Report on the collection of technical and market information on mercury-added products, mercury-using manufacturing processes and their alternatives

Study report prepared by a consultant of the Minamata Convention Secretariat, March – September 2023.

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This study report has been prepared by a consultant contracted with the Secretariat of the Minamata Convention on Mercury to collect information on mercury-added products, mercury-using manufacturing processes and their alternatives, with a view to contributing to the deliberation by the Conference of the Parties to the Minamata Convention at its fifth meeting on Annexes A and B to the Convention. Information collected through this study was made available to Parties in an information document for the Conference, UNEP/MC/COP.5/INF/5. The Secretariat appreciates the financial contribution of the European Commission that made this study possible.

Introduction

The fourth meeting of the Conference of the Parties (COP-4) in March 2022 amended Annex A to the Convention (mercury-added products) and decided (as per MC-4/3) that COP-5 will consider further amendment to Annex A and Annex B (mercury-using manufacturing processes) on the following topics:

For consideration at COP-5 re. Annex A: phase-out dates for:

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Button zinc silver oxide batteries with a mercury content < 2% and button zinc air batteries with a mercury content < 2%	[2025] [2029]
Very high accuracy capacitance and loss measurement bridges and high frequency radio frequency switches and relays in monitoring and control instruments with a maximum mercury content of 20 mg per bridge switch or relay [except those used for research and development purposes]	[2025]
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Halophosphate phosphor ≤ 40 watts with a mercury content not exceeding 10 mg per lamp (b) Halophosphate phosphor > 40 watts	[2025] [2027] [2030]
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Triband phosphor < 60 watts with a mercury content not exceeding 5 mg/lamp	[2027] [2030]

COP-4 also added two additional measures on dental amalgam to part II of annex A.

Further, for consideration at COP-5 re. Annex B: Adding the production of polyurethane using mercury containing catalysts to part I of annex B.

COP-4 requested the secretariat to compile information on the availability and technical and economic feasibility of mercury free alternatives in the production of polyurethane using mercury containing catalysts and to submit it to the Conference of the Parties at its fifth meeting to facilitate its consideration of the matter.

The COP also requested the secretariat to prepare, for consideration by the Conference of the Parties at its fifth meeting, a short report on the technical and economic feasibility of mercury free alternatives for the two processes (vinyl chloride monomer, and sodium or potassium methylate or ethylate) listed in annex B, part II, that refer to the Conference of the Parties establishing such feasibility, and, in so doing, to first identify those parties that have reported the use of those two processes in their national reports under article 21, and then request information from those parties regarding whether they continue to use those two processes, whether either is scheduled to be phased out nationally, and to what extent mercury free alternatives are technically and economically feasible.

The COP decided that, if necessary, the secretariat may request other parties and stakeholders to provide additional information.

This report presents and analyses collected technical and market information on selected products and processes from the received submissions from Parties and stakeholders, from national Article21 reports, from literature and from direct contact to selected stakeholders.

Table 1 presents an overview of submissions from Parties and stakeholders for consideration as regards Annexes A and B.

Table 1 Overview of received submissions on the considerations for Annexes A and B, and the topics they cover.

Party /stakeholder	Gene-ral	Batte-ries	Lamps	Poly-urethane	VCM	Alcoho-lates	Remarks; link to submission
Dominican Republic				**x**	**x**	**x**	Statement that these processes are not used in the country, and that the country is therefore in "total disposition to comply with the alternatives without mercury"; https://mercuryconvention.org/sites/default/files/inline-files/DominicanRepublic.pdf
European Union				**x**	**x**	**x**	Informs of the phase-out dates of mercury use in processes and refers to an earlier submission on technical, economical and environmental description of alternatives; https://mercuryconvention.org/sites/default/files/documents/submission_from_government/EU%20submission%20on%20Annex%20B%20-%2021.12.2022.pdf
Japan		**x**	**x**				Describes the state of substitution for mercury-added batteries and lamps; https://mercuryconvention.org/sites/default/files/inline-files/Japan_AnnexA.pdf
Uganda	**x**			**x**			The submission summarises current regulative measures and initiatives for a number of products and processes using mercury; https://mercuryconvention.org/sites/default/files/documents/submission_from_government/Uganda_Follow-up%20information%20Minamata%20COP4.2.pdf
Battery associations in Japan, Europe, North America and Latin America		**x**					https://mercuryconvention.org/sites/default/files/inline-files/Battery_Associations_Position_COP5_Minamata_Convention.pdf
Clean Lighting Coalition			**x**				https://mercuryconvention.org/sites/default/files/inline-files/Clean_Lighting_Coalition_Information_Document_on_LFLs_for_General_Lighting_Purposes.pdf
Japan Lighting Manufacturers Association			**x**				https://mercuryconvention.org/sites/default/files/documents/submission_from_organization/JLMA_Information_for%20Annexes%20AB%20about%20FLs_2.pdf

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Information on mercury-added products and their alternatives

This section describes the information received and gathered for the mercury-added products.

1. Button zinc silver oxide batteries and button zinc air batteries with a mercury content Introduction

Minamata Convention coverage

Coverage after COP-4 (Annex A):

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Batteries, except for button zinc silver oxide batteries with a mercury content < 2% and button zinc air batteries with a mercury content < 2%	2020

Under consideration for COP-5 (for possible inclusion in Annex A):

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Button zinc silver oxide batteries with a mercury content < 2% and button zinc air batteries with a mercury content < 2%	[2025] [2029]

The amendment under consideration for COP-5 would, if adopted, result in a phase out of all batteries with mercury added, except in the case of the general exemptions for mercury-added products; see Annex A.

Mercury use in button cell batteries

Mercury was added to reduce undesired corrosion of the zinc anode that in turn could cause hydrogen gas production that could result in leakage of the cell due to the increased pressure.

Mercury-free alternatives

Several principles are applied to reduce zinc corrosion, including the use of adjusted zinc alloys, addition of other ani-corrosion additives, surface treatment of electrodes, increased absorption of hydrogen in the cathode material, etc[1].

Information submitted by Parties and stakeholders

A joint position by the Battery associations in Japan (BAJ), Europe (EPBA), North America (NEMA) and Latin America (ALPIPA) was submitted for the inter-sessional work prior to COP-5[2].

As regards the availability of mercury-free alternatives, they state the following:

"*All members of BAJ, EPBA, NEMA and ALPiBa have already ceased manufacturing mercury-added button batteries and supply mercury-free alternatives across the world. The members of these*

[1] 1) Submission from the Government of Japan (available at https://mercuryconvention.org/sites/default/files/inline-files/Japan_AnnexA.pdf), and
2) Phys.org (2004): World's first commercialization of Mercury-Free Silver Oxide Battery. Accessed April 2023 at https://phys.org/news/2004-09-world-commercialization-mercury-free-silver-oxide.html

[2] See all the submission to the Annexes A and B inter-sessional work from the Parties and other stakeholders at https://mercuryconvention.org/en/meetings/cop5#sec1562

signatory associations have prominent button battery brands such as Varta, Rayovac, Maxell, Seiko, Sony, Murata, GP, Panasonic, Duracell, Energizer, etc. When it comes to silver oxide and zinc air batteries exempted by Annex A, we believe our products collectively represent 90% of the global market.

Though we are based in Japan, Europe, and American Continent, our products are widely available in other regions. To take an example from the important Asian markets, India, which has no local producer of button batteries, imports 96 % of silver oxide batteries from Hong Kong and Japan. Hong Kong in turn imports 93 % of those batteries from Japan. As a result, most silver oxide batteries used in India can be seen mercury-free. Many countries depend on import and there are similar cases to India."

They further back this information with mentioning that 42 countries/regions in Europe, North America and Asia "have already banned mercury use in all the batteries" (specifics are given in the submission).

As regards the technical and economic feasibility of mercury-free alternatives, the four battery associations state:

"Mercury-free technology in button batteries has years of history and there exist a lot of usable patents. Technical hurdles to mercury-free alternatives are not so high.

Mercury-free button batteries are already comparable in price with mercury-added ones. As mentioned above, major manufacturers have completely shifted to mercury-free. If they had to restart production of mercury-added products, it could be higher in costs."

The four battery associations also mention that button cell batteries are challenging to separate from other waste, and when such waste is incinerated, it gives rise to mercury emissions that can be avoided with mercury-free batteries.

The four battery associations conclude that they support the phase-out of all mercury-added batteries, and propose to set a threshold of 5ppm mercury in batteries to allow for natural trace concentrations of mercury in the battery materials. They note that *"the proposal contains a 5ppm threshold because mercury exists in nature and is difficult to eliminate completely in manufactured products. The 5ppm threshold is consistent with the EU Batteries Directive that is referenced around the globe. Batteries with a mercury content less than or equal to 5ppm are regarded as mercury-free (i.e., not intentionally mercury-added)." They therefore propose the Annex A, part I text on batteries replaced as follows:*

Current stipulation	*Proposal of the 4 battery associations*
Batteries, except for button zinc silver oxide batteries with a mercury content < 2% and button zinc air batteries with a mercury content < 2%	*Batteries, with a mercury content > 5ppm*

Exemptions from the phase-out dates listed in Part I of Annex A

As of July 2023[3], the following Parties had notified exemptions for button cell batteries from the phase-out dates listed in Part I of Annex A to the Minamata Convention on Mercury (as listed 20 July 2023 at https://mercuryconvention.org/en/parties/exemptions)

Party	**Batteries (2025)**
Bangladesh	Imp
Botswana	Imp
Canada	
Ghana	Man,Imp,Exp
India	Man,Imp,Exp
Iran (Islamic Republic of)	Imp
Lesotho	Imp
Madagascar	Imp
Eswatini (Kingdom of)	Imp
Thailand	

[3] Exemptions from the phase-out dates listed in Part I of Annex A to the Minamata Convention on Mercury (as listed 20 July 2023 at https://mercuryconvention.org/en/parties/exemptions).

2. Mercury use in measurement bridges and switches and relays

Minamata Convention coverage

Coverage after COP-4 (Annex A, part I):

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Switches and relays, except very high accuracy capacitance and loss measurement bridges and high frequency radio frequency switches and relays in monitoring and control instruments with a maximum mercury content of 20 mg per bridge, switch or relay	2020

Under consideration for COP-5 (for possible inclusion in Annex A, part 1):

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Very high accuracy capacitance and loss measurement bridges and high frequency radio frequency switches and relays in monitoring and control instruments with a maximum mercury content of 20 mg per bridge switch or relay [except those used for research and development purposes]	[2025]

The amendment under consideration for COP-5 would, if adopted, result in a phase out of all measuring bridges, switches and relays with mercury added, [except those used for research and development purposes].

Mercury use in measurement bridges and switches and relays targeted

This product group is complex, with many variants – to the extend they are still used –, but earlier, the larger mercury inputs with these products were in tilt switches and thermo-relays/switches, which could contain several grammes of mercury per unit, and as such are already covered by the present provision of the Minamata Convention.

The ad hoc group of experts[4] on review of Annexes A and B established prior to COP-4 received and assessed submissions from Parties and other stakeholders mentioning the following types of switches and relays:

- Tilt switches (with liquid mercury that can make or break an electric circuit depending on physical position)
- Float switches (a use of tilt switches)
- Mercury seismic switches (probably a type of multidirectional tilt switch)
- Mercury reed relays
- Pressure switches (like a manometer that can make or break an electric circuit depending on pressure)
- Temperature switches (like a thermometer that can make or break an electric circuit depending on temperature)
- Mercury displacement relays

The only type of product in this group with mercury contents less than 20mg per unit described in the UNEP Toolkit[32] are so-called wetted read relays. Wetted read relays may be found in small circuit controls for low voltage electronic devices. A wetted reed relay consists of a glass encapsulated reed

[4] Outcomes of the work of the group of experts can be seen on https://mercuryconvention.org/en/meetings/cop4#cop-intersessional-work

with its base immersed in a pool of mercury and the other end capable of moving between two sets of contacts (Galligan et al, 2003). The mercury flows up the reed by capillary action and wets the contact surface of the reed and the stationary contacts. Reed relays are primarily used in test, calibration, and measurement equipment where stable contact resistance over the life of the product is necessary. The mercury content of each relay is typically 1-10 mg (Skårup et al., 2003, as cited in the Toolkit Reference Report).

The ad hoc expert group on review of Annexes A and B (for COP4)[4] reported that: "A number of countries reported on the use of exempted or allowed uses of mercury switches and relays. Japan reported that it could not confirm the domestic manufacturing of such exempted switches and relays. The United States of America reported on the use of mercury and mercury compounds in switches, relays, sensors and valves in the 2018 reporting period under the mercury inventory reporting rule. Canada reported that it is considering removing the exemption in its regulations for high frequency radio frequency switches and relays due to the fact that there were no imports of these products in 2016."

Mercury-free alternatives

There are mercury-free alternatives for all uses in switches and relays and this was confirmed by the export group[4]. However, Japan noted that there were at the time "products (end use) that are difficult to replace with mercury-free relays due to performance and cost issues, and the necessity to change the circuit when using a mercury-free relay. Due to these reasons, there is still a demand for mercury relays for the maintenance of existing (not easily replaceable) products."

The key alternatives are likely digital solutions and, in the case of mechanical tilt switches, (likely still) a steel roller ball system that make or break an electric circuit depending on the ball's physical position in the switch.

No submissions for the inter-sessional work on Annexes A and B prior to COP 5 have been received mentioning the continued need for any mercury-added measuring bridges, switches or relays.

It is noted that products for research, calibration, etc. are excluded from Annex A.

Exemptions from the phase-out dates listed in Part I of Annex A

As of July 2023[5], the following Parties had notified exemptions for switches and relays from the phase-out dates listed in Part I of Annex A to the Minamata Convention on Mercury (as listed 20 July 2023 at https://mercuryconvention.org/en/parties/exemptions)

Party	Switches and relays (2025)
Bangladesh	Man,Imp,Exp
Botswana	Imp
Canada	
Ghana	Man,Imp,Exp
India	Man,Imp,Exp
Iran (Islamic Republic of)	Man,Imp,Exp
Lesotho	Imp
Madagascar	Imp
Eswatini (Kingdom of)	Imp
Thailand	Imp

[5] Exemptions from the phase-out dates listed in Part I of Annex A to the Minamata Convention on Mercury (as listed 20 July 2023 at https://mercuryconvention.org/en/parties/exemptions).

3. Linear fluorescent lamps (LFLs) for general lighting purposes

Minamata Convention coverage

Coverage after COP-4 (Annex A, part I):

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Triband phosphor < 60 watts with a mercury content exceeding 5 mg per lamp; (b) Halophosphate phosphor ≤ 40 watts with a mercury content exceeding 10 mg per lamp	2020

Under consideration for COP-5 (for possible inclusion in Annex A, part 1):

Mercury-added products	*Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)*
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Halophosphate phosphor ≤ 40 watts with a mercury content not exceeding 10 mg per lamp (b) Halophosphate phosphor > 40 watts	[2025] [2027] [2030]
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Triband phosphor < 60 watts with a mercury content not exceeding 5 mg/lamp	[2027] [2030]

The amendment under consideration for COP-5 would, if adopted, result in a phase out of all halophosphate linear fluorescent lamps (LFLs) for general use. Triband phosphor lamps > 60 watts and LFLs for non-general uses would still not be covered.

Mercury use in LFLs

Mercury is used in small amounts per lamp in a number of different types of discharge lamps, with fluorescent tubes and compact fluorescent lamps (CFLs) as the most common examples in general lighting. Significant progress has been made by some producers to reduce the amount of mercury per lamp, with reductions of about a factor 10 achieved in newer mercury-lamps as compared to traditional types.

Elemental mercury is introduced into the tube when it is manufactured, and it acts as a multi-photon source, producing ultra-violet light when an electrical current is passed through the tube. Mercury in fluorescent lamps has essentially two different chemical compositions: vapour-phase elemental mercury and divalent mercury adsorbed on the phosphor powder, the metal lamp ends, or other components. The amount of mercury required in vapour form in the dis-charge to energize the lamp is 50 micrograms – about 0.5 to 2.5% of the total placed in the lamp when manufactured (Dunmire et al., 2003, as cited in UNEP, 2023[6]). Over time, the mercury in the tube reacts with phosphorus powder which coats the inside surface of the tube, and it loses its efficacy. Therefore, there must be enough initial elemental mercury in the lamp, so that at least 50 micrograms is available in vapour form even at the end of the lamp's rated life (typically 5 years of use for linear tubes in commercial service). At the end of lamp life, most of the mercury is in divalent form. 99% of the mercury present in lamps when disposed is embedded in the tube coating powder (UNEP, 2023[6] and references cited therein).

Historically, manufacturers added mercury as droplets into the lamp. But today, mercury is introduced as so-called amalgams (meaning cupper strips or "pills" with amalgamated mercury), or as liquid mercury contained in a glass vial fixed to the cathode, both allowing for a more precise and reduced mercury amount per lamp.

[6] Toolkit for identification and quantification of mercury releases, Reference Report, UNITAR for UNEP, 2023, accessed March 2023 at https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-inventory-toolkit.

Mercury-free alternatives

LEDs is the principal alternative, and they are already widely used globally. In the Submission of Japan, it is stated, citing CSIL (2021)[7], that "the LFLs luminaires themselves are being replaced by integrated LED luminaires of the same shape. More than 75% of luminaires sales are LED luminaires".

Retrofit LED lamps use in existing LFL luminaires is also practised, however, safety issues have been observed with some lamp/luminaire combinations according to the submission of Japan (see below).

Information submitted by Parties and stakeholders

In the submission from **Japan**[8] the following statement is made about the use of LED luminaires:

"*There is no technical problem with using integrated LED luminaires. In addition, the price difference between integrated LED luminaires and conventional LFL luminaires is decreasing, and the energy savings obtained from the dimming function of integrated LED luminaires are significant. Hence, there are significant benefits to replacing conventional LFL luminaires with integrated LED luminaires. In some cases, substitution to LED retrofit lamps is also possible*."

As regards retrofit of LEDs in existing LFL luminaires Japan however cautions that safety issues have been observed with some lamp/luminaire combinations:

"*Not all LED retrofit lamps can be adapted to all luminaires. To ensure safety, it is also necessary to evaluate the safety of luminaires in which LED retrofit lamps are installed. Hence, a separate combination test is considered necessary. Due to this reason, it is technically appropriate to consider replacement with integrated LED luminaires as the main alternative and to use LED retrofit lamps as a supplementary alternative. 2. Economic feasibility Since LED-integrated luminaires are already mainstream in the market, economic feasibility can already be ensured if they are replaced based on the product life of LFL luminaires. The time schedule required for changeover to LED is equivalent to the time required for the changeover of the installed LFL luminaires. Although it will depend on the situation in each country, it may be possible to eliminate LFLs after 2027 if measures such as securing LFL inventory and promoting replacement with integrated LED luminaires can be implemented. Based on the global market share (2023 projection) of the number of installed LFL luminaires and LED production, it is expected that it will take at least 5 years to replace all the installed LFL luminaires with integrated LED luminaires or LED retrofit lamps. Accelerating the process of replacement will require increasing manufacturing capacity. However, problems such as sluggish demand after the switchover and tight supply and demand for semiconductors may lead to a risk of insufficient investment in manufacturing facilities. If a decision is made to discontinue LFLs immediately, it may make it difficult to obtain LFLs and LED luminaires when required, causing disruption to the lives of citizens*."

Japan further states in their submission (see references in the submission):

"*Although the IEC has issued a safety standard (IEC62776) for LED lamps, LED retrofit lamps may have safety implications even if they meet this standard. Therefore, an IEC Technical Report entitled "DESIGN AND APPLICATION OF LED RETROFIT LAMPS" will be published in the first half of 2023 to provide guidance to designers and manufacturers on the safety requirements to be considered and their responsibility to control the suitability of LED retrofit lamps for all applications in which the lamps to be replaced were used. To ensure safety, it is expected that each combination of products to be used will need to be tested in accordance with these guidelines. The lighting circuits that can be used for LED retrofit lamps vary by model, and if incompatible LED lamps are mistakenly installed, there is a risk of fire in the LED retrofit lamps or in the luminaires in which they are installed. In Japan, for example, 328 accidents occurred in the 10 years following 2009*."

Japan notes that it may be difficult to replace LFLs in non-general lighting such as emergency lighting and lighting used in airplanes.

Further details can be seen in the submission of the Government of Japan[8].

[7] LEDS AND THE WORLDWIDE MARKET FOR CONNECTED LIGHTING, CSIL/Nov 2021, as cited in the submission of Japan. https://www.lighting.csilmilano.com/assets/CSIL-Lighting-Reports-2022.pdf

[8] The full text of the submissions of Japan, the Japanese Lighting Manufacturers Association and CLiC can be seen at at https://mercuryconvention.org/en/meetings/cop5#sec1562

The submission of the **Japanese Lighting Manufacturers Association (JLMA)**[8] includes the information on LFLs given in the submission of the Government of Japan, but adds additional detail, numbers and photos.

JLMA states that "*In Japan, 98% of luminaires sold in 2018 will be LED lighting. In the global market as a whole, 76.5% of luminaires sold in 2021 will already be LED fixture*s." (References are given in the submission).

Further JLMA states as regards dimming functions and energy savings: "*By replacing LFLs luminaires with integrated LED luminaires, it is possible to support large-scale lighting control systems and dimming control, which are not possible with LED retrofit lamps. In addition, power consumption can be reduced by approximately 30% compared to LED retrofit lamps. If dimming control is used, power consumption can be expected to be reduced by more than 50%*."

JLMA presents estimates of required to switch to LED lighting based on the number of currently installed LFLs luminaires and the production of LEDs for replacement:

"1) Conversion of all LFLs luminaires to LED retrofits: 12.5 Year

2) Replacement of all LFLs luminaires with integrated LED luminaires: 7.5 Year"

The background for these estimates is given in an annex to the JLMA submission.

JLMA also presents relatively low compatibility rates of tubular LED retrofit lamps from a "Position Statement on the Phasing-out of Fluorescent Lamps" by the Global Lighting Association (year not given).

JLMA presents examples of pay-back time estimates for retrofit LEDs (2.3 years) and LED luminaire/lamp sets (3.1 years) using examples of lamps and energy costs.

According to JLMA, "*LED retrofit lamps have a specific lighting circuit that can be used for each model, and there is a risk of fire if they are installed incorrectly. As there are dozens of different lighting circuits and they can be physically installed in incompatible fixtures, there have been many cases of misuse, for example, more than 160 fires have occurred in Japan in the five years since 2011*." They show photos of examples of mis-matched lamps that have caught fire.

About CFL-ni – meaning not with ballasts integrated; in effect fluorescent lamps with non-linear shapes – JLMA note that they are mainly meant for replacement of spent lamps in existing fixtures, as new fixtures are already mainly sold as LED-integrated fixtures. According to JLMA, a disadvantage of retrofit LEDs for this purpose is that "*a survey of sales of LED retrofit lamps for CFL-ni shows that few are available, so it is practically impossible to replace them with LED retrofit lamps*". They see no technical disadvantages with LED-integrated fixtures/luminaires. An example of a pay-back time for a LED-integrated solution is given (8.6 years with the chosen costs).

The **Clean Lighting Coalition**[8] (CLiC) submitted information on their research and positions as regards the availability and suitability of double-ended LED tubes as alternative to LFLs.

CLiC states the following as regards compatibility of double-ended LED tubes into LFL luminaires: "*The issue of compatibility of LED retrofit tubes comes down to the fluorescent lamp ballast which had been operating the fluorescent lamp. There are two types of ballast – magnetic (also called "choke") ballasts and electronic (also called "high frequency") ballasts. LED retrofit tubes are 100% compatible with magnetic ("choke") ballasts. This type of ballast is particularly common in developing and emerging markets because they tolerate humidity better and can withstand voltage spikes and surges due to power fluctuations. LED retrofit tubes have 80-90% compatibility with electronic ballasts, depending on the manufacturer*."

The "ballast" is integrated in the LFL luminaire and controls the electric discharge needed to activate the light emission in the fluorescent lamp.

CLiC base their compatibility numbers on a review of compatibility tables of major global LED brands available at the European market. They have aggregated this information in a database available online[9]. CliC states that "*Using literature published by the lighting industry, the Clean Lighting Coalition has demonstrated that there can be either direct drop-in replacement LED lamps or, in the very few situations where a compatible LED tube lamp cannot be found, an electrician can*

[9] CliCs compatibility databease can be found at:

https://www.mercuryconvention.org/Portals/11/documents/meetings/COP4/submissions/CLASP_AnnexAB_spreadsheet.xlsx.

"by-pass" the ballast and bring mains voltage to the fluorescent fixture sockets, and then a mains-voltage LED tube can be installed – enabling the existing fixture to remain in place."

CLiC states further that "*IEC safety standards*[10] *have been in place for 8-10 years, and LED lamps that follow these standards are considered safe. The IEC adopted safety standards for self-ballasted LED lamps in 2011, double-ended LED tubes in 2014 and semi-integrated LED lamps in 2015*". They give examples of statements from manufacturers assuring the safety for retrofits in LFL luminaires.

The colour of the light emitted by LEDs was an issue in early examples of LED lamps. However, developments over the last decade have solved this and CLiC states that "LED retrofits for fluorescent lamps already meet or exceed the CRI and CCT[11] values of fluorescent lamps", and give examples of CRI and CCT values for LFLs and LED tubes in their submission.

Another factor influencing lamps choice is the lamp lifetime. CLiC, in their submission, cites examples of 2-3 times longer life for LEDs than their comparable LFLs. Similarly, warranties on LED tubes were found longer than for LFLs. Typically, the warranty periode for LEDs was found to be about the double as for LFLs.

CLiC gives examples of regulation phasing out LFLs in countries and states in Europe, North America, Africa and Asia.

CLiC reports energy input savings in Watt per Lumen produced for retrofit LEDS at typically around 20-30% compared to LFLs (based on CLiC's assessment of lamp declarations in Africa, Asia and the LAC region; with some variation between regions and brands[12]). The higher energy efficiency of LEDs compared to LFLs results, as per CLiC's calculation, in significant energy savings and associated cost reductions, climate gas emission reductions, as well as mercury mobilisation and use reductions (from mercury in the lamps plus mercury emission reductions as a result of energy savings). The detailed numbers are given in the submission text.

While LFLs are still (as of 2022) lower in purchasing price most places, CLiC calculated resulting pay-back times based on local prices in different regions of the world and a general electricity price estimate ranging from 0-12 months, with an overall cross-regional average of about 5 months.

The CLiC submission also describes their assessment of the above key factors for substitution in the African, Asia-Pacific and Latin American regions separately, including examples from a number of individual countries in each region.

For the reasons summarised above, CLiC recommends a phase-out of all LFLs by 2025.

Exemptions from the phase-out dates listed in Part I of Annex A

As of July 2023[13], the following Parties had notified exemptions for LFLs from the phase-out dates listed in Part I of Annex A to the Minamata Convention on Mercury (as listed 20 July 2023 at https://mercuryconvention.org/en/parties/exemptions)

Party	LFLs (2025)
Bangladesh	Man,Imp,Exp
Botswana	Imp
Canada	Triband: Man,Imp,Exp
Ghana	Man,Imp,Exp
India	Man,Imp,Exp
Iran (Islamic Republic of)	Man,Imp,Exp
Lesotho	Imp
Madagascar	Imp

[10] CLiC refers to the standarts as IEC 62776:2014 Double-capped LED lamps designed to retrofit linear fluorescent lamps – Safety specifications: https://webstore.iec.ch/publication/7425.
IEC 62560:2011 Self-ballasted LED-lamps for general lighting services by voltage >50 V - Safety specifications: https://webstore.iec.ch/publication/7199.
IEC 62838:2015 LEDsi lamps for general lighting services with supply voltages not exceeding 50 V a.c. r.m.s. or 120 V ripple free d.c. - Safety specifications: https://webstore.iec.ch/publication/23482.

[11] CRI : Colour rending index. CCT: Correlated colour temperature (CCT).

[12] CLiC mentions in the submission that electricity savings are considered as 50% in their reduction scenarios, a calculation which, according to direct contact with CLiC (August 2023), includes also replacement of CFLs.

[13] Exemptions from the phase-out dates listed in Part I of Annex A to the Minamata Convention on Mercury (as listed 20 July 2023 at https://mercuryconvention.org/en/parties/exemptions).

Party	LFLs (2025)
Eswatini (Kingdom of)	Imp
Thailand	Imp

4. Manufacturing and international trade in dental amalgam

Minamata Convention coverage

Coverage after COP-4 (Annex A, part II, provisions in grey were added at COP-4):

Mercury-added products	*Provisions*
Dental amalgam	Measures to be taken by a Party to phase down the use of dental amalgam shall take into account the Party's domestic circumstances and relevant international guidance and shall include two or more of the measures from the following list: (i) Setting national objectives aiming at dental caries prevention and health promotion, thereby minimizing the need for dental restoration; (ii) Setting national objectives aiming at minimizing its use; (iii) Promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration; (iv) Promoting research and development of quality mercury-free materials for dental restoration; (v) Encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices; (vi) Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration; (vii) Encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restoration; (viii) Restricting the use of dental amalgam to its encapsulated form; (ix) Promoting the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.
	In addition, Parties shall: (i) Exclude or not allow, by taking measures as appropriate, the use of mercury in bulk form by dental practitioners; (ii) Exclude or not allow, by taking measures as appropriate, or recommend against the use of dental amalgam for the dental treatment of deciduous teeth, of patients under 15 years and of pregnant and breastfeeding women, except when considered necessary by the dental practitioner based on the needs of the patient.

Mercury use in dental amalgam

An amalgam is by definition a mix of mercury and one or more other metals. In the case of dental amalgam, the mix of metals is usually mercury (50%), silver (30-35%), tin (9-13%), copper (2-7%), zinc (0-0.5%). For dental fillings, the mouldable character of newly mixed and un-settled amalgam is used to fit the amalgam into the prepared cavity in the tooth. Dental amalgam, unlike the alternatives, does not chemically bind to the tooth material, so the cavity has to be drilled in a shape that anchors the amalgam. The mercury and silver in the dental amalgam is toxic to bacteria and therefore inhibits the formation of secondary caries (cavities) next to the established filling.

The use of amalgam fillings is prohibited in some countries and severely restricted in many countries, they main reason being environmental impacts, but concern for human health from direct exposure from the fillings has also been raised in some countries and regions (the EU [among others]).

The ingredients for dental amalgam may be supplied in three different ways:

1. As pre-dosed amalgam capsules, where liquid mercury and a mix of powders of the other metals are separated by a thin barrier inside a plastic capsule. The mixing of the ingredients happens with rigorous shaking that breaks the barrier when the amalgam is still inside the capsule. The capsule is only opened thereafter to apply the amalgam to the cavity. This limits the evaporation of mercury vapours from handling of mercury in the dental clinic and decreases the losses of excess amalgam due to accurate dosing of the ingredients. This is the

most modern way of supplying and applying dental amalgam, and is among the mercury phase-down measures mentioned in Annex A, part II of the Minamata Convention.

2. As separate powder mix and liquid mercury sets. Here the liquid mercury is supplied in a bottle, and the other metals are supplied in a premixed powder. Mercury and powder is weighed manually to achieve the right ratio in the clinic, leading to more handling of mercury and unsettled amalgam in the open in the dental clinic. This was the dominant way of supplying dental amalgam ingredients in the past, but may still be applied widely in developing countries.
3. As self-mixed ingredients. In principle, all ingredients can be suppled individually and weighed and mixed in the dental clinic. This may result in the least costly filling materials, but it is not known if this procedure is used/widespread in developing countries.

Mercury-free alternatives

The dominant mercury-free alternative for adults and clinic settings is **composite fillings**, consisting of a polymer and silica particles (for hardness). The prepared cavity is primed with a polymeric primer, that is cured with light before the actual composite filling material is applied. For larger fillings, the composite may be applied in layers with intermediate curing with light. It may therefore for larger cavities take a bit longer time to apply composite fillings than amalgam fillings. According to WAMFD (2021)[14], newer generations of composite fillings do not shrink and can therefore be applied more quickly in one operation, resulting in similar costs as amalgam fillings. Primed composites glue to the tooth material, and hence less drilling is needed compared to amalgams to prepare the cavity for filling.

Composite fillings exist in various tooth colours and have therefore for decades been preferred by some users. In some countries with free/low-cost dental care in public hospitals or clinics, a market division has been seen where amalgam is used in public or subsidised clinics (used due to low price), and composites are used in private dental clinics where the patient pays the full price. The latter because of the tooth-coloured filling material (aesthetics) and possibly health and environment concerns.

A sub-type of composite fillings – sometimes called **compomer fillings –** releases fluoride from the filling material in the tooth, and thereby inhibits the formation of secondary caries. Tests performed in the Nordic[15] countries, where dental amalgam has been severely restricted for decades, showed that compomer fillings had similar filling lifetimes as amalgam fillings, whereas other composite fillings (not releasing fluoride) had somewhat lower lifetimes.

Another mercury-free dental filling material is the so-called **GIC fillings (glass ionomer cement**). It also releases fluoride over time to prevent secondary caries, but has lower physical strength and therefore generally have lower durability[Error! Bookmark not defined.,16]. They have however been recommended for so-called atraumatic dental restoration, ideal for example for children and under non-clinic conditions, because it react with the tooth material and can therefore be applied with less preparation (drilling) than amalgam fillings.

Market situation for dental amalgam and alternatives

As mentioned above, the mercury-free alternatives to dental amalgam have been common practice in some parts of the world for more than three decades. By way of example, already in 1994 general use of dental amalgam was prohibited in Denmark (with some exemptions). In the EU and North America, the mercury-free alternatives have steadily grown in relative market share and have for long been dominating the market (see further details about the EU below).

[14] WAMFD (2021): A Comparison of Availability, Affordability, Effectiveness, Risks and Benefits of Dental Materials. Accessed April 2023 at https://mercuryconvention.org/sites/default/files/documents/submission_from_organization/WAMFD_Comparison_report_DentalAmalgam.pdf.

[15] Nordic Council of Ministers (2010): Mercury – Reductions are feasible. Accessed April 2023 at http://norden.diva-portal.org/smash/get/diva2:701717/FULLTEXT01.pdf.

[16] ADA, FDI and IADR (2021): Accelerating the Phase Down of Dental Amalgam (citing British Dental Journal, Volume 224 No. 12. June 22 2018). Presentation at side event to COP4; accessed April 2023 at https://mercuryconvention.org/sites/default/files/inline-files/11%20Fri%2017h00%20Accelerating%20the%20Phase%20Down%20of%20Dental%20Amalgam%20%2722.pdf

In developing countries mercury-free filling materials have also been used for decades, but primarily in private clinics, where more wealthy clients prefer tooth-coloured fillings, whereas dental amalgam has had a bigger role in public clinics due to the slightly higher prices of the alternatives.

On a global scale, the relative market share of dental amalgam is deemed to be decreasing due to the Minamata Convention and other regulation as well as the aesthetic advantages of tooth-coloured fillings materials. As the level of dental care is however increasing in many developing countries, the actual global dental amalgam supply may not necessarily be decreasing to the same degree.

UNEP (2017)[17] estimated the global mercury supply with dental amalgam at 240 - 300 t/y for 2005, at 270 - 341 for 2010 and at 226 – 322 for 2015. Increasing dental care levels (expressed as number of dentists per 10 000 inhabitants[18]), combined with amalgam still being a low-cost filling material, indicate that the supply may not necessarily have decreased since then.

In a combined effort between the preparations for this current report, and the preparations of the consultants' "Report[19] on trade, supply and demand of mercury", the publicly available information was assessed to form an estimate of the current (2019) consumption of mercury with dental amalgam.

Estimation of the consumption of mercury in dental amalgam for 2019 was carried out by utilizing the data obtained from (UNEP, 2017), which serves as the baseline. This estimation considers the impact of the Minamata Convention on mercury uses in dental amalgam and parties to the convention are expected to implement measures outlined in Part II of Annex A, aimed at gradually reducing the use of dental amalgam.

Estimation for the year 2019 by this method was carried out by incorporating data from various sources on measures implemented to reduce the use of dental amalgam. These sources include national and regional reports, as well as information reported by the parties to the Minamata Convention in their full national report (2021) pursuant to Article 21. These policy measures, which reflect the actions taken by different countries, are assigned a score based on their anticipated impact in reducing mercury consumption in dental amalgam. It is also assumed that no reduction is observed in countries that are not parties to the convention, whilst some degree of reduction is seen for countries that are signatories but not parties to the convention. These scores are then utilized in the estimation process using population figures and the baseline data for 2015 as estimated in the 2017 assessment.

Examples of some policy measures for which specific scores are attributed are listed below:

- Banning the use of dental amalgam for persons under 15 years of age, pregnant and breastfeeding women
- Restricting the construction, renovation, and expansion of dental amalgam material production devices
- Banning the use of dental amalgam

In addition to the approach mentioned above, data obtained from Minamata Initial Assessments (MIA) reports on mercury consumption in the dental amalgam sector were also aggregated to estimate the per capita consumption of mercury within each region. This data is extrapolated to account for the consumption of mercury in specific regions, taking into consideration the various policy measures described above. It should be noted that some data obtained from the MIA reports contain some unusually large numbers which can lead to overestimation. However, they are provided for reference purpose.

An alternative approach was also applied for comparison. Using the UNEP Toolkit default method for estimating mercury consumption, yet with updated increased national numbers from WHO on dentists per 10,000 inhabitants[25], as an expression of the dental care level, generates an estimated mercury consumption with dental amalgam at 580 t/y. This number is based on number of inhabitants nationally, in combination with the national dentist's density and the pre-entered Toolkit input factor of 0.2 g Hg/inhabitant*y. The pre-entered input factor is in turn based on data from detailed studies for around year 2000 in countries where substantial substitution with other dental filling materials had already taken place, specifically Denmark (61% reductions at that time), Norway (>39%), Sweden

[17] UN Environment, 2017. Global mercury supply, trade and demand. United Nations Environment Programme, Chemicals and Health Branch. Geneva, Switzerland.

[18] WHO; Global Health Workforce statistics database – Dentistry. Accessed June 2023 at https://www.who.int/data/gho/data/themes/topics/health-workforce

[19] Parajuli, K, Maxson, P. (2023): Report on Trade, Supply and Demand of Mercury. For the Secretariat of the Minamata Convention. Draft, July 2023.

(>94%) and the USA. Taking also into account the observed increased dentist's density, it therefore cannot be ruled out that the real global mercury consumption with dental amalgam could be higher. On the other hand, as mentioned above, some regions have made progress towards reducing the use of dental amalgam in the last decade and this is expected to likely have balanced to some extent the observed rise in dental care levels in developing countries. Using the full range of default factors provided in the Toolkit (0.05-0.2 g Hg/inhabitant*y), the resulting calculated mercury consumption is 150-580 t/y. Independent data from the EU give the possibility for calibrating the estimate. For 2018, the estimated mercury input with dental amalgam in the EU28 was 27-58t/y, whereas earlier studies estimated an input of 55-95t/y around 2008. In comparison, the total estimate range for the EU28 (before 2020) using the Toolkit standard method is 25-99 tonnes Hg/y, which indicates that the Toolkit range may be too wide when seen in a global perspective. Consequently, a reasonable global estimate could be 200-500 tonnes/y.

Based on the two mentioned methods of estimation, the consumption of mercury in the dental amalgam sector for 2019 is estimated to be in the range of 200-500 tonnes. As mentioned, the estimation for 2015 in (UNEP, 2017) was in the range of 226-322 tonnes.

The EU dental amalgam market and trade

The EU region has previously has previously been a major player in the dental amalgam market, but – thanks to gradually implemented measures, the demand in the EU is decreasing, and a rapid fall in the number of suppliers of dental amalgam is observed. The role of the EU region as supplier of dental amalgam is considered closer in this section.

For 2018, the estimated mercury input with dental amalgam in the EU28 was 27-58t/y, whereas earlier studies estimated an input of 55-95t/y around 2008[20].

The EU Medical Devices Regulation (MDR 2017/745), which entered into force in May 2021, has higher documentation requirements on health aspects needed for the certification of medical devices to be marketed in the EU. This has resulted in many suppliers of dental amalgam fillings leaving the EU market, or planning to leave, when their current certificates run out. 15 out of 23 suppliers listed had explicitly left the market or had certificates running out by early 2023[21].

Dental amalgam does not have its own customs code in the European Combined Nomenclature system (CN8; consistent with the Harmonised System, but with up to 8 digits).] However, CN codes potentially relevant to dental amalgam, including semimanufactures for dental amalgam capsules (such as mercury sachets) are shown in **Error! Reference source not found.Error! Reference source not found.** along with observations in the trends of the recorded international trade in and out of the EU; see the detailed background trade data in Annex 1 to this report.

Table 2 CN codes potentially relevant to dental amalgam

CN code	CN code name	Trade trends 2010-2022 (see data in Annex 1)
2805 40 10	Mercury: —In flasks of a net content of 34,5 kg (standard weight), of a fob value, per flask, not exceeding € 224..	After the 2012 EU mercury export ban, (actually after 2013), the export practically ceased, and thereafter the trade was insignificant with a small average net import.
2805 40 90	Mercury: ---Other	Fall in export after 2014 to marginal amounts, but significant increase from 2020; export peak (535t/y, a substantial part of the global mercury supply) in 2022. A moderate increase in export value is observed for 2018-2019, but thereafter the export value low, in spite of increases in export tonnage. The observed increases in export amounts coincide with entering into force of further restrictions on dental amalgam use n the EU (in July 2018 and January 2019). And the observed 2022 tonnage peak (at low value) happened right before the entering into force of the new MD Regulation prompting some dental supplier to leave the EU market (see text above).
2843 90 10	Colloidal precious metals; inorganic or organic compounds of precious metals,	In principle, dental amalgam capsules are not yet amalgams (as mercury and the other metals are not yet mixed), but due to the title,

[20] Deloitte and others for the European Commission 2020, accessed May 2023 at https://circabc.europa.eu/sd/a/4fd46a0f-54aa-48c6-8483-288ad3c1c281/Dental%20Amalgam%20feasbility%20study%20-%20Final%20Report.pdf

[21] According to https://environmentalmedicine.eu/manufacturers-exiting-the-amalgam-business-in-europe/, accessed May 2023.

	whether or not chemically defined; amalgams of precious metals: — Amalgams..........	it cannot be ruled out that some dental amalgam raw materials could be posted under this code. A net import is observed in most years (and on average), but a raise in export is observed from 2021 after a low periode. Export peaks are observed in 2012, 2013 and 2022; export value peaks in 2011-2013 and 2022.
2853 90 90	Phosphides, whether or not chemically defined, excluding ferrophosphorus; other inorganic compounds (including distilled or conductivity water and water of similar purity); liquid air (whether or not rare gases have been removed); compressed air; amalgams, other than amalgams of precious metals: 2853 90 90 —Other........	This code should logically not be associated with dental amalgams (as the silver content is considered “precious” metal), but it was included here as a possible (erroneous) use of custom codes. A significant net import is observed, except in 2022 (data for 2017-2022 only, for this code), with exports in the range of 3000-5000 t/y. IN 2022, the export was appr. 4500 t/y.
3006 40 00	Dental cements and other dental fillings; bone reconstruction cements.	This code appears to be the most logical to enter dental amalgam capsules in, but also the mercury-free alternative dental restoration materials, so a clear trend for amalgam cannot be deducted. A moderate and gradual increase in export and net export is observed throughout the periode (net export ca. 780-1800 t/y). Significant annual increase - average11% up per year - in export value to almost triple value in 2022 compared to 2010. This may be consistent with increased demand for mercury-free dental restoration materials.

Information on mercury-using manufacturing processes and their alternatives

This section describes the information received and gathered for the processes applying mercury.

5. Production of polyurethane using mercury containing catalysts

Minamata Convention coverage

Coverage after COP-4 (Annex B, part II):

Mercury using process	*Provisions*
Production of polyurethane using mercury containing catalysts	Measures to be taken by the Parties shall include but not be limited to: (i) Taking measures to reduce the use of mercury, aiming at the phase out of this use as fast as possible, within 10 years of the entry into force of the Convention; (ii) (ii) Taking measures to reduce the reliance on mercury from primary mercury mining; (iii) Taking measures to reduce emissions and releases of mercury to the environment; (iv) Encouraging research and development in respect of mercury-free catalysts and processes; (v) Reporting to the Conference of the Parties on its efforts to develop and/or identify alternatives and phase out mercury use in accordance with Article 21. Paragraph 6 of Article 5 shall not apply to this manufacturing process.

Under consideration for COP-5:
Inclusion of production of polyurethane using mercury containing catalysts in Annex B, part 1 (phase-out as per Article 5, paragraph 2: Parities shall not allow, by taking appropriate measures, the use…).

Mercury use in polyurethane production

In two-components polyurethanes, for many applications, the catalysts of choice for catalysing the reaction between a polyol and an isocyanate composition, i.e., for hardening or curing the polyurethane (PU) materials, have earlier been organic mercury compounds ((UNEP, 2023[6] and references cited therein). The catalyst in the polyurethanes remains in the final product.

In earlier years mercury was extensively used as a catalyst to promote a large range of polymer reactions. By 2008, mercury compounds were still important catalyst in the production of polyurethane elastomers, coatings, sealants and adhesives (so-called CASE applications). The mercury compounds were in particular used for polyurethane elastomers (flexible plastics) that are cast into sometimes complex shapes, or sprayed onto a surface as insulation, corrosion protection, etc.. Such polyurethane products can/could be seen as a wide range of end-products including for example rollers, flooring, gaskets, encapsulation of electronic components, shoe soles, shock absorption and re-pair of industrial installations.

The main mercury compounds used were phenyl mercury compounds, first of all phenylmercury neodecanoate. The content of the phenylmercury compounds in the catalysts was typically in the range of 60-70% by weight corresponding to 25-30% mercury by weight. The catalyst was added to the polyurethane at levels of 0.2-1%, depending on the other components and the desired properties of the poly-mer. Consequently, the phenylmercury neodecanoate concentration in the polyurethane product is on the order of 0.1-0.6% and the mercury content in the range of 0.05-0.3 % (Lassen et al., 2008). It was estimated that around 2007, about 300-350 metric tons/year of mercury catalyst may have been used globally in polyurethane applications (Lassen et al., 2008, as cited in UNEP, 2023[6]).

Today (2023), mercury compounds have been replaced in big parts of the global market for polyurethane catalysts; see below for further details.

As part of this study, no evidence was observed that mercury compound catalysts are in use in do-it-yourself construction products, and similar. Neither rigid polyurethane foam used for certain insulation and adhesive purposes in construction, nor polyurethane adhesives used for gluing wood or other construction materials and cabinetmaking have been found among the reported polyurethane uses that apply or have applied mercury catalysts. Several examples of polyurethane products for window-making have been found advertised as mercury-free. These are products used for (professional) assembly of multilayer insulation glass panes for windows and doors[22].

There are reports that historically, sports hall flooring and tracks made of polyurethane elastomers were catalysed with phenylmercury acetate. According to US sources, this practice was abandoned in the early 2000s[23]. Outdoor sports tracks and similar flexible surfaces in playgrounds, etc., can alternatively be made of granulated rubber from recycled vehicle tires, glued together with polyurethane elastomers[24]. In the EU, such polyurethane adhesives would be covered by the restriction of mercury compound catalyst. Beyond the USA and the EU, no information was found about mercury compound catalyst types used in sports halls and sport tracks.

Mercury-free alternatives

The use of mercury compounds was investigated in detail in the EU leading to a restriction (prohibition) on the use of the five most used mercury compounds as catalysts for polyurethane production (later, by 2018, the use of all mercury compounds was restricted in the EU, see below). The EU expert Committee for Risk Assessment (RAC) concluded – in the final step for adoption of restrictions for the se compounds in the EU – the following regarding alternatives to the five phenylmercury compounds listed above based on extensive research material[25]:

"*Identified alternatives are numerous. Three groups of alternatives were described: Same PU systems with non-mercury catalyst (using the same polyol and isocyanate components), other PU systems with non-mercury catalyst (reformulating the system using other polyol or isocyanate components), and nonmercury systems based on other polymers (e.g. silicones). Among these numerous alternatives described, DS has compared phenylmercury acetate, other phenylmercury compounds and methylmercury with the following possible alternatives to phenylmercury compounds: bismuth carboxylates, zinc carboxylates, zirconium carboxylates, titanium chelates and tertiary amines. When checking classification and potential PBT properties all these alternatives appear as less hazardous.*

Some organotins compounds were also mentioned as alternatives; for example for silicone and polyurethane systems, catalysts based on dibutyltin diacetate (CAS No 1067-33-0), dibutyltin dilaurate (CAS No 77-58-7), dimetylbis[(1-oxoneodecyl)oxy]stannate (CAS No 68928-76-7), dibutyltin oxide (CAS No 818-08-6) and dioctyltin dilaurate (CAS No 3648-188) can be used. However, entry 20 of Annex XVII of REACH already contains restrictions on organostannic compounds used as biocide in free association paint or to prevent the fouling, or used in the treatment of industrial waters. In addition, Commission Regulation (EU) No 276/2010 completes this annex XVII with a ban on tri-substituted organostannic compounds, and restrictions on dibutyltin compounds and dioctyltin compounds. These restrictions should be considered as a clear signal that organostannic compounds are not suitable alternatives (see also section C of BD containing information about PBT and CMR assessments of four groups of organostannic compounds).

Nevertheless, it should be underlined that this preliminary screening of CMR classification and PBT properties [of alternatives; Eds.] does not take into consideration the fate and behaviour of these potential alternatives in the environment and in living organisms during processing or use of articles, and thus does not replace a full risk assessment."

The ad hoc expert group on review of Annexes A and B[55] prior to COP4 states that the alternative catalysts mentioned above by the ECHA RAC are all currently available on the market.

[22] See for example https://www.igk.global/produkte/?lang=en, accessed May 2023.

[23] See for example https://mercury-instrumentsusa.com/blog/urethane-flooring-mercury-regulations, accessed May 2023.

[24] See for example https://www.genan.dk/anvendelsesomraader/sport-og-fritid/loebebaner/ (in Danish), accessed June 2023.

[25] Opinion on an Annex XV dossier proposing restrictions on Five Phenylmercury compounds ECHA/RAC/RES-O-0000001362-83-02/F, adopted 10 June 2011, accessed April 2023 at https://echa.europa.eu/documents/10162/7dcad2be-8b6c-4c43-bca5-d916e37d59f6. The document was the conclusion of a long decision process to restrict the five phenylmercury PU catalysts in the EU.

Stuart-Turner (2017)[26] reports that following the EU ban on mercury use in PU production, many companies now offer mercury-free polyurethane systems for contour ("domed") prints. The new mercury-free alternatives can be used with existing equipment, and are not sensitive to humidity, temperature and curing time as some earlier mercury-free alternatives were.

Kaul et al. (2010)[27] developed and tested mercury-free polyurethane adhesives to replace previously mercury-containing versions of the same polyurethane systems. The bulk properties and the ultimate performance of mercury and non-mercury versions were similar. The alternatives enable users to easily switch from the mercury version to the non-mercury version without worrying about a loss of performance in the final bonding. Only minor differences were observed in the curing profiles.

Some suppliers promote combined catalysts and "co-catalysts" use, or arrays of catalysts mixes, to fine-tune the curing profiles according to the specific needs of the end-products manufacturers such as long "pot-life", slow initial "front-end" curing to allow for pouring and spreading the blend in the mould, etc., quick "back-end" curing to shorten production time, moisture stability, etc. Examples are Evonik (2023)[28] and Guangzhou Yourun Synthetic Material Co., China (2023)[29], both offering catalysts systems for polyurethane CASE applications that are mercury-free, organotin-free and lead-free (CASE: coatings, adhesives, sealants, elastomers).

Market situation for mercury containing catalysts and alternatives

As part of the research done in the EU, the 2011 ECHA[30] report mentioned the following as regards uses of mercury compounds as catalysts in polyurethane production in the EU, meaning information from around 2007-2008:

"*It is estimated that 300-350 tonnes/year of mercury catalyst may be used globally in PU elastomer applications, of which some 60-105 tonnes/year in the EU (COWI and Concorde East/West[31], 2008). The report use the term "elastomer", which is the main application area, but the estimate seems to cover all CASE applications. This corresponds to an EU + EFTA consumption of approximately 36-70 tonnes phenylmercury neodecanoate. With 44.7% mercury it corresponds to a total mercury content of approximately 16-31.3 tonnes/year. The estimate has for this report been confirmed by the major supplier of the catalysts as being reasonable. Further < 1 tonnes of other phenylmercury compounds (phenylmercury acetate and phenylmercury 2-ethylhexanoate) may be used for the production of PU systems……*

The mercury-catalyzed PU two-component systems with phenylmercury neodecanoate are in particular used for the following CASE applications:

- *Spraying onto a surface as insulation or corrosion protection (coating);*
- *Adhesives.*
- *Sealants and filling materials;*

[26] Richard Stuart-Turner (2017): «Royal Adhesives shows mercury-free doming system at Fespa », accessed April 2023 at https ://www.printweek.com/product-news/article/royal-adhesives-shows-mercury-free-doming-system-at-fespa and: «Kimjaya shows mercury-free doming resins at Fespa» at https://www.printweek.com/productnews/article/kimjaya-shows-mercury-free-doming-resins-at-fespa.

[27] Hans Kaul, Frank Tran and Melanie Wyatt (2010): Mercury-Free Polyurethane Adhesives. Accessed April 2023 at https://www.adhesivesmag.com/articles/89189-mercury-free-polyurethane-adhesives.

[28] Evonik (2023): Additives For Polyurethane CASE Applications – EMEA, accessed April 2023 at https://products.evonik.com/assets/42/86/244286.pdf

[29] Guangzhou Yourun Synthetic Material Co. (2023) : CUCAT Series of Bubble Free Catalyst. Accessed April 2023 at https://www.gzyourun.com/functional-pu-catalyst/cucat-series-of-no-foaming-pu-catalyst.html

[30] Committee for Risk Assessment (RAC); Committee for Socio-economic Analysis (SEAC), July 2011: Background document to the Opinions on the Annex XV dossier proposing restrictions on five Phenylmercury compounds ECHA/RAC/RES-O-0000001362-83-02/S1. Accessed April 2023 at https://echa.europa.eu/documents/10162/4a6220f3-abf4-06dc-b880-23dc139b981b

[31] COWI and Concorde East/West (2008): Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society. For the European Commission. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/13873/ECstudy_report2008.pdf?sequence=1&isAllowed=y

- *Casting of complex shapes of PU elastomers (poured or injected into a mould); Elastomers are polymers with the property of elasticity and are sometimes designated "synthetic rubbers".*

According to a major supplier of catalysts, elastomers take up about 90% of the market of mercury catalysts while about 10% is used for sealants. For adhesives and coatings, according to the supplier, the mercury use is today small while organotin or amine catalysts are the major catalysts for these applications. However, other information indicates that the mercury catalysts are still widely used for coatings."

The same report also lists the following detailed examples of applications of PU systems with mercury catalyst specifically mentioned by suppliers (appr. 2011 status in the EU):

Application	Product
Two-component, elastomeric materials for repairing, rebuilding or creating rubber. Applications include pumps, diaphragms, drive couplings, flexible moulds, shock absorbers, guide bearings, rubber linings, seals, deburring machines, ship fenders, filter casings and conveyor belts.	The Belzona 2100 series (UK) (Belzona, 2009)
2-component polyurethanes that cure at room temperature to tough rubber-like materials, remaining flexible at temperatures down to even -60°C. For making: Vibration dampers, assembling jigs, flexible seals, rubber-like prototypes, foundry patterns and forms For repairs on: Conveyor belts, solid rubber tyres, conveyor rollers For coatings on: Rollers, centrifuges, polishing drums, tanks, chutes and funnels, pumps, bulk containers, dry and wet mixers, cyclones, housings, loading areas. In addition suitable as vibration or insulation protection of machines.	WEICON Urethane 45, 60, 80 (Germany) (Weicon, 2009) Urethane 45 and 60 with phenylmercury neodecanoate, catalyst of Urethane 80 not indicated
Clear polyurethane compound for use on decals, labels, emblems and other decorated substrates	Z-8200 (U.S.A) (Development Associates, 2009)
Self-levelling sealants for penetration into joints of concrete flooring.	Permaflex B Gun Grade (UK) (Permaban, 2009)
For the production of film or theatre props where a firm flexible urethane moulding is required such as reproduction of weapons, etc.	J-Foam 130 (UK) (Jacobson Chemicals, 2009)
Film and television props and special effects applications for embedding hairs and for creating skin effects; Soft encapsulant for low voltage electronic assemblies; Soft seals or gaskets; General purpose mouldmaking; Rubber use as a mould backing material for silicone mould liners where a soft silicone requires firm but flexible support; Wear resistant coating for polyurethane foam and as a general purpose coating or repair system for items such as buoys fenders and conveyor belts. Electronic encapsulation and modelling display applications. Artistic and modelling display applications	E1105, E1118, XE1013, E106, E053 XR3002, XR3006 (UK) (Polymed, 2009) Indicated as "organic mercury catalyst"

As regards coatings, the ECHA 2011 report cites the trade organisation ALIPA (2009) for the following examples of uses of one of the polyurethane systems – aliphatic isocyanates – applying mercury compounds in coatings, for which replacing mercury catalysts was considered challenging, however achievable, at the time:

- Automotive coatings, applied both as original equipment (OEM) and in car repair. Transportation applications such as aerospace, railway equipment, trucks and buses.
- Agricultural, construction and earth moving machinery.
- Plastic articles and components: bumpers, wheel covers, rear mirrors, door handles as well as phones, computers, skis, HIFI equipment, kitchen ware.
- Wood Coatings: parquet flooring, heavy duty and high quality furniture for kitchen, school, counters.

- Maintenance & Protection Coatings: heavy industry anticorrosion (metallic structures), high performance decorative finishes.
- Marine: superstructure, topsides and decks of ships and yachts.
- Coil & Can Coatings: buildings (cladding and roofing), appliances, transport, packaging.
- General Industry: motorcycles, bicycles, metal office furniture.

Extensive research was conducted for selected mercury-added products for the 2019 update of the UNEP Mercury Inventory Toolkit[32], including polyurethanes (PU), as recently mercury catalysts have only been applied in a narrow array of final products. Even the product types, where mercury catalysts have been applied recently, were reported as being widely produced with mercury-free catalysts.

While relevant PU product types are imported to most countries, fewer countries have manufacturing nationally.

1066. The use of mercury compounds as catalysts in polyurethane was restricted several years ago through the September 2012 EU Commission Regulation No.848/2012 amending the REACH regulation’s Annex XVII by adding the following five phenylmercury compounds used as catalysts in polyurethane (PU) elastomer production to a list of restricted substances:

- Phenylmercury neodecanoate (CAS # 26545-49-3)
- Phenylmercury acetate (CAS # 62-38-2)
- Phenylmercury 2-ethylhexanoate (13302-00-6)
- Phenylmercuric octanoate (CAS # 13864-38-5)
- Phenylmercury propionate (CAS # 103-27-5)

After October 10, 2017, these five compounds can no longer be manufactured in the EU, placed on the market or used as a substance or in mixtures, in articles (= final products) or parts of articles in EU-based manufacturing, if the concentration of mercury is equal to or greater than 0.01% by weight.

As of January 2018, all mercury containing catalysts use in polyurethane productions was prohibited with the EU mercury Regulation (EU Reg. 2017/852; see the EU submission[33] for the Annex A and B inter-sessional work).

In principle, many other organomercury compounds can be used as catalysts in polyurethane production. In 2018, at least two additional mercury compounds were marketed for use as a catalyst in PU systems: [μ -[(oxydiethylene phthalato)2-)]] diphenylmercury (CAS No 94070-93-6) and bis(phenylmercury) dodecenylsuccinate (CAS No. 27236-65-3) (ECHA, 2011). The research conducted for the 2019 Toolkit update showed that these compounds were available for sale globally, but to a lesser extent than the five compounds listed above.

Several of these phenylmercury compounds are reported to have (had) other uses[33]. Phenylmercury acetate has traditionally been used as fungicides in agriculture, particularly for seed dressing. Phenylmercury 2-ethylhexanoate has been used as a pesticide and as a biocide (bactericide, fungicide) in paints. Phenylmercury propionate is also reported to have been used as a fungicide, microbiocide and herbicide. The use of mercury compounds in pesticides and paints is believed to have been reduced or abandoned globally, but it cannot be ruled out that some of the mentioned uses still take place (outside the EU).Some polyurethane products were in 2019 marketed as mercury-free and those were in most cases polyurethanes for insulation of windows (not known as a major area for use of mercury compounds).

[32] Toolkit for identification and quantification of mercury releases, Reference Report, UNITAR for UNEP, 2023, accessed March 2023 at https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-inventory-toolkit.

[33] See all the submission to the Annexes A and B inter-sessional work from the Parties and other stakeholders at https://mercuryconvention.org/en/meetings/cop5#sec1562

As of 2023 many catalyst suppliers advertise their polyurethane catalyst as free from mercury; besides the companies mentioned in the section above on alternatives, some examples are given in the footnotes[34].

The research conducted for the 2019 Toolkit update showed that mercury compounds usable as catalysts for polyurethane production were still available for sale from different companies and laboratories. Several companies sold phenylmercury neodecanoate, mentioning that it is intended for use as a catalyst for polyurethane synthesis (a number of companies are mentioned in the Toolkit Reference Report).

The only reply from 2019 offering mercury catalysts in quantities ranging from 25 mg to 500 mg was received from a seller via Indiamart , but it was not clear which company (the initial request was probably forwarded to potential sellers).

Thor Specialties (2019, UK, as cited in the Toolkit Reference Report), formerly a major supplier of mercury compounds for polyurethane production, informed that they have not supplied mercurial polyurethane catalysts since 2013-2014, but they recall that also companies in China and India supplied these chemicals (they could not name the companies however). This is consistent with other findings in the 2019 Toolkit update.

An assessment of data from the Rotterdam Convention's PIC notifications as part of the 2019 Toolkit update, revealed import and export from EU countries of various mercury compounds – though not specified as for polyurethane use – , including diphenyl[mu-[(tetrapropenyl)succinato(2-)-O:O']]dimercury (alternative), (neodecanoato-O)phenylmercury and phenylmercury acetate in the period 2014-2016, but not in 2017 (no data available after 2017 at that time). The individual quantities could not be distinguished, as they were reported as a whole group of mercury compounds. The reporting import countries from the EU (UK, Spain, Italy, Belgium, France, Germany) also reported export of mercury compounds in 2014 and 2015 (before the EU restrictions mentioned above entered into force).

As part of the present study, extensive research was again conducted. Identified and contacted companies offering mercury compounds relevant for catalysis of polyurethane products and production are listed in Annex 2. The questionnaire sent to the companies is shown as Annex 4. Several of these also offer mercury-free polyurethane catalysts. The identified suppliers can be grouped as follows. It should be noted that marketing of these mercury compounds is not restricted for a Party under the Minamata Convention, unless manufactured, imported or exported for other uses than those allowed under the Convention:

- Eight manufacturers in China offer organic mercury compounds that can be applied as catalysts in polyurethane production or products. None of the eight companies have responded to repeated inquiries by email, phone calls and website contact forms (the latter in cases where no functioning email addresses could be identified).
- Three manufacturers in India offer organic mercury compounds that can be applied as catalysts in polyurethane production or products. One of these companies mentions former exports to Yemen, Bangladesh, Saudi Arabia, Pakistan, Egypt in their sales text. One company stated that they had no current sales of these chemicals., and one company informed that they have some customers using these mercury compounds in polyurethane production, but have not provided more detailed information.
- Seven general suppliers of laboratory chemicals from Canada, China, India and the USA offer organic mercury compounds that can be applied as catalysts in polyurethane production or products. None of these companies have replied to inquiries for this study.

[34] Some other examples of polyurethane catalyst suppliers offering mercury-free catalysts; identified via a Google search of mercury-free polyurethane catalysts; all accessed April 2023: https://products.evonik.com/assets/42/86/244286.pdf; https://www.alchemie.com/news/new-mercury-free-water-clear-crystal-cast-polyurethane-systems.html; https://liquid-lens.com/machines-supplies/advanced2-resin-cartridges/; https://syntecshop.com/en/easyflo-60-polyurethane-resin-shore-d-65-fast-curedlow-viscosity; https://www.eci-limited.de/en/; https://patchamltd.com/wp-content/uploads/2020/04/PATcat-7001-Flyer-19.0.pdf; https://csm.umicore.com/en/applications/pu-catalysts/; (continued next page); https://www.uskoreahotlink.com/products/manufacturing/non-toxic-pu-catalysts/; https://www.dorfketal.com/industry-solutions/specialty-catalysts/polyurethane-polyureas; https://www.kingindustries.com/k-kat-xk-604/; https://www.mingxuchem.com/metal-catalyst/;

The Indian Polyurethane Association (IPUA, 2019, as cited in the Toolkit Reference Report) stated that according to discussions with the IPUA members from the elastomer section, no members were using mercury-based catalysts as of 2019.

As part of the present study, 31 industry associations operating globally, in Canada, China, Bangladesh, Brazil, India, Malaysia, Mexico, New Zealand, Korea (Rep.), South Africa, Taiwan, Thailand, Turkey and the EU, were contacted about their knowledge of any remaining use of mercury compounds as catalysts for polyurethane products and production. The replies received after extensive follow-up to the contacted associations are summarised below. The associations contacted are listed in Annex 3. The questionnaire sent to (non-EU) trade associations is shown as Annex 4 (same questionnaire as to supplier companies).

The Comissão Setorial de Colas, Adesivos e Selantes (glues, adhesives and sealants commission) of the Brazilian Association of Chemical Industries (Associação Brasileira da Indústria Química; ABIQUIM[35]) informed that one of their members (a global chemicals supplier) did not use mercury compound catalysts for polyurethanes in Brazil. Another global and regional chemicals supplier replied that to their knowledge, mercury compounds were not used for any polyurethane use in South America. A third member replied that this use of the mercury compounds was not relevant to them. Other members did not reply to the questions posed.

The Malaysian Paint Manufacturers Association (MPMA[36]) informed that their members do not use mercury in polyurethane coatings.

The Mexican chemicals industry association's, PU section, La Asociación Nacional de la Industria Química, A.C. (ANIQ[37]), informed that no use of mercury compound catalysts in polyurethane production or products manufacture was identified in the country.The Canadian Paint and Coatings Association (CPCA) informed that one Canadian-based paint and coatings manufacturer is using mercury compound catalyst in (mostly) industrial coatings.

Information provided by the Canadian polyurethane industry was that polyurethane manufacturers have been working towards a mercury free product since the 1990s. The preferred catalyst was mercury neodecanoate which was typically purchased from agricultural suppliers as it was used as an antifungal agent for food products. There are two types of urethane 1) foams which account for about 90% of the market and do not require mercury; and 2) casting adhesive sealant elastomers (CASE), which have been produced using mercury. Most of the North American market has transitioned to mercury-free production processes, although, there are some products for which mercury-catalysts produce superior quality items. For example, CASE products that are used in highly abrasive or high impact environments cannot be made to the same quality with non-mercury alternatives. These types of products would be used in the mining, automotive, and manufacturing industries to protect parts and machinery.

In anticipation of a phase out of mercury use through domestic regulations, Canadian polyurethane producers have discontinued the use of mercury in their processes by using a combination of a number of mercury free catalysts. However, the industry reported that some customers were not able to use their mercury free products because the properties of the final products were not the same as those made with mercury catalysts. Additionally, the longer curing times for mercury-free catalysts has dropped their production efficiency.

The industry noted that mercury catalysts are less volatile and do not form carbon dioxide when associated with water like mercury-free catalysts do. Because the mercury catalysts are hydrophobic, they do not produce bubbles forming in the end product. For hard plastics and coatings, bubbles are not desired because it weakens their strength. Mercury catalysts have a long life, quick gel time, and quick development of properties (12-24h) compared to the alternatives (24h to 7 days). In order to achieve a mercury-free product with the same properties as one made with mercury it is necessary to control moisture and humidity. This comes at a much higher cost to the producers. Customers are accepting a lower quality product, and have complained to the manufacturers about the quality and longevity of the mercury-free products. For example, according to the industry, a product made with mercury could last 70 years and the lifespan of the alternative is about 20% of that. Some customers

[35] Direct contact with ABIQUIM, May and June 2023.

[36] Direct contact with MPMA, May 2023.

[37] Direct contact with ANIQ, May and June 2023.

are able to substitute the polyurethane for epoxies, resins, or rubber alternatives, but this substitution cannot be done for all purposes.

In 2017, Japan[38] 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'.

The Center for the Polyurethanes Industry (CPI[39], USA) informed that mercury compounds are believed to be no longer in use in the USA.

The Polyurethane Manufacturing Association (PMA, 2019, as cited in the Toolkit Reference Report) provided the following information: "*Traditionally, mercury catalysts were used in room temperature processable and curable systems, particularly those that are used outdoors where there is potential water exposure. Mercury catalyst is unique in that it is active down to about 40 F and it does not promote the water reaction which can cause bubbles or foaming. To our knowledge, most of this industry has switch away from mercury*."

PMA, a USA based association with global outreach, was contacted again for the present study[40]. They noted that the industry generally had moved away from the use of these mercury compound catalysts, and that the estimated share of relevant products and formulations with mercury compounds was now <1% globally. They had however identified one Australian global supplier of polyurethane systems, supplying raw materials for final manufacture by others, that was phasing down mercury compounds catalyst use, but still used it in some of their formulations. The largest end-use is cold-cast (room temperature) production of very large moulds for casting of concrete objects (as mercury catalysts give a long "front-end" curing time needed for making the moulds). Use for cold casting of clear polyurethane products was also mentioned as a continued use of mercury compound catalysts. PMA mention that some users have observed performance shortcomings with some mercury-free alternative catalysts, particular in regard to tackiness of the material upon room temperature cure. PMA, which – according to themselves – mainly represents the "hot cast" polyurethane elastomer segment, however supports a global phase-out of mercury compound catalysts for polyurethane products and processes. PMA noted that to their knowledge, there is no trade association specifically representing cold cast polyurethane elastomers segment.

The Adhesive and Sealant Council, Inc. (ASC[41], USA) informed that their PU members removed mercury compounds from all processes over 20 years ago.

The USA informed for the pre-COP4 review of Annex B processes[55], that neither their 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.

The use of mercury compounds in the polyurethane sector is severely restricted in the EU, implying that there are technically and economically feasible alternatives available (as confirmed below). The pre-COP4 ad hoc expert group on review of Annexes A and B[55] cites COWI/Concorde (2008) and ChemEurope (2019) for the information that non-mercury catalysts are available for the majority of applications and are used as catalysts in over 95% of polyurethane elastomer applications (ChemEurope, 2019). The expert group further state (citing ChemEurope, 2019) that bismuth and zinc carboxylates have been adopted as catalysts for many decades, and are designed to replace the use of mercury, lead and tin catalysts. These bismuth and zinc carboxylates catalysts have displayed commercial success, despite their shortcomings relative to mercury. The ad hoc expert group further states (in 2021) that only non-mercury alternatives are used for manufacturing of polyurethane in the EU.

[38] National Implementation Plan for Preventing Environmental Pollution of Mercury and Mercury Compounds. (Japan). Available at: http://www.mercuryconvention.org/Portals/11/documents/NIP/Japan_NIP_EN.pdf . As cited in the processes compilation document of the pre-COP4 ad hoc expert group on review of Annexes A and B.

[39] Direct contact with CPI, June 2022.

[40] Direct contact with PMA, May 2023.

[41] Direct contact with ASC, May and June 2023.

Euro-Moulders[42], a European association of moulders of polymer vehicle parts, described the experience with the accomplished substitution of mercury compound catalysts for polyurethane applications in the EU for this study based on feedback from members. They state that the main alternatives for organic mercury compounds as catalysts for PUR applications are based on special amine compounds. The change has been achieved by optimizing existing formulations and adding certain compounds to mitigate performance gaps. The organic mercury performance is described as unique because of long pot life (long processing time), snap cure (very fast curing process) and robustness towards contamination. The new generation of catalysts replacing organic mercury catalysts comes close to this unique performance, but is not a drop-in. Euro-Moulders state that the costs-in-use (= unit price times use level) is very similar to organic mercury catalysts.

A global polyurethane systems supplier informed, on behalf of the trade association ALIPA[43], about the experience in the EU to this study. They mentioned tin and amine based catalysts as key replacements for mercury compounds. This change has required reformulations, and the use of a more diverse palette of formulations, instead of the single very flexible mercury compound catalysed system. Particular challenges have been in wet-on-wet (multiple layer) castings, for example for mining screens, and in water exposed static applications. In wet-on-wet castings, the challenge has been overcome by using a blend of non mercury catalyst in combination with adaptation of the process (shorter casting time, change in hardness for example). For water exposed static applications, anti fungi additives are applied, causing additional costs. Overall, however, the costs of using the non-mercury alternatives have now reached feasible levels again.

Similarly, FEICA[44], the EU-based trade association for manufacturers of adhesives and sealants provided information on polyurethanes for this study based on feedback from members. The main alternative catalysts mentioned are amine, bismuth, some titanium-based catalysts, as well as some tin-based catalysts, used to generate the same delayed action cure profile as mercury compounds give. Processes were reviewed. For example, cure times did reduce slightly. Handling was adjusted as well, due to extra intolerance to water of the systems. Reformulations were inevitable due to differences in reaction profile – some for the better. Some were more challenging in nature due to casting sizes, etc. According to FEICA, casting size, water tolerance and reactivity profile (gel versus maintaining demould time thus reducing differences in production output) were challenging, but good close customer support, and knowledge of the process and final applications played a big factor in making the changes away from mercury. Close customer support and relationships definitely influenced the willingness to change. Costs were around even as the alternative catalysts are more expensive but generally used in lower quantities – all in all cost neutral.

According to CEPE[45], the European coatings and inks manufacturers association contacted for this study, members state that mercury compounds have not been used for very many years in the EU (if ever) for coatings and inks. They mention that popular alternative catalysts for 2-K PUR are organic tin compounds like for example DBTL (dibutyltindilaurate) and some other dibutyltin diesters (-octoate, etc.), as well as bismuth, zinc compounds and tertiary amine compounds, for example DABCO (1,4-diazobicyclo{2,2,2}octane) or other non-protic tertiary amines. CEPE members conveyed that with these substances, the change away from mercury can be achieved with reformulation with no other new raw materials. No extraordinary challenges were observed, including the costs.

In conclusion, a minor use of mercury compound catalysts in polyurethane production and products remains in 2023, for example in some cold cast elastomers, but no evidence was observed that indicate that this use of mercury compounds is essential. Mercury-free alternatives seem to be available for all relevant uses, and are generally assessed as technically and economically feasible by industry in a region where regulation prohibiting mercury compound use for this purpose entered into force some years ago (the EU). Some companies in Parties, where regulation has not yet entered into force, mention reduced quality and higher costs for some uses.

[42] Direct contact with Euro-Moulders, representing the European manufacturers of moulded PU parts for the Automotive Industry, July 2023.

[43] Direct contact with ALIPA - European Aliphatic Isocyanates Producers Association (raw materials suppliers for polyurethane production) – and one of its members, June and July 2023.

[44] Direct contact with FEICA July 2023.

[45] Direct contact with CEPE, July 2023.

Data submitted for Annex A and B work and in §21 reports

As mentioned above, the submission for the Annexes A and B inter-sessional work from the EU[33] states that with its Mercury Regulation (EU 2017/852) that use of mercury or mercury compounds, whether in pure form or in mixtures, in manufacturing processes, is prohibited, including "from 1 January 2018: the production of polyurethane, to the extent not already restricted or prohibited in accordance with entry 62 of Annex XVII to Regulation (EC) No 1907/2006."

As part of its Article 21 report to the Minamata Convention[46], Canada reported the following:

"Canada's Products Containing Mercury Regulations requires facilities to report triennially on the quantities of mercury used in catalysts for polyurethane production. In 2016, there were fewer than five polyurethane production facilities using mercury-containing catalysts, all located in the province of Ontario. The five listed measures in Part II of Annex B are addressed predominantly via implementation of the Government of Ontario's Toxics Reduction Act (2009) whereby these facilities have prepared a toxic substance reduction plan for mercury, and are taking measures to reduce the use of mercury in their processes. Since 2017, one of these facilities has phased out its mercury use. Under the proposed amendments to the Products Containing Mercury Regulations the use of mercury for polyurethane production will be prohibited by 2028. The Government of Ontario has additional measures in place to address any potential emissions and releases of mercury to the environment from industrial facilities…"

"Based on the most recent available data under Canada's Products Containing Mercury Regulations, in 2019 the remaining facilities using mercury-added catalysts for the production of polyurethane reported using a combined 22.3 kg of mercury. This is a reduction from 2016 when 28.9 kg were reportedly used in polyurethane production. Since reporting is done on a triennial basis, no data is available for the years 2017, 2018 and 2020."

Uganda wrote in its Article 21 report (and also referred to PU in its submission to the Annexes A and B inter-sessional work): "*The National Minamata Initial Assessments report of 2018, revealed annual total mercury emissions of 197.64 kg from Production of polyurethane using mercury containing catalysts[47]. On 22nd October 2021, during a national stakeholder preparatory meeting for COP4.1, it was reported that polyurethane using mercury as a catalyst may be used in a wide range of products in Uganda including production of adhesives and mattresses. When products get exposed to Ultra Violet light, abrasions etc. mercury is released. … However, continued national stakeholder engagement on mercury pollution in 2021, revealed that in Uganda, polyurethane using mercury as a catalyst is used in a wide range of products like adhesives, mattress production. It would require an updated inventory of mercury sources to be able to confirm which facilities could be producing polyurethane using mercury as a catalyst…"*

Ghana wrote in its Article 21 report: "*There are no known facilities engaged in the primary production of polyurethane using mercury-containing catalysts. However, there might be potential sources of mercury or mercury compounds used in the secondary production of polyurethane foams. There is Ghana Standard for Environment and Health Protection – Requirement for Ambient Air Quality and Point Source/Stack Emissions (GS 1236:2019). This set the limit for environmental emissions which includes mercury and mercury compounds*".

Upon follow-up contact from the Minamata Convention Secretariat, the Ghana Minamata focal point confirmed that there was a potential for mercury use in polyurethanes in the country, but that it was not yet confirmed by specific data.

India wrote in its Article 21 report: "*Use of mercury containing catalysts has discontinued in Polyurethane production*."

The countries listed below answered as part of their Article 21 report, "Not applicable (do not have these facilities)" to the question "5.3. Are measures in place to restrict the use of mercury or mercury compounds in the processes listed in Part II of Annex B in accordance with the provisions set out therein? - Production of polyurethane using mercury-containing catalysts":

- Antigua and Barbuda

[46] All Article 21 reports are available at: https://mercuryconvention.org/en/parties/reporting/2021.

[47] Based on the Uganda MIA, the number may indicate potential use of mercury catalysts in polyurethane products sold in Uganda. The UNEP Mercury Inventory Toolkit methodology applied roughly estimated total sales of mercury-containing catalysts in polyurethanes, but did at that time not specify if the polyurethanes were produced domestically or imported.

- Argentina
- Austria
- Bahamas
- Benin
- Bolivia (Plurinational State of)
- Brazil
- Bulgaria
- Burkina Faso
- Chad
- Chile
- China
- China (Macao SAR)
- Congo (Republic of the)
- Costa Rica
- Côte d'Ivoire
- Croatia
- Cyprus
- Czechia
- Djibouti
- Dominican Republic
- Ecuador
- El Salvador
- Equatorial Guinea
- Estonia
- Eswatini (Kingdom of)
- Finland
- France
- Gabon
- Gambia
- Germany
- Guinea
- Guyana
- Honduras
- Iceland
- Indonesia
- Iran (Islamic Republic of)
- Ireland
- Jamaica
- Japan
- Jordan

- Korea
- Kuwait
- Lao People's Democratic Republic
- Latvia
- Lebanon
- Lesotho
- Liechtenstein
- Lithuania
- Luxembourg
- Madagascar
- Mali
- Malta
- Marshall Islands
- Mauritius
- Mexico
- Moldova
- Monaco
- Mongolia
- Namibia
- Nicaragua
- Niger
- Nigeria
- North Macedonia
- Norway
- Oman
- Palau
- Panama
- Paraguay
- Peru
- Philippines
- Portugal
- Romania
- Rwanda
- Saint Lucia
- Samoa
- Senegal
- Seychelles
- Sierra Leone
- Singapore
- Slovakia

- Slovenia
- South Africa
- Sri Lanka
- Suriname
- Sweden
- Thailand
- Togo
- Tuvalu
- United Kingdom of Great Britain and Northern Ireland
- United States of America
- Uruguay
- Vanuatu
- Viet Nam
- Zambia

6. Production of sodium or potassium methylate and ethylate

Minamata Convention coverage

Coverage after COP-4 (Annex B, part II):

Mercury using process	*Provisions*
Sodium or Potassium Methylate or Ethylate	Measures to be taken by the Parties shall include but not be limited to: (i) Measures to reduce the use of mercury aiming at the phase out of this use as fast as possible and within 10 years of the entry into force of the Convention; (ii) Reduce emissions and releases in terms of per unit production by 50 per cent by 2020 compared to 2010; (iii) Prohibiting the use of fresh mercury from primary mining; (iv) Supporting research and development in respect of mercury-free processes; (v) Not allowing the use of mercury five years after the Conference of the Parties has established that mercury-free processes have become technically and economically feasible; (vi) Reporting to the Conference of the Parties on its efforts to develop and/or identify alternatives and phase out mercury use in accordance with Article 21.

COP-4:

"*Requests* the secretariat to compile information on the availability and technical and economic feasibility of mercury-free alternatives in the production of polyurethane using mercury-containing catalysts and to submit it to the Conference of the Parties at its fifth meeting to facilitate its consideration of the matter described in paragraph 6 of the present decision;"

The text in the below section is, if not otherwise noted, based on a European Commission (2017) study[48].

Mercury use in alcoholates production

The four alcoholates were produced with mercury cell technology very similar to the mercury cell chlor-alkali production that has been abandoned by most users in recent decades. In the mercury cells,

[48] ICF/COWI (2017): Support to assessing the impacts of certain amendments to the Proposal of the Commission for a Regulation on Mercury. ICF/COWI for the European Commission, accessed March 2023 at https://ec.europa.eu/environment/chemicals/mercury/pdf/Final%20Report_KH0617141ENN.pdf

a floating mercury cathode is used for electrolysis, making sodium available for chemical reactions with added organic chemicals. This process was used for alcoholate production by two companies globally, both in Germany (in the EU).

Mercury-free alternative production and alternative techniques

The 2017 EC study cites COWI/BiPRO/ICF/Garriques (2015 status) for the following overview of alternatives to mercury cells for production of alcoholates.

Table 3 Overview of alternatives (in 2015) to mercury cells for production of alcoholates.

Alcoholate	Status on availability of alternative production methods	Remarks
Sodium methylate	Readily commercially available from production inside and outside the EU.	From 1) reactive distillation and 2) reaction of methanol with metal sodium (the latter with higher energy consumption). Production capacity may need to be raised.
Sodium ethylate	Commercially available from one producer globally (in Japan)	From reaction of ethanol with metal sodium (with higher energy consumption)
Potassium methylate	Not commercially available as of 2015, but about 30% of the biodiesel production from animal fats in the EU is based on self-production of potassium methylate for own use by biofuel producers. About 10% do not use alcoholates for biofuel production from animal fat (but instead strong acids and bases). The remaining about 60% uses commercially available potassium methylate (Hg based; Türck, 2016).	From reaction of methanol with metal potassium (with higher energy consumption). Biofuel producers can use other method (strong acids and bases) but sometimes with lower yield that makes production less economical and climate friendly
Potassium ethylate	Commercially available from one company globally (in India).	Availability may have been limited by 2015
All four alcoholates	Pre-pilot scale available, but was not considered sufficiently developed to transform to full scale operation by 2017.	Ceramic membrane process and reactive distillation

The market for alcoholates and alternatives

Sodium methylate is used in the largest volumes of the four alcoholates and primarily for “cracking” plant oils for bio-fuel production, but also for production of pharmaceuticals, food ingredients and pigments. Potassium methylate is primarily used for “cracking” animal fat and used cooking oils for biofuel use. Sodium ethylate and potassium ethylate was used (in 2016) in minor volumes in the EU, primarily for synthesis of pharmaceuticals, pesticides, aroma substances, coatings, edible fats and fine chemicals.

According to COWI/ICF/BiPRO/Garriques (2015)[49], the global market for sodium methylate in 2013 was estimated at 480,000 metric tonnes (sold as a 30% solution in methanol), of which 250,000 – 300,000 tonnes were produced with mercury cell technology in the EU. COWI/ICF/BiPRO/Garriques (2015) lists the production of sodium ethylate and potassium methylate as in the range of 1,00-10,00 tonnes/y, and the production of potassium ethlate as <100 tonnes/y, all based on REACH registration

[49] Based on COWI/BiPRO/ICF/Garriques (2015): Study on EU Implementation of the Minamata Convention on Mercury. For the European Comission. Accesssed march 2023 at https://ec.europa.eu/environment/chemicals/mercury/pdf/MinamataConventionImplementationFinal.pdf

status. It should be noted that sodium methylate is the substance that was assessed as the least problematic as regards substituting the mercury cell process, being already widely produced by other methods as indicated by the production numbers.

Technical and economical feasibility of alternatives

The European Commission 2017 study concluded that **sodium methylate** from non-mercury processes was commercially available in significant amounts.

The commercial availability of the **three other alcoholates** with smaller use volumes in the EU varied and was questioned for some of them, though examples of alternatives existed, and they were commercially produced in Japan and India, respectively, at the time.

Alternative processes for the production of all four alcoholates in the same type of process were in development in pre-pilot scale since 2012 (or earlier), but in 2016 it was not established if the method was suitable for large scale production. With sodium methylate supplied in the largest quantities among the three alcoholates, the two European companies using the mercury-cell process at the time stated that continuation of the production of sodium ethylate, potassium methylate and potassium ethylate was not considered economically viable for them in case the production of sodium methylate with the mercury process was prohibited in advance of the others.

European downstream users of the alcoholates were contacted in that study. According to the response from the European Biodiesel Board (EBB), the supply of the alcoholates (from mercury-cells) was not a critical issue for the industry while two organisations (ECPA and CEPE) reported that no downstream users were identified. The exception is the case of production of pharmaceuticals, for which EFPIA reported three downstream user companies that were each dependent on the availability and reasonable price of some of the three minor alcoholates. The alcoholate producers using mercury cells also identified a number of downstream users which were dependent on the three minor alcoholates.

As per the EU submission on Annex B[50], the EU Regulation 2017/852 on mercury exempted the use of mercury cells for alcoholates production until 1 January 2028. According to the ICF/COWI 2017 study, this time frame was considered challenging but feasible by the two companies using mercury cells for alcoholates production. The EU mercury Regulation imposes severe restrictions and mercury emission and releases reduction measures on the remaining mercury cell based production, including a commitment to not increase the mercury-based production capacity and supporting research and development of mercury manufacturing processes.

7. Production vinyl chloride monomer (VCM)

Minamata Convention coverage

Coverage after COP-4 (Annex B, part II):

Mercury using process	*Provisions*
Vinyl chloride monomer production	Measures to be taken by the Parties shall include but not be limited to: (i) Reduce the use of mercury in terms of per unit production by 50 per cent by the year 2020 against 2010 use; (ii) Promoting measures to reduce the reliance on mercury from primary mining; (iii) Taking measures to reduce emissions and releases of mercury to the environment; (iv) Supporting research and development in respect of mercury-free catalysts and processes; (v) Not allowing the use of mercury five years after the Conference of the Parties has established that mercury-free catalysts based on existing processes have become technically and economically feasible; (vi) Reporting to the Conference of the Parties on its efforts to develop and/or identify alternatives and phase out mercury use in accordance with Article 21..

[50] EU submission on Annex B, accessed March 2023 at https://mercuryconvention.org/sites/default/files/documents/submission_from_government/EU%20submission%20on%20Annex%20B%20-%2021.12.2022.pdf

COP-4:

"Also requests the secretariat to prepare, for consideration by the Conference of the Parties at its fifth meeting, a short report on the technical and economic feasibility of mercury-free alternatives for the two processes (vinyl chloride monomer, and sodium or potassium methylate or ethylate) listed in annex B, part II, that refer to the Conference of the Parties establishing such feasibility, and, in so doing, to first identify those Parties that have reported the use of those two processes in their national reports under article 21, and then request information from those Parties regarding whether they continue to use those two processes, whether either is scheduled to be phased out nationally, and to what extent mercury-free alternatives are technically and economically feasible."

Mercury use and alternatives in VCM production

Two processes are used to manufacture vinyl chloride: The acetylene process, based on coal feedstock or natural gas, uses mercuric chloride on carbon pellets as a catalyst. The other process used is based on the oxychlorination of ethylene (without mercury use)[32,**Error! Bookmark not defined.**]. The latter uses oil derivatives as feedstock and is the dominant process outside China.

The GEF/UNIDO/China Project Document on mercury reduction in VCM production[51] (ca. 2017) gives an overview of non-mercury alternatives tested at different levels for VCM production based on acetylene (much of the research was done in China). Some of these technologies was at that time not considered technically adequate, and others – more promising – involving the use of precious metals (gold, platinum, palladium, etc.) in the catalysts, were considered economically challenging. A main part of the GEF project is to promote the further development and commercialization of non-mercury catalysts.

The GEF/ UNIDO/China VCM project's implementation report (covering the period 1 July 2022 – 30 June 2023[52]) describes further that "*In January 2023, FECO* [the executing agency, eds.] *held the expert meeting to review and assess the mercury-free evaluation applications[53] submitted by the 8 test units of the 5 PVC plants. The initial assessment points out some challenges:*

- *The economic feasibility of the Au-based [gold] mercury-free catalyst is unstable considering the volatility of gold price and the limited quantity of this resource.*

- *The technological feasibility of the Cu-based [copper] mercury-free catalyst needs further examination if spontaneous combustion could pose a risk to the process*."

According to information received for this study from the catalyst producer Johnson Matthey[54], one facility in China has recently implemented the gold-based (mercury-free) technology full scale, and one other facility in China and one facility in India have announced publicly that they are going to implement the gold-based technology full scale in their new facilities. Johnson Matthey also reported that three companies in China manufacture gold-based VCM catalysts and one company, also in China, manufactures copper-based VCM catalysts.

The market for VCM production with mercury catalysts

Worldwide around 100 facilities were earlier reported to use the mercury chloride technology (Chemical and Engineering News, 2010 as cited in the UNEP Toolkit Reference Report). The technology has been most extensively used in China, where the availability of coal as feedstock favoured the use of this technology. China has however issued a strategy to reduce mercury releases from the sector.

Outside China, the dominant VCM production method is the oil-derivatives-based ethylene process not using mercury. In the Russian Federation, four enterprises used mercury-dichloride around 2004. Their total mercury input and output balance at the time is presented in the Toolkit. One VCM facility applying mercury catalysts is operational in India.

[51] Demonstration of Mercury Reduction and Minimization in the Production of Vinyl Chloride Monomer in China. GEF ID 6921. Accessed April 2023 at http://www.thegef.org/projects-operations/projects/6921

[52] Project PIR report accessed September 2023 at https://www.thegef.org/projects-operations/projects/6921.

[53] The 5 PVC plants applied for support for testing the mercury-free technologies.

[54] Direct contact with Johnson Matthey, August and September 2023.

One facility in the EU used the mercury chloride technology until recently[55]. This use is however prohibited with the EU Mercury regulation since 1 January 2022 (EU submission for the Annex B inter-sessional work[50]).

The GEF/UNIDO/China Project Document[51] (ca. 2017), mentions that in China, the VCM/PVC sector consumes more than half of the total mercury supply in the country, accounting for 30% of world's total mercury consumption.

The GEF project document further describes that "*there were 15 companies producing mercury-containing catalyst with a total output of about 10,000 t in China in 2010. In 2014, the number of companies and the production of mercury-containing catalyst increased to 22 and 16,800 t respectively. […]. The inventory given mentions that about 800t of mercury is used in the VCM production in China, of which 60-90% in considered to end up in spent catalysts and waste activated carbon (most of this mercury is recycled).*

Currently [2017], high-mercury catalyst (HMC) containing about 10-12.5% mercuric chloride (HgCl2) is still the mainstream technology in the VCM/PVC sector. This technology has grown in usage and has been very cost effective over the past decades because China's coal and limestone reserves are abundant but oil resources are scarce. Low-mercury catalyst (LMC) containing 4%~6.5% HgCl2 has been developed and promoted as an alternative to high-mercury catalyst (HMC) containing 12% HgCl2 for the synthesis of VCM since 2010."

The GEF project document also states that China has enacted progressively stricter environmental policies and standards for the VCM industry over the past few years. However, at the time the reduction of mercury was still slow due to challenges with incentives, local enforcement, lower efficiency of low-mercury catalysts, etc..

[55] Ad hoc expert group on review of Annexes A and B for COP4; processes. Accessed April 2023 at https://mercuryconvention.org/sites/default/files/documents/submission_from_government/compilation_10_processes.pdf

Annex 1 – EU Trade data with relevance for dental amalgam for the period 2010-2022

CN8 code	CN code name	Trade flow	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2805 40 10	Mercury: —In flasks of a net content of 34,5 kg (standard weight), of a fob value, per flask, not exceeding € 224..	Import, t/y	10.65	43.56	10.31	2.06	0.89	1.34	0.04	0.00	0.05	NA	2.06	NA	0.00
		Export, t/y	474.11	105.01	33.24	71.94	0.01	0.01	0.00	0.31	0.45	NA	0.00	NA	NA
		Net exp., t/y	463.46	61.45	22.93	69.88	-0.87	-1.33	-0.03	0.31	0.40	0.00	-2.06	0.00	0.00
		Exp. value, mil. EUR/y	7.59	3.05	2.01	0.23	0.01	0.00	0.00	0.01	0.01	NA	0.0003	NA	NA
		Exp. value, EUR/t	16,012	29,043	60,481	3,246	401,071	364,714	338,000	29,223	32,346	0	0	0	0
2805 40 90	Mercury: ---Other	Import, t/y	163.42	43.55	33.09	54.32	9.32	50.28	13.63	84.62	1.31	0.49	11.03	3.95	3.24
		Export, t/y	541.44	317.40	321.72	386.48	232.80	3.81	1.50	0.26	6.88	3.63	151.62	184.92	534.79
		Net exp., t/y	378.02	273.85	288.62	332.16	223.48	-46.48	-12.13	-84.37	5.57	3.14	140.59	180.97	531.56
		Exp. value, mil. EUR/y	10.74	6.85	2.35	2.83	1.49	0.22	0.15	0.03	0.32	0.30	0.06	0.002	0.003
		Exp. value, EUR/t	19,829	21,576	7,293	7,323	6,394	57,297	100,869	123,699	46,337	82,272	414	11	6
2843 90 10	Amalgams of precious metals: —Amalgams..........	Import, t/y	10.37	13.14	26.33	13.13	17.21	4.80	2.87	40.19	29.03	28.80	10.37	22.09	30.49
		Export, t/y	7.16	11.14	13.77	15.54	6.35	7.01	5.90	4.56	3.93	3.42	3.46	10.34	18.85
		Net exp., t/y	-3.21	-2.00	-12.56	2.41	-10.86	2.21	3.02	-35.64	-25.10	-25.38	-6.91	-11.74	-11.64
		Exp. value, mil. EUR/y	1.40	2.46	3.16	2.45	1.90	1.99	1.94	1.68	1.43	1.19	0.91	1.28	2.32
		Exp. value, EUR/t	196,054	221,157	229,171	157,789	299,716	283,428	329,431	369,368	365,350	347,293	263,495	124,024	123,329
2853 90 90	-- Other amalgams than of precious metals.	Import, t/y								4,365	22,330	20,567	49,996	58,387	3,414
		Export, t/y								4,292	5,344	5,469	3,299	4,071	4,544
		Net exp., t/y								-72	-16,987	-15,098	-46,697	-54,316	1,130
		Exp. value, mil. EUR/y	NA	NA	NA	NA	NA	NA	NA	128	70	35	24	30	43
		Exp. value, EUR/t								29,896	13,041	6,468	7,287	7,441	9,464
3006 40 00	Dental cements and other dental fillings; bone reconstruction cements.	Import, t/y	1,599	1,724	1,603	1,468	1,459	1,374	1,391	1,302	1,415	1,480	1,003	1,346	1,399
		Export, t/y	2,380	2,487	2,678	2,547	2,629	2,752	2,839	2,808	3,233	3,332	2,334	3,204	3,202
		Net exp., t/y	782	762	1,076	1,078	1,170	1,378	1,448	1,506	1,818	1,852	1,332	1,858	1,804
		Exp. value, mil. EUR/y	298	324	397	406	406	446	474	501	576	625	473	710	884
		Exp. value, EUR/t	125,303	130,345	148,170	159,618	154,475	162,052	166,841	178,561	178,298	187,610	202,544	221,555	275,965

Annex 2 – Suppliers identified and contacted in this study of mercury compounds that can be used as catalyst in polyurethane products and production

Substance	Country of supplier	Link (accessed April/May 2023)	Remarks
Producers of chemicals contacted that offer relevant organic mercury compounds			
Mercury 2-ethylhexanoate	China	https://www.gsypu.com/metal-catalyst/	Offers both Hg and non-Hg PU catalysts.
Phenylmercury acetate	China	https://www.polyurethane-catalyst.com/buy-phenylmercury.html	Offers both Hg and non-Hg PU catalysts.
Phenylmercury neodecanoate	China	https://www.sincerechemical.com/product/neodecanoato-ophenylmercury-cas-26545-49-3	
Phenylmercury acetate, and others	China	https://www.keyingchem.com/search.do?q=phenylmercur	Does also offer other organomercurials that may have relevance as catalysts for polyurethane production: 4-(4-Dimethylamino-phenyl-trans-azo)-phenylmercury (1+), acetate, CAS 19447-62-2; 2-hydroxy-5-nitro-phenylmercury (1+), acetate, CAS 63468-53-1
[Hydroxy(phenylmercuriooxy)boranyl]oxy-phenylmercury, CAS # 6273-99-0	China	http://www.joxbio.com/products_detail_en/id/5.html	May have relevance as catalysts for polyurethane production, but not confirmed on the website.
Phenylmercury neodecanoate	India	https://www.abenterprisesindia.com/search.html?ss=Phenylmercury+neodecanoate	
Phenylmercury acetate	India	https://www.ottokemi.com/organomercury/phenyl-mercury-acetate-99.aspx	Mentioned as catalyst in polyurethane production as well as other uses (disinfectant, preservative, etc.)
Phenylmercuric 2-ethylhexanoate and phernylmercury neodecanoate	India	http://www.chloralchemicals.com/products/	
General laboratory chemicals suppliers contacted that offer			

relevant organic mercury compounds			
Phenylmercuric propionate, phenylmercury neodecanoate, phenylmercury acetate, phenylmercuric octanoate, and others	Canada	https://www.trc-canada.com/products-listing/?searchBox=phenylmercur&type=searchResult	
Phenylmercury acetate	India (and United Kingdom)	https://www.fishersci.co.uk/shop/products/phenylmercury-acetate-98-thermo-scientific/11334297 https://www.thermofisher.in/chemicals/shop/products/phenylmercury-acetate-98-thermo-scientific/ALF-037125-18	
phenylmercury acetate	India	https://www.lobachemie.com/mercury-salts-05225/PHENYL-MERCURY-ACETATE-CASNO-62-38-4.aspx	Hit on phenylmercury acetate (but with CAS 62-38-4, not – 2).
Phenylmercury 2-ethylhexanoate	USA	https://www.parchem.com/chemical-supplier-distributor/-2-ethylhexanoato-phenylmercury-147898.aspx	
Phenylmercury 2-ethylhexanoate	USA	https://www.benchchem.com/product/b078177	
Phenylmercury 2-ethylhexanoate	China	https://www.001chemical.com/chem/13302-00-6	
Phenylmercury 2-ethylhexanoate	India	https://www.clearsynth.com/CST84744-Phenylmercury-2-Ethylhexanoate	Sales offices in Canada, Brazil also.

Annex 3 – Industry and trade associations related to polyurethane production and products contacted as part of this study

Contacted industry and trade associations
PMA – Polyurethane Manufacturers Association; https://pmahome.org/membership/meet-our-members/
Center for the Polyurethanes Industry (CPI); a part of American Chemistry Association, https://www.americanchemistry.com/industry-groups/center-for-the-polyurethanes-industry-cpi
ALIPA - European Aliphatic Isocyanates Producers Association, www.ALIPA.org
China Polyurethane Products Association of CPPIA, http://www.cppia.com.cn/en
Indian Polyurethane Association, http://www.ipua.in/
Korea Polyurethane Society, http://www.kpus.or.kr/
International Isocyanate Institute, https://www.diisocyanates.org/
Polyurethanes Industry (PUI; Thailand), http://polyurethanethai.com/en/contact_us.php
ISOPA, ISOPA.org
CEPE, https://www.cepe.org/
APPLIA, https://www.applia-europe.eu/about-applia/our-team
Euro-Moulders, https://euromoulders.org/
FEICA; Association of the European adhesive and sealant industry (FEICA). https://www.feica.eu/; members list at https://www.feica.eu/get-involved/feica-members
World Coatings Council; https://worldcoatingscouncil.org/#about
Abrafati, Associacão Brasilieira dos Fabricantes de Tintas, https://abrafati.com.br/
Canadian Paint and Coatings Association (CPCA), https://www.canpaint.com/
China [National] Coatings Industry Association (CNCIA), https://www.chinacoatingnet.com/index2.php
Mexican Paint and Printing Ink Manufacturers' Association (ANAFAPYT), https://anafapyt.com/
New Zealand Paint Manufacturers Association (NZPMA), https://www.paintman.org.nz/
South African Paint Manufacturers Association (SAPMA), https://www.sapma.org.za/
Association of the Paint Industry in Turkey (BOSAD), http://bosad.org.tr/home
Malaysian Paint Manufacturers Association (MPMA), https://www.mypma.org.my/
The Adhesive and Sealant Council, Inc. (ASC)
La Asociación Nacional de la Industria Química, A.C. (ANIQ), PU-section: https://aniq.org.mx/webpublico/poliuretanos.asp
Comissão Setorial de Colas, Adesivos e Selantes (ABIQUIM)
The National Adhesive & Sealant Manufacturers Association (NASMA)
China Adhesives & Tape Industry Association (CATIA)
The Adhesives & Sealants Association (TASA)
Korea Adhesive Industry Association (KAIA)
Taiwan Synthetic Resins & Adhesives Industrial Association, R.O.C. (TSRAIA)
Bangladesh Adhesive Manufacturer's Association (BAMA)

*

Annex 4 – Questionnaire about mercury compound use as polyurethane catalysts sent to companies and industry associations.

For the Secretariat of the Minamata Convention on Mercury

Questionnaire on the use of mercury compounds as catalysts for polyurethane production and products

The global Minamata Convention on Mercury controls the supply, trade, use, emissions, releases, storage and disposal of mercury. Its Annex A provides for mercury-added products, and Annex B provides for manufacturing processes in which mercury or mercury compounds are used. The Conference of the Parties, the governing body of the Minamata Convention, is to consider the availability and feasibility of non-mercury alternatives to those products and processes, in view of the amendment of those annexes and the implementation of measures stipulated in those annexes. To prepare for the consideration by the Conference of the Parties, the Secretariat of the Convention is collecting data on certain mercury-added products and mercury-using processes and their alternatives.

This questionnaire pertains to the use of organic mercury compounds as catalysts in the production of polyurethane (PU) production. A key aspect in establishing whether polyurethane production with mercury compounds can be restricted under the Convention is whether technically and economically feasible alternatives are available. Organic mercury compounds have particularly been reported used in the so-called CASE products (coatings, adhesives, sealants, elastomers), and have been reported to have ceased being used in some regions of the world due to environmental concerns and related legislative restrictions. Examples of mercury compounds having been used as catalysts in polyurethane production/products include, among others:

- Phenylmercury neodecanoate (CAS # 26545-49-3)
- Phenylmercury acetate (CAS # 62-38-2)
- Phenylmercury 2-ethylhexanoate (13302-00-6)
- Phenylmercuric octanoate (CAS # 13864-38-5)
- Phenylmercury propionate (CAS # 103-27-5)

With this questionnaire the Convention's Secretariat seeks information on any continued use of mercury compounds as catalysts in polyurethane production, and if so, which are the causes for the continued use. To read more about this study and the Minamata Convention, see the attached introduction letter including links to the Convention's website.

The Secretariat ask you kindly to fill in your organisation answers, to the questions below to the best of your organisation's knowledge, and **submit the filled-in questionnaire to the Secretariat of the Minamata Convention via email to [email address] no later than 8 June 2023**.

Should you have answers to some questions but not all, kindly fill in the answers you have and submit the questionnaire.

1.	Name of your organisation/company
2.	Contact person and contact details (name, email, phone number, website)

3. Type of organisation/company:			
Industry/trade organisation	Supplier of raw materials /additives for PU production	Producers of polyurethane products	Other (please specify)

4. To the best of your organisation's knowledge, is there continued use of mercury compounds in polyurethane production in the geographical area that the organisation covers? Yes: __ / No: __
a. Which geographical does your organisation cover (global/ region?/ countries?)?
b. If yes to question 4, for which end product types are mercury compounds known to still be used (in a few words)?

5. If yes to question 4, please fill in - as feasible - the data types requested in the table overleaf to the best of your organisation's knowledge. Kindly distinguish between end products used by professionals and by consumers, as feasible. Please insert more rows as needed.

Information on any continued use of mercury compounds as catalysts for polyurethane production

End products for which mercury compounds are used in production*)	**Country** (of end products production)	**Region** (of end products production)	**Reasons for using mercury compounds**	**Reasons for not using mercury-free catalysts**	**End product company name**, if feasible**)

Notes: *) Kindly distinguish between end products used by professionals and end products used by consumers. **) If company names cannot be given, kindly name companies as “Company 1”, Company 2, etc. so that we can get an impression of how many companies still use the mercury compound catalysts in which countries/regions and for which purposes.

*

6. What is your estimate of the market share of mercury compound use versus use of mercury-free catalysts in the production of the following product types? Please fill in the table below (insert more rows as needed).						
Product type	Country or region that your reply covers	Market share of end-products with mercury compounds use:				
		0%	<1%	1-5%	5-15%	>15%
PU coatings						
PU adhesives						
PU sealants						
PU elastomers						
Others, please specify:						
Specific end products, please specify:						

7. In case you have estimates of the total global or regional supplies of mercury compounds used as catalysts in polyurethane production, kindly fill them in below. Note that we are asking about your organization's specific supplies, but for the totals. The estimate(s) may be expressed in ranges to reflect uncertainty on the estimate. Insert more rows as needed.			
Substance (/group of substances)	Geographical coverage (Global/which regions)	Estimated total supply in geographical area	Unit and year for supply numbers (tonnes substance/year, or which other)/ in year(s)
Phenylmercury neodecanoate (CAS # 26545-49-3)			
Phenylmercury acetate (CAS # 62-38-2)			
Phenylmercury 2-ethylhexanoate (13302-00-6)			
Phenylmercuric octanoate (CAS # 13864-38-5)			
Phenylmercury propionate (CAS # 103-27-5)			
Others (please specify):			
Mercury compounds in total (PU catalysts)			

8. Do you have other relevant information or positions your organisation wish to share as regards use of mercury compounds in the production of polyurethane? Please reply in a few words to make the information clear.

9. Please list titles and links to any supporting documents:		
Title	Links	Remarks/keywords

10. Any other organisations or companies you would suggest we contact for this study (name of organisation and contact details, if feasible)? Insert more rows as needed.	
Name of organisation/company	Contact details, if feasible (name, email, phone no.)