

## Manufacturing processes in which mercury or mercury compounds are used

Information provided by Argentina, Colombia, EU, Indonesia, Montenegro, Uganda, the USA, and other stakeholders (IPEN)

<p><b>1. Category of manufacturing process in which mercury or mercury compounds are used</b></p>	<p>Chlor-alkali production</p>
<p><b>2. Further description of the process (if any)</b></p>	
<p><b>3. Information on the manufacturing activities using the process (incl. amount of mercury or mercury compounds used, production amount, etc.)</b></p>	<p>The mercury cell process          In Mercury Process, the cell consist of cell box, adjustable anode, decomposer, and mercury circulation pump. The feed brine (NaCl solution) is introduced to the cell box , where mercury is circulated by a special pump, from the decomposer and flows continuously at the bottom of cell box. The applied current is introduced through adjustable anode so then in the cell box, NaCl will be electrolyzed to the Na<sup>+</sup> and Cl<sup>-</sup>. The ion Na<sup>+</sup> will be bonded to mercury (where act as cathode) to form amalgam , Na(Hg)<sub>x</sub> and flows to decomposer. While the Cl<sup>-</sup> will be oxidized at anode to form Cl<sup>2</sup> and leaves from top nozzle of cell box to go to chlorine handling unit.</p> <p>Entering to the decomposer, the amalgam, Na(Hg)<sub>x</sub> will react with de-mineralized water to form NaOH and Hydrogen gas, H<sub>2</sub>. The generated NaOH then submitted to product NaOH handling where it will be cooled and filtered to minimized carry over of mercury in Caustic Soda product.          The produced NaOH by decomposer having around 50 %wt of concentration, so that not necessary to be concentrated further and can be delivered to customers, directly.</p> $\text{NaCl} \xrightarrow{\text{H}_2\text{O} \ \& \ \text{Hg}} \text{Na(Hg)}_x + \frac{1}{2} \text{Cl}_2 \quad (\text{in cell room/ cell box})$ $\text{Na(Hg)}_x + \text{H}_2\text{O} \longrightarrow \text{NaOH} + \text{H}_2 + x\text{Hg} \quad (\text{in decomposer})$ <hr/> $\text{NaCl} + \text{H}_2\text{O} \xrightarrow{\text{H}_2\text{O} \ \& \ \text{Hg}} \text{NaOH} + \frac{1}{2} \text{Cl}_2 + \frac{1}{2} \text{H}_2$ <p>There are several disadvantages in Mercury Process :</p> <ul style="list-style-type: none"> <li>➔ It's easier any generated hydrogen in the cell box, due to dirty, higher concentration amalgam, un-even circulation and distribution mercury. The generated hydrogen will carry over in chlorine gas and in certain level will create an explosion. The generated hydrogen in the cell box also can happen with the presence of heavy metals such as Vanadium (V), molybdenum (Mo), and chromium (Cr), at the 0.01–0.1 ppm level</li> <li>➔ Due to directly contact in generated of the products, the content mercury for each of product is very difficult to be avoided.</li> <li>➔ Another serious case with Mercury process is mercury emission to the environment, where needs hardest effort for protection this.</li> </ul>

	<p><b>Colombia</b> Regarding the industries in Colombia, in 2016, the chlor-alkali industry, a single factory operating in Zipaquirá - Cundinamarca, eliminated the use of mercury in its production process. The use of mercury for processes in Colombia will be prohibited as of July 15, 2023.</p> <p><b>USA</b> Chlor-alkali production (labelled as “Chlorine production”) is the only process in the Minamata listing that was identified as actively practiced in the United States in 2018. There is only one remaining facility using this process in the United States.</p>
<p><b>4. Information on the availability of mercury-free (or less-mercury) alternatives</b></p>	<p>(1) The diaphragm process</p> <p>In the diaphragm cell process, there are two compartments separated by an asbestos fibers where act as the permeable diaphragm. Brine is introduced into the anode compartment and flows into the cathode compartment. The chloride ions are oxidized at the anode to produce chlorine, and at the cathode, water is split into caustic soda and hydrogen. The diaphragm prevents the reaction of the caustic soda with the chlorine. A diluted caustic brine leaves the cell, then has to be concentrated to 50% by weight which consume around three tones of steam per tone of caustic soda.</p> <p>The disadvantage of this process is on usage of asbestos where well known harmful for human body and the environment</p> <p>(2) The cell membrane process</p> <p>In the membrane process, the cell is divided into two compartments, anolyte and catholyte compartment and separated by a thin activated selective membrane, which passes of sodium ion ion (Na<sup>+</sup>) during electrolysis process.</p> <p>The anode is used an expanded metal coated by Titanium and for cathode normally using expanded metal coated by nickel, both coatings give less drop voltage and increase current efficiency.</p> <p>The saturated pure brine solution (NaCl ± 27% wt) is circulated to anolyte compartment and lean caustic soda solution (NaOH ± 28 %wt) is circulated to the catholyte compartment, and the DC-current is introduced to electrolyze electrolyze NaCl to make ion Na<sup>+</sup> and ion Cl<sup>-</sup> in anolyte compartment, and electrolyze water H<sub>2</sub>O into ion H<sup>+</sup> and ion OH<sup>-</sup> in catholyte compartment.</p> <p>The ion sodium (Na<sup>+</sup>) will pass through the membrane and entering to catholyte compartment, meet with hydroxyl ion (OH<sup>-</sup>) become to NaOH (Caustic Soda) and increase the concentration of lean NaOH to 32 – 34 %wt, and also, the ion hydrogen (H<sup>+</sup>) will be reduced at the cathode to H<sub>2</sub> Gas. Then, the caustic soda solution and Hydrogen is separated in the separator for further handling.</p> <p>Leaves the separator, the caustic soda will be collected in the circulation tank, where some amount of it will be send to concentrator to increase the concentration to 50 %wt as the finish product, while the other amount of caustic soda will be re-diluted again by de-mineralized water to be re-circulated to the cell membrane.</p>

	<p>In the anolyte compartment, the ion chloride (Cl<sup>-</sup>) will be oxidized at the anode to chlorine gas, where come out from the cell together with lean brine solution to be separated in the separator., for further treatment.</p> $\begin{array}{l} \text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^- \\ \text{Cl}^- \rightarrow \frac{1}{2} \text{Cl}_2 + \text{e}^- \text{ (at anode)} \end{array} \left. \vphantom{\begin{array}{l} \text{NaCl} \\ \text{Cl}^- \end{array}} \right\} \text{(in anolyte compartment, where Na}^+ \text{ will pass through the membrane to catholyte compartment)}$ $\begin{array}{l} \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^- \\ \text{Na}^+ + \text{OH}^- \rightarrow \text{NaOH} \\ \text{H}^+ + \text{e}^- \rightarrow \frac{1}{2} \text{H}_2 \text{ (at cathode)} \end{array} \left. \vphantom{\begin{array}{l} \text{H}_2\text{O} \\ \text{Na}^+ \\ \text{H}^+ \end{array}} \right\} \text{(in catholyte compartment)}$ <hr/> $\text{NaCl} + \text{H}_2\text{O} \xrightarrow{\text{DC Current}} \text{NaOH} + \frac{1}{2} \text{Cl}_2 + \frac{1}{2} \text{H}_2$ <p>The disadvantage of the membrane process is that the activity of membrane can be contaminated by such metal ion (mainly Ca<sup>2+</sup>, and Mg<sup>2+</sup>), so that requires a super purified brine, but this requirement can be fulfilled easily by using ion – exchange resin.</p> <p><b>Argentina</b>  Argentina has registered an exemption for the phase-out date on Chlor-alkali production, and the expiry date for the exemption is 2030.  INDUPA, a caustic soda producer in Argentina, plans to convert its mercury cell process to ion exchange membrane technology during 2022-2025. The plan would be carried out in three stages, gradually replacing the mercury cell process with membranes.</p>
<p><b>5.(i) Information on the technical feasibility of alternatives</b></p>	<p><b>Indonesia</b>  In 1998, The 2<sup>nd</sup> large of Chlor Alkali Plant in Indonesia has successful in converting previous using Mercury Process into Cell Membranes Process . The plant capacity also increase more than two times (by expansion) to 215,000 DMTPA of Caustic Soda , instead previous capacity at 90,000 DMTPA.  The success story of conversion also followed by continuously optimizations (by re-arrangement cell configurations, converting the conventional finite gap cell into zero gap cell, and some additional cell units), so that in few years, the capacity could be increased to 320,000 DMTPA, mostly with existing plant area and plant’s facilities.  Refer to his experience, seems that the converting Mercury Process to Cell Membrane Process is possible and relatively easy. Also, the optimization project to obtain higher productivity can be done, relatively easy.</p>

<b>5.(ii) Information on the economic feasibility of alternatives</b>	<b>Indonesia</b> The main term of economic consideration in chlor alkali industry is unit consumption of power. Refer to the experience, by operate cell membrane, the unit consumption of power for rectifier is 2.2 – 2.4 MWH/DMT NaOH comparing by cell mercury, the unit consumption power is 2.7 – 2.9 MWH/DMT NaOH, means cell membrane giving less around 0.5 MWH/DMT of NaOH or any reduction for around 17%
<b>6. Information on the environmental and health risks and benefits of alternatives</b>	<b>Indonesia</b> It's already clear that among of proven process in the chlor alkali plant, the cell membrane process will give less impact to the environment, due to using non-hazardous material, comparing to usage mercury (in mercury cell process) and usage asbestos (in diaphragm process). Both Mercury and Asbestos are well known as heavy dangerous to the environment and human being. According safety risk, in the mercury cell, some factors such as un-even of distribution mercury, un-uniform distribution of current, higher concentration amalgam, disturbing mercury pump circulation, un-even bottom of cell box, are the factors that can boost an explosion in the cell box. On other hand, the potential of explosion just will happen if the membrane get big leaking during operation, so that some hydrogen can enter to anolyte compartment and meet with chlorine, to make explosion. For protect this, generally the cell membrane is equipped with interlocking system to stop operated cell whenever any indication big leaking of the membrane. Based on both explanations regarding with environment and safety risk, it's concluded that cell membranes process will be operated safely compared to Mercury cell and Diaphragm cell.
<b>7. Other relevant information pursuant to Decision MC-3/1</b>	<b>EU</b> Under Regulation (EU) 2017/852, the use of mercury as an electrode in chlor-alkali production is prohibited since 11 December 2017.

## 8. References

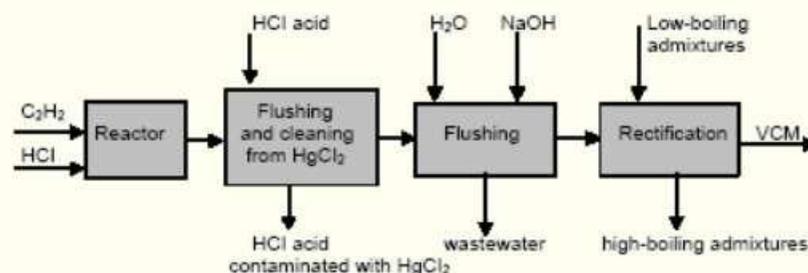
- ❖ EPA. 2020. Inventory of Mercury Supply, Use, and Trade in The United States – 2020 Report.

## Vinyl chloride monomer production

<b>1. Category of manufacturing process in which mercury or mercury compounds are used</b>	Vinyl chloride monomer production
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<p><b>2. Further description of the process</b> (if any)</p>	<p><b>EU</b></p> <p>Vinyl chloride monomer (VCM) is an industrial chemical mainly used in the production of polyvinyl chloride (PVC), an important polymer used (&gt;45 million tonnes/yr globally) as a building material and in household products (IPEN, 2015).</p> <p>Two synthesis routes are used for VCM production in an industrial scale: based on</p> <ol style="list-style-type: none"> <li>1 ethylene (produced from natural gas or crude oil; no mercury used; more prevalent now)</li> <li>2 acetylene (coal and natural gas derived; mercury catalyst is utilized; largely phased-out for economic and environmental reasons)</li> </ol>
<p><b>3. Information on the manufacturing activities using the process</b> (incl. amount of mercury or mercury compounds used, production amount, etc.)</p>	<p><b>EU</b></p> <ul style="list-style-type: none"> <li>• Mercury catalysts (in the acetylene process) are in large-scale commercial use in VCM production primarily in China (DCM Shriram, 2019), but also in India (ICIS, 2005) and Russia (UNEP, 2017).</li> <li>• The acetylene process is used in the EU by Fortischem AS (formerly Novacke Chemicke Zavody AS) in the Slovak Republic, in parallel to the ethylene process. It is used for approximately 25% of the total VCM production at this facility. Approximately 20 t of catalyst containing 10% by weight of mercury chloride (2 t) is consumed annually in this plant. Under Annex III of Regulation (EU) 2017/852 on mercury, this manufacturing process will be phased out by 1 January 2022.</li> <li>• In acetylene process, coal-derived coke is heated with calcium carbonate to produce calcium carbide, which is then hydrolysed to create acetylene. Acetylene is then reacted with hydrogen chloride using mercury (II) chloride (HgCl<sub>2</sub>) as a catalyst to produce vinyl chloride, which is then polymerized to create PVC. The catalyst is used with activated carbon as a support. When the support is installed, it contains between 8-12% mercury (II) chloride. Over time, the catalyst is depleted and once the content in the support drops below 5%, it will be replaced. However, since 2010 China promotes the use of low-mercury catalyst with an initial mercury content of about 4-5% (The GEF, 2018).</li> </ul>

Figure 1 – Production of VCM using a mercury catalyst (Danish EPA, 2005)



- Acetylene process of PVC synthesis was largely phased out in most of the world between 1960 and 2000 due to high energy consumption and waste, however in China this method is still pervasive due to the use of coal as a starting material (IPEN, 2015). China’s VCM mercury consumption is the principal reason for continued mercury production from primary mercury mining in China, since it consumes the majority of China’s mercury supply (The GEF, 2018).
- There were 14 million tonnes of VCM produced via the acetylene process in China in 2014, with a mercury consumption of 1,216 tonnes (UNEP, 2017). The amount of mercury per ton of VCM produced ranges from 97 g Hg/t VCM to 49 g/t as a result of the shift to a lower mercury catalyst (Lin et al., 2016).
- The fate of mercury lost from the catalyst as it depletes is not well understood. The 2017 UNEP report on global supply, trade and demand of mercury reported that 30-50% of mercury remains in the spent catalyst and is mostly recycled while another 30-50% is caught in activated carbon filters that are also recycled. 4-6% of mercury ends up in waste products, meaning that there is approximately 30% of mercury that is lost in the process with unknown destination (UNEP, 2017). Catalyst recycling may result in significant mercury emissions due to “lack of effective mercury management and properly guided mercury recovery practices”.<sup>1</sup>
- Global mercury consumption for VCM production was 1210-1240 tonnes in 2015 (UNEP, 2017). China accounted for 1217 tonnes of mercury consumption in this sector in 2014.<sup>2</sup> For calendar years 2017-2018, China reports mercury use in the range of 700-820 tonnes at 69 facilities.<sup>3</sup> 520 tonnes of

<sup>1</sup> [https://open.unido.org/api/documents/5974278/download/UNIDO%20GEF%206%20China%20VCM\\_CEO%20Endorsement%20%206921%20app.pdf](https://open.unido.org/api/documents/5974278/download/UNIDO%20GEF%206%20China%20VCM_CEO%20Endorsement%20%206921%20app.pdf), p. 53

<sup>2</sup> [https://open.unido.org/api/documents/5974278/download/UNIDO%20GEF%206%20China%20VCM\\_CEO%20Endorsement%20%206921%20app.pdf](https://open.unido.org/api/documents/5974278/download/UNIDO%20GEF%206%20China%20VCM_CEO%20Endorsement%20%206921%20app.pdf), p. 38

<sup>3</sup> [http://www.mercuryconvention.org/Portals/11/documents/Notifications/China\\_Article5\\_5c.pdf](http://www.mercuryconvention.org/Portals/11/documents/Notifications/China_Article5_5c.pdf)

	<p>mercury were retrieved from recycling VCM catalysts in China in 2014 and estimates have been as high as 650 tonnes for 2015 figures (UNEP, 2017). The 2018 Global Mercury Assessment reported for the first time an estimate of emissions to air from VCM production at 58 tonnes in 2015 (UNEP, 2018).</p> <p><b>Uganda and the United States/ Information from experts</b></p> <ul style="list-style-type: none"> <li>• There is no vinyl chloride monomer production using mercury as a catalyst in Uganda and in the United States.</li> </ul> <p><b>NRDC</b></p> <p>In China, notwithstanding the prohibition in the Convention against the construction of new mercury-using factories, the PVC sector is still growing, presumably through facility expansion. About 80% of China’s PVC production is by the calcium carbide (mercury catalyst) process, and 20% is by the ethylene (non-mercury) process.</p> <p>Uzbekistan's largest PVC production project, undertaken as part of the "one belt and one road" initiative, was officially completed in the industrial city of Navoi, central Uzbekistan on December 28, 2019, according to People's Daily and Xinhua news agency<sup>1</sup>. Cohesion (Beijing) Technology Co., Ltd. provided technical support for environmental protection of the project in Uzbekistan”<sup>2</sup> and refers to the use of mercury on its website.</p>
<p><b>4. Information on the availability of mercury-free (or less-mercury) alternatives</b></p>	<p><b>EU</b></p> <p><u>Main alternatives:</u> <i>Use of ethylene instead of acetylene; use alternatives to PVC.</i></p> <p>The production of VCM in most countries does not involve mercury catalysts as using ethylene as the hydrocarbon feedstock in VCM production is preferred to using acetylene. Ethylene is produced from petroleum or natural gas, while acetylene is produced mainly from coal (it can also be produced from natural gas), which is the primary reason for its continued usage in China, which has large coal reserves but must rely on imported petroleum which is subject to price fluctuations. Additionally, PVC plants are often located far from the sea and so use of local coal has been preferred to transporting ethylene long distances by land.</p> <p>Comments from experts</p> <ul style="list-style-type: none"> <li>• There is no easy conversion from an acetylene-based process to an ethylene-based process; virtually all legacy equipment from the acetylene process would have to be abandoned if a conversion was contemplated.</li> </ul>
<p><b>5.(i) Information on the technical feasibility of alternatives</b></p>	<p><b>EU</b></p>

	<ul style="list-style-type: none"> <li>• As previously mentioned, it is possible to produce VCM from ethylene, rather than acetylene, using petroleum and gas as a feedstock. In China due to an abundance of coal resources and a lack of natural gas, it is likely that usage of acetylene will continue, especially in inland regions far from seaports.</li> <li>• There is ongoing research into production of VCM using acetylene using alternative catalysts, most notably gold catalysts, which have been demonstrated to have comparable catalytic efficiency to commercial mercury catalysts (Chai et al., 2019). Other alternative catalysts include nitrogen-doped activated carbon, copper and ruthenium (Shen et al., 2018) (Li et al., 2018).</li> </ul>
<b>5.(ii) Information on the economic feasibility of alternatives</b>	<b>EU</b> <ul style="list-style-type: none"> <li>• Most VCM production around the world uses ethylene as a feedstock derived from natural gas which does not make use of a mercury catalyst. This process is less energy-intensive than the mercury catalyst using acetylene process. According to an industry expert, there are economic costs related to the transportation and storage of ethylene as it is a liquid. There are also differences in investment costs of technical process equipment, with costs being higher for ethylene.</li> <li>• Usage of mercury-free alternative catalysts, most notably gold catalysts, in the acetylene process are potentially limited by economic performance. However, (1) very low gold levels are needed as gold has a much higher activity than mercury, (2) gold catalysts have been proven to have a much longer life-time than mercury catalyst, (3) significantly less catalyst is needed due to a much lower catalyst density and (4) gold can be recovered very efficiently from spent catalyst so it can be used again to manufacture fresh catalyst. Hence it is estimated that the overall life cycle cost of gold catalyst will be in the same order as that of mercury catalyst even before including the cost of additional mercury containment measures to protect workers and the environment that may need to be implemented as long as the use and recycling of mercury catalyst continues, see for example (Johnston, P. et al , Davies C. J et al), The GEF-funded project, noted below, will be examining the economic feasibility of mercury-free catalysts.</li> </ul>
<b>6. Information on the environmental and health risks and benefits of alternatives</b>	NA
<b>7. Other relevant information pursuant to Decision MC-3/1</b>	<ul style="list-style-type: none"> <li>• Mercury use in the production of VCM is prohibited in the EU from the 1 January 2022 according to Regulation (EU) 2017/852 on Mercury (Article 7(1) and Annex III (Part I)).</li> </ul>

	<ul style="list-style-type: none"> <li>• There is a five-year Global Environment Facility (GEF) funded project underway with funding of over USD 16 million for the reduction and minimization of mercury in PVC production in China. This project is scheduled to be completed in 2022, and includes an expert panel established to review the mercury-free VCM production technologies, and at least two mercury-free VCM production technologies evaluated</li> <li>• In Japan, the Regulation on the use of mercury or mercury compounds in products and manufacturing processes prohibits the use of mercury in VCM production (Ministry of the Environment Japan, No date).</li> </ul>
<b>8. References</b>	<ul style="list-style-type: none"> <li>❖ Chai et al. (2019). Aul as a cheap, nontoxic, and efficient alter nate to commercial mercury catalyst for production of vinyl chloride monomer. Retrieved from <a href="https://www.science-direct.com/science/article/pii/S0926860X1830574X">https://www.science-direct.com/science/article/pii/S0926860X1830574X</a></li> <li>❖ Danish EPA. (2005). Assessment of Mercury Releases from the Russian Federation - Intentional use of Mercury. Retrieved from <a href="https://www2.mst.dk/udgiv/publications/2005/87-7614-539-5/html/kap03_eng.htm">https://www2.mst.dk/udgiv/publications/2005/87-7614-539-5/html/kap03_eng.htm</a></li> <li>❖ DCM Shriram. (2019). Calcium Carbide. Retrieved from <a href="https://www.dcmshriram.com/calciumcarbide">https://www.dcmshriram.com/calciumcarbide</a></li> <li>❖ ICIS. (2005). India's DSCL expands Kota calcium carbide capacity 79%. Retrieved from <a href="https://www.icis.com/explore/resources/news/2005/07/25/2003669/india-s-dscl-expands-kota-calciumcarbide-capacity-79-">https://www.icis.com/explore/resources/news/2005/07/25/2003669/india-s-dscl-expands-kota-calciumcarbide-capacity-79-</a></li> <li>❖ IPEN. (2015). China chemical safety case study: Qihua PVC plant in Qiqihar, Heilongjiang Province. Retrieved from <a href="https://ipen.org/sites/default/files/documents/Case%20Study%20Report%20Qihua%202015r.pdf">https://ipen.org/sites/default/files/documents/Case%20Study%20Report%20Qihua%202015r.pdf</a></li> <li>❖ Li et al. (2018). Synthesis of Vinyl Chloride Monomer over Carbon-Supported Tris- (Triphenylphosphine) Ruthenium Dichloride Catalysts. Retrieved from <a href="https://www.mdpi.com/2073-4344/8/7/276/pdf">https://www.mdpi.com/2073-4344/8/7/276/pdf</a></li> <li>❖ Lin et al. (2016). Material flow for the intentional use of mercury in China. Retrieved from <a href="https://pubs.acs.org/doi/suppl/10.1021/acs.est.5b04998/suppl_file/es5b04998_si_001.pdf">https://pubs.acs.org/doi/suppl/10.1021/acs.est.5b04998/suppl_file/es5b04998_si_001.pdf</a></li> <li>❖ Ministry of the Environment Japan. (No date). Major points of measures to implement the Minamata Convention in Japan. Retrieved from <a href="https://www.env.go.jp/en/chemi/mercury/mcm/kokunaitaisaku.html">https://www.env.go.jp/en/chemi/mercury/mcm/kokunaitaisaku.html</a></li> <li>❖ Shen et al. (2018). Mercury-free nitrogen-doped activated carbon catalyst: an efficient catalyst for the catalytic coupling reaction of acetylene and ethylene dichloride to synthesize the vinyl chloride monomer. Retrieved from <a href="https://pubs.rsc.org/en/content/articlelanding/2018/re/c7re00201g#!divAbstract">https://pubs.rsc.org/en/content/articlelanding/2018/re/c7re00201g#!divAbstract</a></li> <li>❖ The GEF. (2018). Demonstration of Mercury Reduction and Minimization in the Production of Vinyl Chloride Monomer in China. Retrieved from <a href="https://www.thegef.org/project/demonstration-mercury-reduction-and-minimization-production-vinyl-chloride-monomer-china">https://www.thegef.org/project/demonstration-mercury-reduction-and-minimization-production-vinyl-chloride-monomer-china</a></li> <li>❖ UNEP. (2017). Global mercury supply, trade and demand. Retrieved from <a href="https://wedocs.unep.org/bitstream/handle/20.500.11822/21725/global_mercury.pdf?sequence=1&amp;isAllowed=y">https://wedocs.unep.org/bitstream/handle/20.500.11822/21725/global_mercury.pdf?sequence=1&amp;isAllowed=y</a></li> <li>❖ UNEP. (2018). Global Mercury Assessment 2018. Retrieved from <a href="https://wedocs.unep.org/bitstream/handle/20.500.11822/27579/GMA2018.pdf?sequence=1&amp;isAllowed=y">https://wedocs.unep.org/bitstream/handle/20.500.11822/27579/GMA2018.pdf?sequence=1&amp;isAllowed=y</a></li> </ul>

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### Manufacturing processes using mercury as electrodes

<b>1. Category of manufacturing process in which mercury or mercury compounds are used</b>	Manufacturing processes using mercury as electrodes, including sodium or potassium methyrate or ethylate production
<b>2. Further description of the process (if any)</b>	
<b>3. Information on the manufacturing activities using the process (incl. amount of mercury or mercury compounds used, production amount, etc.)</b>	<p>EU</p> <p>Apart from chlor-alkali and alcoholates production, mercury electrodes are found to be used in the production of sodium dithionite and production of alkali metals.</p> <p>Sodium dithionite is a reducing agent, which is primarily used in vat dyeing and bleaching (Chavan, 2011). It is primarily supplied as a dry powder and is known to be effective for stripping colour and removal of multiple types of dyes.</p> <p>Alkali metals are a group of six reactive metals (lithium, sodium potassium, rubidium, caesium and francium). Due to their reactive nature, alkali metals tend to be found combined with other elements. Due to the distinct nature of these metals, their uses vary greatly, including the manufacture of fertilizers, construction of lightweight batteries and the reduction of organic compounds.</p>
<b>4. Information on the availability of mercury-free (or less-mercury) alternatives</b>	<p>EU</p> <p>Suitable non-mercury alternatives are available for both sodium dithionite and alkali metal production processes, such as the zinc dust process for the production of sodium dithionite and the electrolysis of liquid sodium chloride.</p>

<b>5.(i) Information on the technical feasibility of alternatives</b>	<p>EU</p> <ul style="list-style-type: none"> <li>• In 2006, the mercury amalgam process accounted for only 15% of the global production capacity of sodium dithionite. The sodium borohydride process, zinc dust process and sodium formate process accounted for 10%, 35% and 40% respectively (OECD SIDS, 2006). Therefore, the mercury-free alternatives are already commercially available, and the zinc dust and sodium formate processes comprise the greatest capacity to produce sodium dithionite.</li> <li>• In addition, Hagemann &amp; Bischofer (2013) state that alongside the market share for the mercury cell process being relatively small, there are no specific product qualities which are associated with the mercury cell process that alternative processes cannot produce.</li> </ul>
<b>5.(ii) Information on the economic feasibility of alternatives</b>	<p>EU</p> <ul style="list-style-type: none"> <li>• As mercury now comprises one of the least used catalysts for the production of sodium dithionite, this suggests that the alternative methods of production are economically feasible.</li> <li>• Production of sodium metal using the amalgam process consumes approximately 40% less energy than the Downs process (Verband Der Chemischen Industrie e.V., 2005). However, about 99% of sodium metal is produced applying the Downs process and is accepted by the market.</li> </ul>
<b>6. Information on the environmental and health risks and benefits of alternatives</b>	<p>EU</p> <ul style="list-style-type: none"> <li>• The health effects associated with the alternative processes used to manufacture sodium dithionite are not well documented (PubChem, 2019).</li> </ul>
<b>7. Other relevant information pursuant to Decision MC-3/1</b>	<ul style="list-style-type: none"> <li>• In Montenegro, the Law on Industrial Emissions ("OG of MNE", No. 17/19) prohibits the use of mercury and mercury compounds and mixtures of mercury in plants, i.e., appropriate production processes. Exceptionally, the use of mercury and mercury compounds and mixtures of mercury in production processes is allowed in the production of sodium, or potassium methylates and ethylates. Furthermore, the Rulebook on the conditions of use and release of mercury and mercury compounds ("OG of MNE", No. 068/19) prescribes the conditions of use and release of mercury, mercury compounds and mixtures of mercury in the production processes of sodium or potassium methylates and ethylates.</li> <li>• Under Regulation (EU) 2017/852, the use of mercury as an electrode in manufacturing processes is prohibited from January 2022.</li> </ul>

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### Production of polyurethane

<b>1. Category of manufacturing process in which mercury or mercury compounds are used</b>	Production of polyurethane using mercury containing catalysts
<b>2. Further description of the process</b> (if any)	
<b>3. Information on the manufacturing activities using the process</b> (incl. amount of mercury or mercury compounds used, production amount, etc.)	<ul style="list-style-type: none"> <li>• Polyurethane is a polymer comprised of a series of organic units, which are linked by urethane (ChemEurope, 2019).</li> <li>• Polyurethane is available in a number of forms and densities, and is used in bedding, thermal insulation and in floorings (ibid). However, the primary use of mercury catalysts is in the production of polyurethane coatings, adhesives, sealants, and elastomers (referred to as CASE applications).</li> <li>• According to a major catalyst supplier, elastomers comprise approximately 90% of the mercury catalyst market (Norwegian Climate and Policy Agency, 2010).</li> <li>• In the formation of polyurethane, mercury catalysts are used in the reaction between a polyol and an isocyanate component. During the reaction, mercury catalysts enable a long induction period, followed by a rapid reaction for curing the product. The catalyst tends to be present in the polyol component. The mercury catalyst is integrated into the polymer and remains present in the final polyurethane product (Norwegian Climate and Policy Agency, 2010).</li> <li>• Organic mercury compounds provide the desired characteristics of catalysts for the majority of polyurethane applications. Mercury catalysts offer an initial induction period (pot life) where the reaction between polyurethane and the catalyst is slow or does not occur. This enables sufficient time for the</li> </ul>

mixture to be cast, following the addition of the catalyst. This provides the manufacturer with greater oversight of the polyurethane application (ibid).

- Secondly, mercury catalysts engender a rapid reaction following the initial induction period, which enables the product to reach its final form and adopt the desired properties in relation to shape, density and malleability. In addition to allowing the product to take on its desired characteristics, the rapid reaction enables the production process to occur in a timely manner (COWI, 2008).
- The mercury catalyst is typically added to the polyurethane systems at concentration levels of 0.2 % – 1 %. However, this depends on the specifications of the end product and the other components present (Norwegian Climate and Policy Agency, 2010).
- Uses include the manufacturing of doming prints (or domed/ doming labels/stickers). They are produced by special (desktop) devices that add a liquid polyurethane on top of a printed label. The mixture is left standing to cure for a period of time and solidifies into a flexible and transparent thick resin / coating. Mercury containing catalysts were and possibly are often used to facilitate the polymerization process, leading to mercury emissions at the (indoor) place of the doming machine (ST Media Group International 2004). Following the EU ban on mercury use in PU production, many companies now offer mercury-free doming liquids that can be used with existing equipment (e.g. Stuart-Turner 2017ab).
- In Uganda, at disposal phase, production of polyurethane using mercury containing catalysts contributes to 282.34 hg/kg/Yr (NEMA, 2018).

#### **USA**

Rubberized polyurethane flooring that was installed in schools, hospitals, retirement homes, community centers, and other public spaces beginning in the 1960s and continuing into the 1990s was a historical use in the United States. A number of studies have been conducted over the years that indicate these floors, which often contain mercury in the finished product as a result of its use as a catalyst in the manufacturing process, can emit mercury vapors over the course of their lifetime, as well as when the flooring material is removed. The finished flooring typically contains 0.1 percent to 0.2 percent of mercury, usually phenyl mercuric acetate (PMA). This flooring material was previously manufactured in the United States and other countries; however, U.S industry has indicated that no one has manufactured or offered this type of flooring for sale for many, many years, thus rendering it a legacy product. In addition, neither the 2017 Initial Mercury Inventory nor the 2020 Mercury Inventory Report indicates any production or use of polyurethane using mercury containing catalysts in the United States.

#### **Information from experts**

	<p><i>Mercury-catalyzed polyurethane elastomers consist basically of cast PU elastomers and PU elastomer coatings. Like any catalyst used in PU elastomer systems, the mercury catalyst is incorporated into the polymer structure and remains in the final product. Over time – and accelerated by exposure to harsh environments, UV, abrasion, etc. – the polymer structure breaks down and mercury is released. (COWI, 2008, 115)</i></p>
<p><b>4. Information on the availability of mercury-free (or less-mercury) alternatives</b></p>	<p><u>Main alternatives:</u> <i>bismuth and zinc carboxylates, tertiary amines, organotin compounds</i></p> <ul style="list-style-type: none"> <li>• According to the European trade association for producers of diisocyanates and polyols (ISOPA) and the European Aliphatic Isocyanates Producers Association (ALIPA), using the polyurethane systems currently in place with a non-mercury catalyst does not enable the same level of performance as using these systems with mercury catalysts. Therefore, designing alternative polyurethane systems, which use alternative polyol or isocyanate components, with a non-mercury catalyst is preferable (ISOPA, 2009).</li> <li>• There is also the potential for the development of systems based on other polymers to replace mercury polyurethane systems. However, due to the wide range of applications required, finding suitable polymers is expected to be a complex task (Norwegian Climate and Policy Agency, 2010).</li> <li>• In contrast, non-mercury catalysts are available for the majority of applications and are used as catalysts in over 95% of polyurethane elastomer applications (ChemEurope, 2019). Several nonmercury catalysts with distinct properties have been developed for polyurethane elastomers, as a ‘one-size-fits-all’ approach is not applicable in the case of replacing mercury catalysts for multiple applications (Norwegian Climate and Policy Agency, 2010).</li> <li>• Bismuth and zinc carboxylates have been used as alternatives to mercury catalysts since the 1980s. Bismuth and zirconium systems are also available on the market as mercury catalyst alternatives. In addition, tertiary amines and organotin compounds have also been used as substitutes to mercury catalysts in a range of applications (ibid).</li> </ul> <p><b>Information from experts</b>  <i>Perfectly viable substitutes to mercury catalysts are already in use for over 95% of PU elastomer systems and have been in use for many years. Tin and amine catalysts are alternatives to Hg catalysts for some PU elastomer applications, titanium and zirconium compounds have been introduced for others, while bismuth, zinc, platinum, palladium, hafnium, etc., compounds are marketed for still others. (COWI, 2008, 117)</i></p>
<p><b>5.(i) Information on the technical feasibility of alternatives</b></p>	<ul style="list-style-type: none"> <li>• Bismuth and zinc carboxylates have been adopted for many decades, and are designed to replace the use of mercury, lead and tin catalysts. These catalysts have displayed commercial success, despite their shortcomings relative to mercury (ChemEurope, 2019). For example, bismuth compounds require manufacturers to make adjustments to account for the differing reactivity of bismuth relative to mercury.</li> </ul>

	<p>In addition, bismuth compounds result in greater viscosity relative to mercury, as the reaction occurs. This produces polymers with different consistencies, relative to the polymers which a mercury catalyst produces. However, the use of a bismuth neodecanoate and zinc neodecanoate mixture enables users to adjust the concentration of the two metals, and hence adjust the behaviour of the gel (Norwegian Climate and Policy Agency, 2010).</p> <ul style="list-style-type: none"> <li>• Bismuth and zirconium systems are also used as mercury catalysts for the production of polyurethane elastomers. However, their sensitivity to moisture renders it difficult for these systems to act as catalysts in the presence of water.</li> <li>• Organotin compounds are not considered direct replacements for mercury catalysts, although they have been used to replace mercury in some applications. For example, organotin compounds are used in polyurethane systems to produce foams, coatings, adhesive and elastomers. However, these compounds cannot replace the use of mercury in all applications (ibid).</li> <li>• Tertiary amines have also been used as catalysts, producing a long pot life, followed by rapid reaction rate, two characteristics necessary for a suitable alternative to mercury catalysts. These can be used in adhesive, sealant and elastomer applications. However, the water content of polyurethane systems needs to be controlled, to ensure that foaming issues do not occur (ibid).</li> <li>• The aforementioned catalysts are all currently available on the market.</li> </ul> <p><b>Information from experts</b>  <i>Known mercury-free catalysts could be used for nearly all elastomer applications, but some reduction in the key performance characteristics of activity, selectivity, catalyst lifetime, etc., may have to be accommodated until the best system is identified for a given application. (COWI, 2008, 117)</i></p>
<p><b>5.(ii) Information on the economic feasibility of alternatives</b></p>	<ul style="list-style-type: none"> <li>• The cost of mercury-free catalysts is expected to be comparable with the cost of mercury catalysts. The cost of mercury catalysts has increased, and therefore, the price of alternatives is not expected to be a barrier (COWI, 2008). Broader research and development is expected to engender higher costs, as sourcing substitutes for a relatively simple polyurethane system is expected to require two months of research from one researcher (equivalent to €10,000 - €15,000). However, it is not expected that additional machinery costs will be incurred, as the same machinery can be used for both mercury and non-mercury systems (Norwegian Climate and Policy Agency, 2010).</li> <li>• Only non-mercury alternatives are used for manufacturing of polyurethane in the EU.</li> </ul> <p><b>Information from experts</b></p>

	<p><i>The cost of most mercury-free catalysts is quite competitive with the typical mercury catalyst cost, and even more so if one takes account of waste disposal costs, environmental and other customer concerns. (COWI, 2008, 117)</i></p>
<p><b>6. Information on the environmental and health risks and benefits of alternatives</b></p>	<ul style="list-style-type: none"> <li>• All of the mercury catalyst used in polyurethane production remains in the product. This represents 0.2 to 1% of the polyurethane in products and several hundred tonnes of mercury catalyst globally. In most cases, polyurethane waste is subject to unspecific waste disposal and therefore represents significant risks of emissions and releases to the environment.</li> <li>• There are in some cases health concerns associated with non-mercury alternatives. For example, zinc neodecanoate is reported to cause potential irritation to skin and eyes. In addition, there are some adverse effects associated with ingestion of zinc and bismuth. However, bismuth and zirconium are not considered to be skin irritants (ibid).</li> <li>• One of the primary environmental concerns associated with the use of mercury in polyurethane elastomers is the contamination of municipal waste streams and waste incinerators. This contamination is likely to contribute towards atmospheric mercury releases (COWI, 2008), as well as being toxic to aquatic organisms (Norwegian Climate and Policy Agency, 2010). In contrast, mercury-free alternatives have minimal impact on the toxicity of aquatic organisms.</li> <li>• In relation to both health and environmental impacts, mercury-free alternatives have minimal impact relative to mercury.</li> </ul>
<p><b>7. Other relevant information pursuant to Decision MC-3/1</b></p>	<ul style="list-style-type: none"> <li>• <b>USA:</b> Rubberized polyurethane flooring that was installed in schools, hospitals, retirement homes, community centers, and other public spaces beginning in the 1960s and continuing into the 1990s was a historical use in the United States. A number of studies have been conducted over the years that indicate these floors, which often contain mercury in the finished product as a result of its use as a catalyst in the manufacturing process, can emit mercury vapors over the course of their lifetime, as well as when the flooring material is removed. The finished flooring typically contains 0.1 percent to 0.2 percent of mercury, usually phenyl mercuric acetate (PMA). This flooring material was previously manufactured in the United States and other countries; however, U.S industry has indicated that no one has manufactured or offered this type of flooring for sale for many, many years, thus rendering it a legacy product. In addition, neither the 2017 Initial Mercury Inventory nor the 2020 Mercury Inventory Report indicates any production or use of polyurethane using mercury containing catalysts in the United States.</li> <li>• In the EU, Regulation (EC) No 2017/852 prohibits manufacturing processes in which mercury or mercury compounds are used as a catalyst from 1 January 2018.</li> <li>• Before Regulation (EC) No 2017/852 came into effect, national legislation in Norway exceeded EU-level restriction, prohibiting the production, use and sale of mercury compounds, which include polyurethane elastomers using mercury (COWI, 2008).</li> </ul>

	<ul style="list-style-type: none"> <li>In 2017, Japan implemented the Mercury Pollution Prevention Act, which adopts measures in line with the Minamata Convention, as well as additional stricter measures. In the National Implementation plan, Japan states that ‘no manufacturing process using mercury catalysts has been found in the polyurethane production processes’ (Mercury Convention, 2017, p. 16).</li> </ul> <p><b>ZMWG</b></p> <p>In Serbia, the national legislation on Chemicals prescribes bans and restrictions of use, placing on the market and production of Mercury and Mercury compounds. The law established the legal basis for adoption of the Rulebook on Bans and Restrictions of Production that introduces annex XVII of EU REACH Regulation and stipulates that five phenylmercury compounds are known to be used especially as catalysts in polyurethane systems shall not be produced, placed on the market or used as substances or in mixtures after 10 October 2017 if the concentration of mercury in the mixtures is equal to or greater than 0.01% by weight (Mihajlov et al., 2018).</p>
<p><b>8. References</b></p>	<ul style="list-style-type: none"> <li>❖ ChemEurope, 2019. Polyurethane. Available at: <a href="https://www.chemeuropa.com/en/encyclopedia/Polyurethane.html">https://www.chemeuropa.com/en/encyclopedia/Polyurethane.html</a></li> <li>❖ COWI, 2008. Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society. [Online] Available at: <a href="http://ec.europa.eu/environment/chemicals/mercury/pdf/EU_Mercury_Study2008.pdf">http://ec.europa.eu/environment/chemicals/mercury/pdf/EU_Mercury_Study2008.pdf</a></li> <li>❖ ISOPA, 2009. Personal communication with Wolfram Frank, ISOPA Secretary General/ALIPA Sector Manager. European Aliphatic Isocyanates Producers Association (ALIPA) and the European trade association for producers of diisocyanates and polyols (ISOPA).</li> <li>❖ Mercury Convention, 2017. National Implementation Plan for Preventing Environmental Pollution of Mercury and Mercury Compounds. Available at: <a href="http://www.mercuryconvention.org/Portals/11/documents/NIP/Japan_NIP_EN.pdf">http://www.mercuryconvention.org/Portals/11/documents/NIP/Japan_NIP_EN.pdf</a></li> <li>❖ Minister of Justice, 2019. Products Containing Mercury Regulation. Available at: <a href="https://lawslois.justice.gc.ca/PDF/SOR-2014-254.pdf">https://lawslois.justice.gc.ca/PDF/SOR-2014-254.pdf</a></li> <li>❖ Norwegian Climate and Policy Agency, 2010. Annex XV Restriction Report: Proposal for a Restriction. Available at: <a href="https://echa.europa.eu/documents/10162/13641/annex_xv_restriction_report_phenylmercury_compounds_en.pdf">https://echa.europa.eu/documents/10162/13641/annex_xv_restriction_report_phenylmercury_compounds_en.pdf</a></li> <li>❖ ST Media Group International (2004) Raising Product Appeal Through Doming. <a href="https://www.screenweb.com/content/raising-product-appeal-through-doming">https://www.screenweb.com/content/raising-product-appeal-through-doming</a></li> <li>❖ Stuart-Turner (2017a) Royal Adhesives shows mercury-free doming system at Fespa. <a href="https://www.printweek.com/product-news/article/royal-adhesives-shows-mercury-free-doming-system-at-fespa">https://www.printweek.com/product-news/article/royal-adhesives-shows-mercury-free-doming-system-at-fespa</a></li> <li>❖ Stuart-Turner (2017b) Kimjaya shows mercury-free doming resins at Fespa. <a href="https://www.printweek.com/product-news/article/kimjaya-shows-mercury-free-doming-resins-at-fespa">https://www.printweek.com/product-news/article/kimjaya-shows-mercury-free-doming-resins-at-fespa</a></li> <li>❖ US EPA, 2015. Petition to promulgate reporting rules for mercury manufacturing, processing, and importation under Section 8(a) of the Toxic Substances Control Act. Available at: <a href="https://www.epa.gov/sites/production/files/2015-09/documents/2015-06-24-tsca_hg_reporting_petition-final_0.pdf">https://www.epa.gov/sites/production/files/2015-09/documents/2015-06-24-tsca_hg_reporting_petition-final_0.pdf</a></li> </ul>

	<ul style="list-style-type: none"> <li>❖ World Bank, 2019. Capacity Strengthening for Implementation of Minamata Convention on Mercury Project. Available at: <a href="http://projects.worldbank.org/P151281?lang=en">http://projects.worldbank.org/P151281?lang=en</a></li> <li>❖ NEMA. (2018). National Minamata Initial Assessment (MIA) Report. Available at <a href="http://www.mercuryconvention.org/Portals/11/documents/MIAs/Uganda-MIA-2018.pdf">http://www.mercuryconvention.org/Portals/11/documents/MIAs/Uganda-MIA-2018.pdf</a></li> <li>❖ Mihajlov et al. 2018. Mercury Initial Assessment for the Republic of Serbia. Available at <a href="https://www.researchgate.net/publication/330514455_Mercury_initial_assessment_for_the_Republic_of_Serbia">https://www.researchgate.net/publication/330514455_Mercury_initial_assessment_for_the_Republic_of_Serbia</a></li> </ul>
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<b>1. Category of manufacturing process in which mercury or mercury compounds are used</b>	Other processes using mercury containing catalysts
<b>2. Further description of the process</b> (if any)	EU Apart from VCM and polyurethane production, mercury catalysts may also be used to promote a large range of polymer reactions in production processes (COWI, 2008), for example, in producing 1- aminoanthraquinone and anthraquinone derivatives, vinyl acetate and keto acids.
<b>3. Information on the manufacturing activities using the process</b> (incl. amount of mercury or mercury compounds used, production amount, etc.)	EU Vinyl acetate monomer is an important material used in the production of polymers, and is used in plastics, paints, varnishes, and glues (Kumar, et al., 2006). Similarly, keto acids are used in industry as solvents and in pharmaceuticals. 1-aminoanthraquinone is used for colorants and pigments in a number of products (PubChem, 2019a).
<b>4. Information on the availability of mercury-free (or less-mercury) alternatives</b>	EU There are substitutes available to the use of mercury in polymer production processes, such as zinc and palladium. In addition, alternative processes can be used to synthesise some materials. The development of substitutes is still ongoing in some cases, in attempts to reduce the complex nature of separating by-products.
<b>5.(i) Information on the technical feasibility of alternatives</b>	EU

	<ul style="list-style-type: none"> <li>• The alternative process to produce 1-aminoanthraquinone does result in the production of multiple products, requiring hydrogenation. This results in the need for complex methods of separation to produce pure 1-aminoanthraquinone (IFI CLAIMS Patent Services, 2019a).</li> <li>• Zinc and palladium provide technically feasible substitutes for mercury and are currently used in polymer production processes (COWI, 2008).</li> <li>• Research into alternatives to the use of mercury in the synthesis of keto acids for polymer applications are still ongoing. Therefore, technically feasible alternatives are not currently available and further research developments are necessary (IFI CLAIMS Patent Services, 2019b).</li> </ul>
<b>5.(ii) Information on the economic feasibility of alternatives</b>	<p>EU</p> <ul style="list-style-type: none"> <li>• Regulation (EU) 2017/852 prohibits mercury use as a catalyst, which implies that it is economically feasible for EU industry to use mercury-free alternatives.</li> </ul>
<b>6. Information on the environmental and health risks and benefits of alternatives</b>	<p>EU</p> <ul style="list-style-type: none"> <li>• The phasing out of the use of mercury as a catalyst in the polymer industry will engender beneficial health and environmental effects. Alternatives such as zinc or iron chloride catalysts do not pose the same health threats linked to exposure or the environmental concerns associated with the release of mercury.</li> </ul>
<b>7. Other relevant information pursuant to Decision MC-3/1</b>	<ul style="list-style-type: none"> <li>• Under Regulation (EU) 2017/852, processes using mercury as a catalyst are prohibited. Little information exists on the use of these processes in the EU. However, the lack of protest during the negotiations of the Regulation implies that there is no significant use.</li> </ul>

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## Gold plating

<b>1. Category of manufacturing process in which mercury or mercury compounds are used</b>	Gold plating
<b>2. Further description of the process (if any)</b>	Alternative names: fire gilding, mercury gilding
<b>3. Information on the manufacturing activities using the process (incl. amount of mercury or mercury compounds used, production amount, etc.)</b>	<p><b>IPEN</b>          Metal plating (gold plating) is a process in which gold lining/painting is conducted on metal objects (e.g. statues, sculptures) by mixing mercury and gold together in a hand held mortar and pestle for extended hours thus preparing paste of gold and mercury. The paste is applied over the metal statue and then heated with a blow torch to evaporate mercury with gold plating remaining on the statue.</p> <p>Gold plating (gold-mercury amalgam) is one of the traditional works primarily practiced by an ethnic community in Nepal and has a history of many centuries. According to Department of Archaeology (DOArc), a total of 190,212 items of gold-plated sculptures having a total weight of 1255.33 MT were exported in the year 2016/17 and this led to an estimation of 12,825 Kg of mercury used in preparing the above sculptures. The gold-plated sculptures are mainly exported to China, India, Sri Lanka, Thailand, Bhutan, including others.</p> <p><b>Information from experts:</b>          Fire gilding is sometimes used for the restoration of ancient artwork to provide a surface structure and color that resemble the original product. In that case, strict measures are mandated to ensure safe working conditions and to minimize mercury releases to the environment. However, many originally fire gilded objects are restored by electroplating (Darque-Ceretti and Aucouturier 2013).</p>
<b>4. Information on the availability of mercury-free (or less-mercury) alternatives</b>	<p><b>IPEN</b>          There is a strong belief among processors that gold plating carried out through this process lasts longer and is better quality than gold electroplating – the main industrial alternative. The latter methods does have some limitations with larger statues requiring a large bath and a lot of gold.</p> <p><b>Information from experts:</b>          Other methods for gilding objects include leaf gilding (by attaching very thin pieces of gold), depletion gilding and powder gilding (Darque-Ceretti and Aucouturier 2013).</p>

<b>5.(i) Information on the technical feasibility of alternatives</b>	NA
<b>5.(ii) Information on the economic feasibility of alternatives</b>	NA
<b>6. Information on the environmental and health risks and benefits of alternatives</b>	<p><b>IPEN</b> As regards gold plating, it is estimated that about 95% of the used mercury is released to atmosphere while blow torching the sculptures with hot flame to remove the mercury; also, 3% of Hg may get into water used to wash the sculptures and only 2% might deposit into the soil in the immediate vicinity of gold plating activities. Gold plating (gold-mercury amalgam) is identified as the highest contributor in releasing mercury in Nepal.</p> <p>Studies of occupationally exposed workers in Iran confirm health impacts from gold plating using mercury (Vahabzadeh and Balali-Mood, 2016).</p>
<b>7. Other relevant information pursuant to Decision MC-3/1</b>	<p><b>IPEN</b> Metal (gold) plating technique has been used for centuries to decorate religious statues, artworks, clocks, porcelain and furniture. The practice was made illegal in France in the 1830's due to the severe health impacts on artisans using the technique.</p>

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## Other information

US EPA identified the following additional uses of mercury in manufacturing processes through the information submitted under the mercury inventory reporting rule:

- Bonding weld head (catalyst)
- Molecular beam epitaxy
- Quality analysis (density measurement of tungsten bars)
- Inactivation
- Quality control test (small arms ammunition case-mercury stress crack)

#### Information from experts

Welding is a process of joining two pieces of material (typically a metal) through the use of force or heat. In (resistance) seam welding workpieces are moved along a line between two rotating welding heads/wheel electrodes. The heat caused by an electric current produces a continuous welding seam. In some welding machines, mercury is used as an electric contactor between the rotating welding heads and the arms that are holding them.

Mercury-free welding heads and welding machines are available on the market.