The Mercury Ban and its Effects on the UV LED Printing Industry

Technical Note

Overview

The paper in front of you is meant to clarify if mercury vapor lamps used in the printing industry for the UV curing of inks are going to be phased out in 2020 at the latest and whether there is still a need to keep on curing ink with this old technology.

Introduction

2020 is the year of a worldwide ban on mercury. In May 2014, the World Health Assembly (WHA), the forum through which the World Health Organization (WHO) is governed by its 194 member states, started the implementation of the Minamata Convention on mercury (Hg) to protect human health and the environment from effects of exposure to mercury and mercury compounds. Since then, 128 countries have joined the Convention and 107 have ratified it.

The European Union (EU) wrote its first directive on the Reduction of Hazardous Substances (RoHS) in 2002. RoHS was followed by RoHS 2 in 2011. RoHS 2 is an expanded version of the original directive in terms of the number of substances, scope and restrictive application of exemptions. However, a key principle in EU legislation remains that the application of EU rules must not undermine growth and development, so RoHS 2 legislation is never as straightforward as it seems.

As a result, RoHS 2 exemptions are in place for low, medium and high-pressure mercury arc lamps which are being phased out from April 2015 as suitable replacement technologies become available. Exemptions can be renewed and the mercury lamp manufacturing industry, which has the most to lose with this ban, has successfully requested a renewal for category 4(f) devices – the category that includes the UV curing lamps for printing – in 2015 and they are already working on a request for the upcoming 5-year period renewal.

The EU subscribed to the rules of the Minamata Convention in 2016 when RoHS 2 and other directives and regulations were aligned with the treaty. Hence, the EU, along with many other environmentally aware countries, is bound by what has now been known as the “2020 mercury ban”.

Why a Mercury Ban is long overdue?

Minamata disease is a neurological syndrome caused by severe mercury poisoning. In extreme cases, insanity, paralysis, coma, and death follow within weeks of the appearance of the first symptoms. The Minamata treaty has been named after the Japanese city that witnessed one of the worst incidents of industrial poisoning by mercury in 1956. The cause was the release of methyl mercury in the industrial wastewater from the Chisso Corporation's chemical factory, which continued from 1932 to 1968 (See also ‘Minamata Disease’. In *Wikipedia*, 2 March 2019. https://en.wikipedia.org/w/index.php?title=Minamata_disease&oldid=885857261).

There is *no* known safe exposure level for elemental mercury in humans. Effects have been seen even at very low levels. Together with its various compounds, it has a range of severe health impacts, including damage to the central nervous system, thyroid, kidneys, lungs, immune system, eyes, gums and skin. Surviving victims may suffer memory loss or language impairment and the damage to the brain cannot be reversed. And yet, the print industry often neglects the dangers of working with mercury based lamps and disposes of them in unsafe ways. This is partly due to the misconception that investing in UV-LED is more expensive, a prejudice that is fed by lobbyists of the mercury lamp industry (see pages 4 and 5) and partly because following the rules for disposing of the lamps at the end of their lifespan requires a printer to implement a procedure while just throwing them away is easier.

But, more importantly and perhaps more alarmingly, recycling hazardous waste is such a high-worth business that it often leads to illegal schemes such as overseas shipping and dumping. For the EU, there are no figures, but MoneyCrashers reports that a 2008 study from the U.S. Government Accountability Office found that some recyclers ship e-waste to third world countries under the guise of philanthropy, claiming that these "donations" bring technology to developing nations. (See 'Electronic Waste (E-Waste) Recycling & Disposal - Facts & Statistics'. https://www.moneycrashers.com/electronic-e-waste-recycling-disposal-facts/).

In Minamata, methyl mercury bio-accumulated in the shellfish and fish of Minamata Bay and the Shiranui Sea. The local population, who depends largely on what the sea provides for their daily food intake, was subjected to mercury poisoning over the course of the 36 years the factory kept releasing the toxic chemical.

In March 2001, 2265 victims had been officially recognized as having Minamata disease (1,784 of whom had died) and over 10,000 had received financial compensation from Chisso Corporation. By 2004, the company had paid $86 million in compensation and in the same year was ordered to clean up its contamination. On March 29, 2010, a settlement was reached to compensate as-yet uncertified victims.

A second outbreak of Minamata disease occurred in Niigata Prefecture in 1965. These cases are misleading in that they seem to suggest poisoning is life-threatening only if it has a chance to invade the body for a long time. However, the Karen Wetterhahn case tells an even more horrific story.

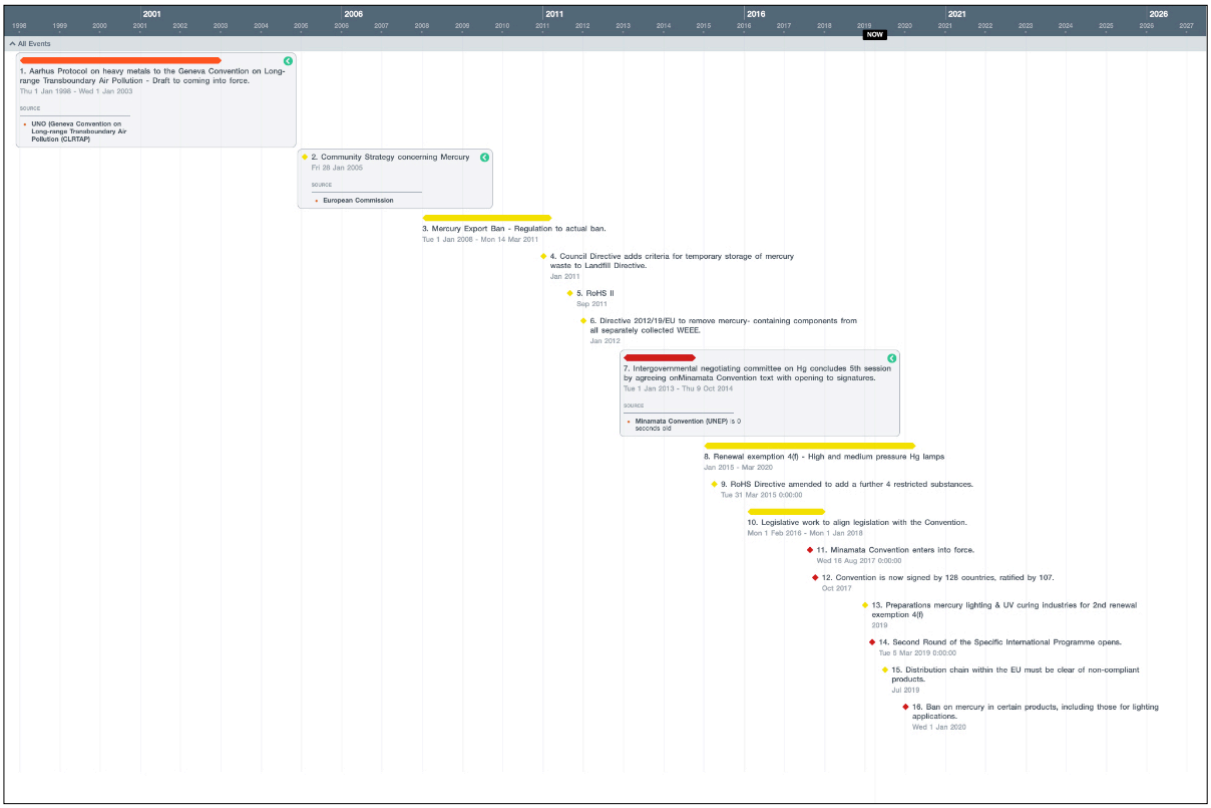
Karen Wetterhahn, an American professor of chemistry at Dartmouth College, New Hampshire, was specialized in toxic metal exposure. She died in 1997 at the age of 48 as a result of accidental exposure to the organic mercury compound dimethylmercury. Protective gloves *did nothing* to protect her and only a few drops of the chemical absorbed through the gloves proved to be fatal after less than a year (See 'Karen Wetterhahn'. In *Wikipedia*, 25 January 2019. https://en.wikipedia.org/w/index.php?title=Karen_Wetterhahn&oldid=880125787).

The Minamata Convention

The Minamata Convention is the treaty that proves the world has taken heed of the risks and is aware that, because mercury is transported around the globe through the environment, its emissions and releases can affect human health and the environment even in remote locations.

Due to the transboundary effects of mercury, countries need to cooperate in order to decrease mercury emissions and releases. The objective of the treaty is to protect us from anthropogenic emissions and releases of mercury and mercury compounds. It contains provisions that relate to the entire life cycle of mercury, including controls and reductions across a range of products, processes

and industries where mercury is used, released or emitted. The treaty also addresses the direct mining of



mercury, its export and import, its safe storage and its disposal as waste.

Timeline of Minamata Convention (red) and RoHS 2 (yellow) events.

The Convention entered into force on 16 August 2017. 128 countries actually signed the Convention, while 107 ratified. The ban will particularly affect artisanal gold mining, which has become a lucrative source of income in countries such as Thailand, Peru and Senegal over recent years. From 2020, the Convention will ban the production, import and export of products that contain mercury, including blood pressure monitors, clinical thermometers and other products. (See 'Minamata Convention on Mercury'. http://mercuryconvention.org/Home/tabid/3360/language/en-US/Default.aspx).

The Minamata mercury ban lists "high-pressure mercury vapor lamps (HPMV) for general lighting purposes", but ratifying parties can interpret any treaty's definitions restrictively, so it's up to those parties to include specialized lamps in their planning to phase out mercury.

Timeline of Minamata Convention (red) and RoHS 2 (yellow) events.

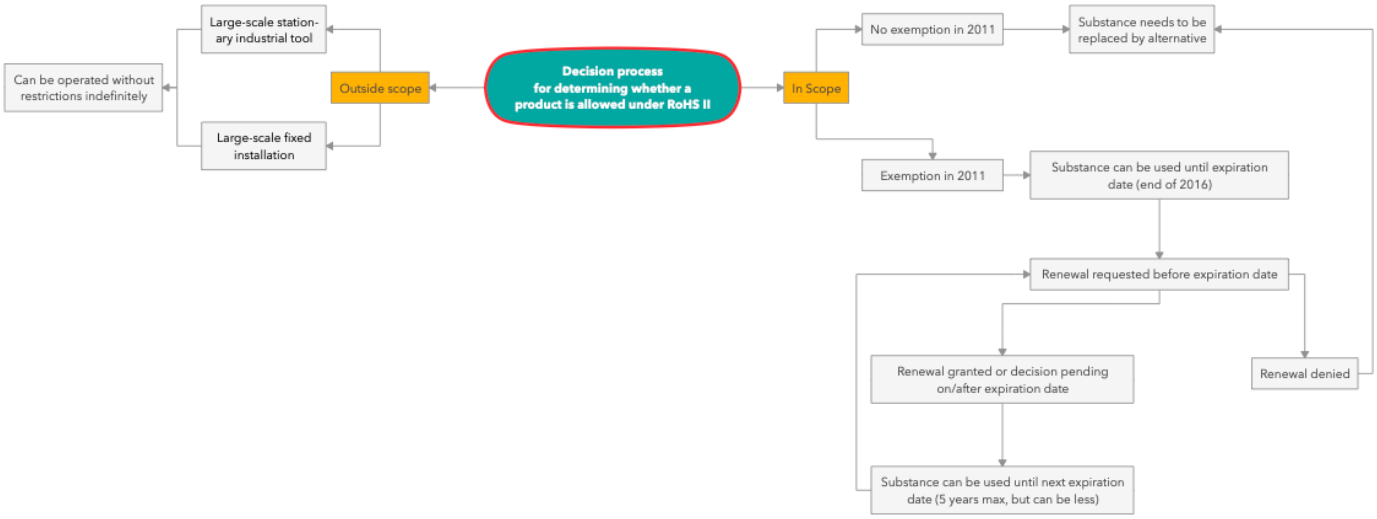
RoHS2 and the environment vs. the UV Curing Mercury Lamp

RoHS 2 is the EU's answer to the problem of hazardous waste, but the directive, in order not to undermine growth and development, allows for exceptions and exemptions. These are granted after going through a review process that takes anywhere from a couple of months to a couple of years, with input (pros and cons) from all the parties that have an interest and a subsequent analysis by one of the certified institutes.

Another obstacle a total mercury ban faces is the interpretation of the terms "large-scale stationary industrial tool" and "large-scale fixed installation". These terms are related to the scope of RoHS 2. "Scope" refers to whether a device is affected by RoHS 2 restrictions or not. If a device is not in scope, it is automatically exempted.

Outside RoHS 2's scope would be, for example, a printing press that the vendor needs a lorry for to deliver it at the customer's doorstep, must assemble and install, and can't move without taking it apart it and repeating the process. This means such large mercury-driven UV curing presses can continue to be operated as they were. Spare parts distribution is also guaranteed.

Large industrial installations are completely exempt, so industrial printing machines are not concerned by the ban and will not be unless the Directive is updated after a round of legislative consultations and with the blessings of the EU Commission. The reasoning is that the amount of mercury is very low and that the lamps should be completely recycled as enforced by the WEEE rules (See page 7). There is no restriction to store them (See 'RoHS 2 FAQ'. 12 December 2012 . http://ec.europa.eu/environment/waste/rohs_eee/pdf/faq.pdf).
For smaller printing presses – the ones you can (even theoretically) install yourself and are more or less easy to move around – mercury lamps would have been banned by now, were it not for the exemption system. In order to generate investment security, an application was made in 2015 to the European Commission for a clear regulation by a number of industry associations who 'defend' their members' interests. The aim was to renew the exemption in place for all mercury arc UV lamps used *for any* UV curing purpose, including printing (See also .'Where to Find the Latest Global RoHS Exemption List'. Last updated 10 March 2019. https://www.chemsafetypro.com/Topics/Restriction/Where_to_Find_Global_RoHS_Exemption_List.html).



Deciding whether RoHS 2 has an effect on a substance.

One of the signatories involved in requesting the renewal was RadTech, the European Association which promotes the use of UV/EB curing technology for inks, coatings and adhesives. Regarding the extension, the Secretary-General of RadTech Europe said: "Incredible as it may seem, the formal decision is still pending, even though the exemption should have entered into force years ago. The institute responsible for the review has recommended the Commission to extend the exemption, but the decision is lagging at the side of the Commission, as the Commission had other priorities. The industry is, in fact, already starting preparations to submit the application for extension of the exemption for the next deadline."

If an exemption expires while still under review, it is extended to allow time for the request to be reviewed and legislation to be updated. For the exemptions scheduled to expire on July 22, 2016, a large number of requests were received, causing a backlog in the review process, and the expiration date for them was pushed back for an official decision to be made. Decisions have been made on a rolling basis. Given the number of extension requests that have been made, it could take some time before all of them have been officially released.

A RadTech member, when asked about why mercury lamps still require exemptions, said: “Large industrial installations are completely exempt. Therefore, the ban does not affect industrial printing machines. The amount of mercury is very low compared to mass products like mercury bulbs. These lamps are “generally” completely recycled. There is no restriction to store them.” However, if all industrial printing equipment is outside RoHS 2’s scope anyway, it’s not readily apparent why RadTech should support exemption renewals. In reality, a lot of UV-curing printing presses are small enough to be in scope.

For completeness sake, we should consider that other countries also have a RoHS 2 ‘directive’. These include China, Taiwan, Japan, Korea, and there’s also California with its Electronic Waste Recycling Act of 2003. Except for the latter, all of them follow the EU RoHS 2 format and exemptions scheme (See ‘Where to Find the Latest Global RoHS Exemption List’. Last updated 10 March 2019. https://www.chemsafetypro.com/Topics/Restriction/Where_to_Find_Global_RoHS_Exemption_List.html).

Mercury lamps: bad for growth and development

From a business point of view, it’s understandable that mercury lamp producers defend the status quo. That’s probably why they give the consultants of the institutes a hard time advising for the extinction of an exemption. They try to be as expansive as possible with regards to the application of the targeted mercury vapor lamps, in order to gain a maximum renewal period.

That isn’t in everyone’s best interest and certainly not in that of the environment, or as the European Environmental Bureau puts it: “We do not favor the length of many of the requested mercury exemptions largely on the statement that equivalent LED lamps are not a practical replacement today for *every* application. Instead, we are requesting definite, near-term expiry dates in certain categories of lamps on the basis that LEDs are environmentally preferable and practical for most applications.”

Even from a strict business point of view, mercury lamps aren’t always the best choice. The type of lamp used in printing applications is usually a medium pressure linear mercury vapor arc lamp. Medium pressure UV lamps do cure inks and coatings instantly, allowing the equipment to run at very high speeds for extended periods, but they operate at very high temperatures (850 to 950 Celsius or 1550 to 1750 Fahrenheit). And here we have the first disadvantage from a cost perspective. If the lamps run too cool, they may not cure the ink or coating, so printers need to keep them on at all times, wasting a great deal of energy – expensive both in terms of money and environmental cost.

When I asked Durst Phototechnik AG about why they’re still offering mercury next to their LED machines, their spokesperson said: “Conventional mercury and/or gallium vapor lamps are a well-established technology for industrial curing of UV inks. The hardware costs, especially for large, industrial production machines, are much lower – by a factor two to three – than, for example, UV-LED systems.”

However, the hardware cost is only one factor and it is not even the most important one. The cost of wasted energy because of the ”always on” necessity when measured over the entire lifespan of a printing press should be counted in too. Also, it should be stated that these lamps generate a lot of heat and ozone as well. Both need to be forced out of the production area away from press operators – again costing a lot of otherwise useless energy.

There’s also the risk of contaminants such as spray powder from other presses or dust particles that can bake on the lamps, creating a haze and decreasing lamp performance and the high temperature these lamps run at prevents printing on delicate materials such as bubble plastic or very thin substrates.

Durst also mentioned that mercury curing materials, photoinitiator concentrations and photoinitiator costs are lower than those used with LED technology, but, on the other hand, users sometimes waste output because of uneven curing or color shifts that often result from mercury bulb degradation or from operators trying to find the right mix of cure energy for ink on a particular substrate.

According to Durst, UV LED is not fully on par for all UV curing purposes in the industry, either. The spokesperson said: "There is currently no practical alternative than conventional gas-discharge lamps to generate UV-C and UV-B wavelengths which will be needed to achieve specific properties in UV curing, such as the highest surface hardness and good scratch resistance."

However, Jennifer Heathcote, Eminence UV, said: "The desired physical and aesthetic properties of the final cure as well as the intended product use should be specified and are instrumental in driving the (ink) formulation chemistry and, ultimately, whether a UV LED cured solution is even possible today. For example, inks, varnishes and adhesives generally cure well with LED *and meet most graphic print requirements*. Silicone release and industrial hard coats, however, still are very much in development and are at least three to five years away from wide-scale commercial availability." (See Brandy. 'State of UV LED Curing Applications'. *UV+EB Technology* (blog), 27 February 2019. https://uvebtech.com/articles/2019/state-of-uv-led-curing-applications/)

Finally, mercury lamps come with a hidden cost: recycling. The European WEEE directive ('L_2012197EN.01003801.Xml'. 24.7.2012. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012L0019&from=EN) requires companies to recycle the mercury in these lamps and each EU member country imposes its own fines to make sure the requirement is met (See, for example 'Non-Compliance with the WEEE Directive: What's the Worst That Can Happen? - The Compliance Map Blog'. edie.net. 4 July 2016. https://www.edie.net/blog/Non-compliance-with-the-WEEE-Directive-whats-the-worst-that-can-happen/6098068).

The recycling need is fully regulated, meaning that printers can't just toss these lamps in a bucket. Instead, each country's applicable laws define the whole process from beginning to end and the burden for the recycling process is on the lamp supplier (the brand owner, actually) who can charge the end-user an extra cost per lamp and make it compulsory for the printer to rent a specially designed container (See 'WEEE: Obligations on B2B Producers | B2BWEEE'. June 2014. http://www.b2bweee.com/weee-directive/weee-legislation/weee-obligations).

UV LED Technology's Merit

For UV curing of inks, RoHS 2 exemptions should really be denied because there's a perfectly viable alternative that – over the lifespan of the equipment – does not have a negative impact on economic growth and development while having a much lower impact on the environment.

That alternative is UV-LED technology and it has matured over the past decade to a point where it starts to be better than mercury in a number of areas.

The most obvious advantage of LED is that it is a solid-state light array in contrast to a mercury lamp. The benefit of an array is that if one diode fails, the light intensity of the surface light is only minimally affected. However, most importantly, LED lamps emit only in a narrowband of UV wavelength reducing heat transfer to the substrate. Mercury lamps emit in a broad spectrum including visible and infrared (IR) wavelengths. IR wavelengths transfer heat directly to the material and substrate, potentially damaging them In contrast to mercury lamps, even the low-energy ones, LED lamps are far more energy-efficient. LED lamps convert a significantly higher percentage of the electrical input power to UV output powered compared to mercury lamps, making them far more energy efficient.

A study by Fogra Graphic Technology Research Association ("Energy efficiency of large and small format printing systems"; report behind a paywall) showed that LED curing reduces energy consumption with up to **82%** when compared with devices that use conventional mercury arc lamps.

While it's true that UV-LED systems need specially formulated inks to benefit the most of the technology, with UV inks formulated to match the wavelength of the LED diodes, systems that cure with LED lamps are faster than mercury-cured systems. A few years ago, LED systems started matching the speed of high-speed production presses. One reason for this is that LED cured artwork is dried immediately upon exposure, which has a positive effect on overall production speed.

LED technology as a whole consumes less ink, minimizing waste, another environment-friendly feature. Inks developed for UV-LED technology are more responsive and if the printing press has digital front-end software that's optimized for LED, it will be able to apply a thinner layer of ink to obtain the same results as with conventional curing. During LED curing, the ink is not absorbed into the substrate – 100% of the pigment solidifies.

All of this does require the printer and the inks to be carefully matched with each other. Ken Hanulec, EFI VP of Marketing Inkjet Solutions, said: "EFI considers all parameters when bringing a new product to market. These include the printer, printheads, curing system, ink and all the other technical components."

To make their systems the printer of choice for 3M™ MCS™ certifications, EFI formulated its inks in collaboration with 3M. The 3M warranty assures that the graphics produced with EFI inkjet technologies in combination with 3M media will perform as expected for the lifetime of the graphic. To make this possible, EFI uses automotive-grade pigments, grinding and controlling them to maintain tight distribution.

In addition, LED lamps are safe while mercury lamps are a risk in the workplace. If the outer shield of a LED array is damaged, there are no harmful effects. If the outer bulb of a mercury lamp breaks, then intense UV radiation is emitted. UV exposure can cause eye and skin burns, and other discomforts.

UV-LED also allows you to print on unusual substrates, including highly reflective metallics, highly textured surfaces, sliver-thin, heat-sensitive films and more. Polyester and other special textiles too can be printed on as LEDs are cool compared to mercury lamps. In fact, UV-LED printers let you print on PVC as thin as 0.2 to 0.5 mm.

While the mercury lobby suggests that everything LED-driven is going to cost you more, I personally have interviewed many an EU-based printer who said it actually made their business grow for two reasons:

- They can print on cheap and exotic substrates such as mirrors, thin glass and other delicate materials
- Customers love being able to say they only use environment-friendly products and services – it pays to be "green".

And LEDs are more cost-effective in other ways too. Manufacturer Agfa Graphics states: "As less heat is dissipated from a LED lamp, it is easier to keep the media flat under the shuttle. This eliminates head crashes and thus less need for rework that would waste media and ink. In addition, a LED system contains fewer parts that might require replacement, such as shutters and mirrors." Furthermore, as UV LED lamps don't contain mercury, there is no need for mercury disposal or any related costs. LEDs don't produce ozone gas that needs to be extracted by ventilation, either (See 'The Benefits of UV LED Print Technology'. 18 April 2017. https://www.agfagraphics.com/global/en/articles/papers/the-advantages-of-uv-led-print-technology.html).

Even printing presses like a Heidelberg 5-color press converted to LED have advantages, as UK-based Opal Print's CEO Keith Lunt explains in a case study video on BluPrint UK's website (http://www.bluprintuk.com/Catalogue/LED-UV-Retrofit/The-Benefits-of-LED-UV-Curing-for-Print). He mentions more vibrant colors and a sharper dot and he's not alone. In a 2018 feature story, FESPA staff reported that printers who are already using UV-LED are reporting energy consumption as much as 70% lower than conventional systems and increased color brilliance, stemming from higher pigment content ('Five Major Technology Advances in UV Curing Print Market'. 25 January 2018. https://www.fespa.com/en/news-media/features/five-major-technology-advances-in-uv-curing-you-should-know).

Properly designed UV-LEDs have an operating lifespan of over 40,000 hours. Mercury arc lamps have a lifespan at most of 1,500 hours. This means you have to replace the hazardous mercury lamp about 26 times more often than its LED counterpart. At the end of their lifespan, LEDs ideally are recycled to make the most of the rare minerals inside them and fit them in a circular economy, not because they contain so many toxic materials that can be released into the air or seep through in water reserves, but because of the expensive rare earth minerals they contain. An all-encompassing recirculation programme has been discussed by the Fraunhofer Project Group Materials Recycling and Resource Strategies IWKS and the Technische Universität Darmstadt Institute for Materials Science (See Theresa Luger. 'LED Lamps Recycling Technology for a Circular Economy — LED Professional - LED Lighting Technology, Application Magazine'. Rich document. Accessed 25 Agust 2016. https://www.led-professional.com/resources-1/articles/led-lamps-recycling-technology-for-a-circular-economy).

Conclusion

The Minamata Convention by itself will have little or no direct impact on the printing industry. As the Convention concentrates efforts around mining on the one hand and more general-purpose use of mercury on the other, and RoHS 2 works with scope exceptions and exemption renewals, the 2020 mercury ban imposed by the Minamata treaty's product definitions certainly has no immediate impact on the conventional UV cured printing industry.

As far as RoHS 2 is concerned, mercury lamp producers keep trying to extend and renew the whole of category 4(f) mercury lamps. They thereby seem to benefit from the confusion caused by the broad range of products that fall under this category, making the consultants' task to advise the Commission on a renewal of the exemption near-impossible.

That is strangely at odds with the objective of the directive to ban mercury by 2020, certainly taken into account the advance UV-LED technology has made over the past decade in purely technological terms and the total absence of mercury (See also FESPA's 'Five Major Technology Advances in UV Curing Print Market'. 25 January 2018. https://www.fespa.com/en/news-media/features/five-major-technology-advances-in-uv-curing-you-should-know — which is in stark contrast to their feature story of four years earlier 'Mercury Arc vs LED Curing'. 21 July 2015. https://www.fespa.com/en/news-media/features/mercury-arc-vs-led-curing).

The many positive user reports I have personally heard from multiple interviews with printers in Great-Britain and on the European continent seem to indicate that printing companies who hold on to the conventional UV curing methods are doing less well in terms of expanding their business than their colleagues/competitors who are embracing UV-LED technology, the latter which is seen as clean and ecologically sound.