncertainties

• Default 40-year plant life expectancy
• New project start year (where not indicated) – operational by 2030
• Mercury emissions
  o Defined APCD configurations on unit level limited
    o Assumption – **ESP + FGD** for all existing and new builds (construction/pre-construction)
  o Unit-level capacity factors
  o Unit-level GCV (kJ/kg coal) – average levels per coal type based on Annex 28 of the Stockholm Convention Toolkit

<table>
<thead>
<tr>
<th>GCV (kJ/kg coal)</th>
<th>Av</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous</td>
<td>29300</td>
</tr>
<tr>
<td>Subbituminous</td>
<td>14500</td>
</tr>
<tr>
<td>Anthracite</td>
<td>30667</td>
</tr>
<tr>
<td>Lignite</td>
<td>8583</td>
</tr>
<tr>
<td>Unknown</td>
<td>25000</td>
</tr>
<tr>
<td>Waste coal</td>
<td>25000</td>
</tr>
</tbody>
</table>

• Mercury coal input factor – 0.15 mg/kg – Default input factor & also used in Pakistan’s MIA
• Limitations: Additions of mercury-specific controls, Br additions, coal washing, Hg speciation, Cl content, coal blending/co-firing
CFPP capacity outlook - Vietnam

**Business-as-usual (BAU)**

- **2023**: 27.2 GW
- **2030**: 30.6 – 34.6 GW
- **2050**: 29.4 – 33.3 GW

**10-year early retirement (AERS)**
*All subcritical CFPP units*

- **2030**: 30.6 – 34.6 GW
- **2050**: 19.1 – 23.1 GW
Methodology – Mercury Emissions Estimate (UNEP toolkit)

**Mercury emission (kg/year) =** $\text{Coal consumption} \times \text{IF} \times \left(\frac{100 - \text{RF}}{100}\right)$

$\text{HRV} / \text{GCV} \times \text{CAP} \times \text{CF} \times 9.24 \times 10^3$

Vietnam CFPPs (2023) = 54.6 million tonnes / year

### Mercury input factor by country (mg/kg) - USGS default

<table>
<thead>
<tr>
<th>Country</th>
<th>IF</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>0.17</td>
<td>Liu et al., 2019</td>
</tr>
<tr>
<td>India</td>
<td>0.22</td>
<td>India country profile GEF/UNEP</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0.06</td>
<td>BCRC-SEA, 2017</td>
</tr>
<tr>
<td>Vietnam</td>
<td>0.28</td>
<td>UNEP, 2017</td>
</tr>
<tr>
<td>Philippines</td>
<td>0.08</td>
<td>USGS</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.14</td>
<td>USGS</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0.08</td>
<td>USGS</td>
</tr>
<tr>
<td>South Africa</td>
<td>0.21</td>
<td><a href="https://link.springer.com">https://link.springer.com</a></td>
</tr>
<tr>
<td>REMAINING WORLD</td>
<td>0.15</td>
<td>USGS</td>
</tr>
<tr>
<td>Australia</td>
<td>0.08</td>
<td>USGS</td>
</tr>
<tr>
<td>United States</td>
<td>0.13</td>
<td><a href="https://pubs.usgs.gov">https://pubs.usgs.gov</a></td>
</tr>
</tbody>
</table>

---

Table 3-11  Mercury retention rates and application profile developed by UNEP/AMAP (2012).
CFPP Mercury Emissions

2023 estimate – 7.7 tonnes / year

BAU – Business as Usual

AERS – Early Retirement
- All subcritical CFPPs retire 10 years earlier

CFS (Capacity factor scenario)
- 2024 – 0.53 (default global average)
- 2030 – 0.3
- 2050 – 0.2

More alternative energy resources (e.g., RE, nuclear, etc)

RETROFIT scenario

<table>
<thead>
<tr>
<th>RETROFIT scenario criteria</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit remaining lifetime =&gt;</td>
<td>20</td>
</tr>
<tr>
<td>Original APCD configuration</td>
<td>ESP + FGD</td>
</tr>
<tr>
<td>New APCD configuration</td>
<td>ESP + FGD + SCR</td>
</tr>
<tr>
<td>Unit status to retrofit</td>
<td>Operating</td>
</tr>
<tr>
<td>Retrofit by</td>
<td>2030</td>
</tr>
</tbody>
</table>
Project Outcomes

Activities

• Synthesis of results from completed & ongoing CFPP projects

• Selection criteria: Future projects based on highest impact potential
  o Guidance on where to support large scale projects – Training/Capacity-Building

• Assist public and private sectors in their decision-making processes

OUTCOME 2:
STRATEGY FOR THE COAL SECTOR’S EMISSIONS REDUCTION CONTRIBUTION TO STOCKHOLM AND MINAMATA CONVENTIONS
Thank you

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Workshop to enhance inventories and strategies under Article 8 of the Minamata Convention in Vietnam

Hanoi, Vietnam
Hotel du Parc  10th June 2024
Wojciech Jozewicz, PhD
Background

- iPOG is an interactive application for UNEP’s POG
- Developed for UNEP Coal Partnership by Niksa Associates
- Tool to help determine approaches to Hg emission control and rank them for individual coal-fired units
- Tradeoffs were made to only include basic inputs at the expense of quantitative accuracy
- Allows for addition of flue gas cleaning approaches and systems according to BAT/BEP
  - Improved fuel quality and blending
  - PM, SO$_2$, and NO$_X$ control systems for co-benefit
  - Dedicated Hg control technology
- Follows “Decision Tree” logic from the POG
iPOG “Decision Tree” Structure

NO\textsubscript{X} Control

PM Control

SO\textsubscript{2} Control

Hg Control Options
iPOG Calculations Tab - Example

- Final tab to initiate calculations sequence
- In this example: older but well-controlled 500 MW, wall-fired boiler, burning low-S coal, cold-side ESP
- Essentially no Hg removal predicted (<10%)  
- Estimated Hg emissions of 24 g/h or up to about 0.2 ton Hg/year
Data Quality Very Important

• Stakeholders should ensure that any missing data are obtained directly from the plant considered for the project rather than by the proxy calculations
• Unit details: generating capacity, commissioning date, planned retirement
• Unit performance: operational load, utilization, gross efficiency, coal consumption, LOI
• Coal quality: calorific value, ash-S-Hg-Cl content
• Emissions controls: PM, FGD, Hg controls
• Quality data in – Quality results out!
Unit with Wet FGD

- 800 MW unit with ESP and wet FGD
- Only about 17% Hg removal; emissions 98% of Hg0 and 2% of Hg++
- More mercury removal could be accomplished with more efficient Hg0 oxidation
Strategy for Improvement

- Over 65% removal with addition of 250 ppm of Br to coal
- Some other options
  - Activated carbon injection upstream of the ESP
  - SCR- expensive
Another Strategy

- Addition of 0.02 g/m3 of activated carbon upstream of the baghouse increases Hg removal to 72%
Rapid Development

• Projections of 97 million tons of coal used and 48 GW coal power installed by 2025

• Duyen Hai 1 and Vinh Tan 2 plants installed seawater FGD for SO$_2$ and SCR system with ammonia and nitrogen oxides (NOx) emission control

• Environmental impact
Seawater FGD

- Back in 2010, Alstom alone reported more than 90 units corresponding to about 30 GW capacity
- How many today?

From: https://www.alstom.com/

From: ICSC 2023
Seawater FGD vs. WFGD

- SWFGD designed for SO$_2$ control
  - similar capture to that in WFGD
  - about 20-30% lower capex
  - lower opex - no sorbent purchased
  - no land transport of coal
- SWFGD can provide up to ~85% Hg removal
  - similar Hg chemistry to WFGD
  - waste handling different
Seawater FGD – Potential Issues

• Hg re-emission may occur in the scrubber
• Effluent aerated to convert sulfites to sulfates - Hg\(^0\) may be released into the air
• Specialized Hg-focused treatment of “spent” seawater needed to prevent releases into oceans
• Precipitation and separation/capture of Hg
• Sulfurized activated carbon may be used for removing Hg\(^{++}\)

https://www.fossilconsulting.com/
Plant with a Seawater FGD

- About 65% Hg removal measured
- Stack emissions mostly Hg$^0$
- Seawater Hg enhancement

<table>
<thead>
<tr>
<th>Type of sample</th>
<th>Plant 1 (5 cycles)</th>
<th>Plant 2* (5 cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed coal (µg/kg)</td>
<td>59.90±12.10</td>
<td>132.52±8.46</td>
</tr>
<tr>
<td>Sea water-In (µg/L)$^b$</td>
<td>0.004±0.002</td>
<td>114.97±14.28</td>
</tr>
<tr>
<td>Limestone (µg/kg)$^c$</td>
<td></td>
<td>75.19±30.45</td>
</tr>
<tr>
<td>Bottom ash (µg/kg)</td>
<td>1.21±0.50</td>
<td>48.95±8.40</td>
</tr>
<tr>
<td>Fly ash (µg/kg)</td>
<td>47.59±17.22</td>
<td>8.27±11.18</td>
</tr>
<tr>
<td>Sea water-Out (µg/kg)$^b$</td>
<td>0.09±0.02</td>
<td>22.37±3.60</td>
</tr>
<tr>
<td>Gypsum (µg/kg)$^c$</td>
<td></td>
<td>168.92±38.92</td>
</tr>
<tr>
<td>Stack gas (µg/m³)$^-particulate (µg/m³)$</td>
<td>0.69±0.39</td>
<td>7.99±3.94</td>
</tr>
<tr>
<td>Stack gas (µg/m³)$^-oxidized Hg (µg/m³)$</td>
<td>0.07±0.14</td>
<td>0.45±0.30</td>
</tr>
<tr>
<td>Stack gas (µg/m³)$^-Vapor Hg (µg/m³)$</td>
<td>0.61±0.34</td>
<td>7.52±3.88</td>
</tr>
</tbody>
</table>

ATLANTIC ENERGY ASSOCIATES
Summary

• Limited information on FGD or seawater FGD
• Performance strategies available to improve Hg performance
• Limited information available on handling of effluent from SWFGD, fate of mercury

• However,
  • Growth projected for power demand
  • Ambitious renewable energy goals
Thank you!