Canada's submission on information on the uses of mercury and non-mercury alternatives

Canada has controlled mercury-containing products through the *Products Containing Mercury Regulations* (see Canada's Article 30.4 submission for information on how Article 4 obligations, in particular for paragraph 1, are met using these regulations). The Regulations prohibit the manufacture and import of all mercury added products except for certain exempted products for which there are no mercury alternatives available.

Information on the following products has been collected to support the development of the Regulations as well as an ongoing process to amend the Regulations, which will include the removal of some products from the list of exemptions because they are no longer used in Canada, or because mercury-free alternatives are readily available. In 2018, Canada conducted public consultations on proposed amendments to the Regulations.

Mercury-containing counter balancers (tire balancers/wheel weights)	
Description:	Mercury-containing counter balancers can be used in a variety of mechanical components including engines, drive shafts and pumps. It is estimated that each mercury-containing balancer contains 99.2g of mercury. Although now prohibited for use in Canada, previously they were used mostly on tires in various types of vehicles including trucks, cars, motorhomes, motorcycles, jet skis, and ultralites. Mercury-containing tire balancers consist of mercury filled tubes that are fitted to rotating mechanical parts. This type of tire balancer uses mercury in a continuous active balancing system that uses centrifugal force to position the liquid weight (mercury) in counterweight positions. This allows tires to rotate without causing vibrations. The purpose of a tire balancer is to eliminate uneven tire wear to extend the useful life of the tire. Manufacturers claim that using tire balancers results in a greater tire footprint and more control in adverse driving conditions. They also suggest that mercury-containing tire balancers increase fuel mileage by up to 5% and tire life by up to 50%.[1]
Alternative:	The most similar available products to mercury-tire balancers are bolt-on centrifugal liquid rings and internal liquids that are injected into the tire. Non-liquid types of tire-balancers (wheel weights) are also available alternatives and are typically made from tin, steel or high-density polymer composites. These wheel weights can be coated or non-coated, and adhesive or clip-on. Clip-on or adhesive wheel weights made from lead are also alternatives; however, they may not be an appropriate substitute due to environmental and human health concerns.
Availability:	The manufacture and import of mercury wheel weights is prohibited under Canada's *Products Containing Mercury Regulations* which came into effect in 2014. New cars entering the Canadian market currently have mercury-free tire balancers installed. As a result, no mercury-containing tire balancers are expected to be available in Canada.

	Mercury-containing tire balancers have also been banned in some American states and in the European Union. There was little information on the availability of mercury-containing tire balancers and their alternatives in other regions.
Technical and economic feasibility of alternatives:	Mercury-containing tire balancers are not produced in Canada, and there is little information comparing the costs and performance of them to mercury-free tire balancing products. However, anecdotal research suggests that mercury-containing tire balancing products have a higher up-front consumer cost compared to other tire balancing products.[2] A study conducted for the Government of Canada found that that for most manufacturers, wheel weights made of steel had no higher costs than wheel weights made of lead and performed similarly although the costs of metal wheel balancers fluctuate with the costs of the raw materials.[3] The non-toxic tin, steel and composite alternatives that have been developed meet the main technical requirements for tire balancing products. Mainly that they are: made of a dense material, corrosion resistant and function in a range of operating temperatures.
Risks and benefits of alternatives:	Mercury-free tire balancing products contain internal compounds or liquids that are non-toxic; making their use and disposal safer for the environment and human health compared to mercury-containing tire balancing products. External wheel weights made of steel are also non-toxic to the environment or human health. One benefit of metal wheel weights is that they can be recycled. However, steel wheel weights made of recycled material may contain additives such as nickel and chromium, which could have a relatively small impact on human and/or environmental health.[4] Coated steel weights are currently the most environmentally friendly solid wheel weight product.[6] Solid wheel weights are often mismanaged at the end of product life when taken out of service. Employees in the tire and wheel service industry who handle lead wheel weights, in particular, can be exposed and also bring contamination home with them.[4] Solid wheel weights fall off during normal use. Although lead is a toxic substance, it is still preferable to use lead wheel weights compared with mercury tire balancers because lead is less volatile than mercury and solid wheel weights are relatively easier to collect and contain than a liquid containing mercury.[7]

1. For example: http://www.balancemasters.com/trucks/index.html
2. For example: http://forum.prevostownersgroup.com/archive/index.php/t-3485.html; https://www.turbodieselregister.com/threads/balance-master-vs-centramatics.238074/
3. Toxecology Environmental Consulting Ltd. (2013). Background study and use pattern for lead wheel weights in Canada.

4. California Environmental Protection Agency (2011). Wheel weight alternatives assessment. Available from: https://dtsc.ca.gov/wp-content/uploads/sites/31/2017/05/AAWheelWeights.pdf
5. Minnesota Pollution Control Agency. (N.D.) Lead and mercury wheel weights. Available from: https://www.pca.state.mn.us/quick-links/lead-and-mercury-wheel-weights
6. State of Washington. (2008). Environmentally preferable purchasing fact sheet: wheel weights. Publication No. 13-07-008. Available from https://fortress.wa.gov/ecy/publications/documents/1307008.pdf
7. Government of Canada. (2007). Proposed risk management instrument for mercury-containing products. Available from: https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/proposed-risk-management-instruments-mercury-products.html#s2_7

Mercury slip rings	
Description:	A device that provides 360-degree rotations to transmit signal and power between stator (stationary) side and rotor side of different industrial equipment. This product uses mercury as a conductor to transfer current and signal as a liquid at normal temperatures.
Alternative:	Conductive block slip rings: used mainly for lower technology applications involving transmitting power or simple signals. These use carbon or metal alloy brushes to transmit signals. Fiber brush slip rings: suited for a wide variety of applications and come in many sizes. Brushes made of different metal fibers transmit power and signals from a rotating ring. Metal fiber brushes ensure a high contact quality and low wear due to their flexibility. Alloys of steel and other common metals are common for power transmission, whereas gold alloys are used for signal transmission since gold does not oxidize and therefore maintains quality over time. Wireless slip rings: use the principle of capacitive or inductive coupling for power and signal transmission. Fiber optic slip rings (fiber optic rotary joints): the optical equivalent of a wireless slip ring. Light waves are synchronized between two ends using optic fibers. Liquid metal slip rings using a gallium alloy instead of mercury are also available.
Availability:	There are many manufacturers of mercury-free slip rings, which are widely available in all shapes and sizes.
Technical and	Compared to mercury slip rings, conductive block slip rings have greater weight and volume for the same circuits, greater capacitance and crosstalk, are louder, do not

economic feasibility:	last as long and require regular maintenance. Sparking may also occur if dust is present. Conductive block slip rings are low cost and are easily customized for mechanical assemblies in house since brushes and rings are available separately.[1] Fiber brush slip rings have a large flexibility in use and can be used in a wide range of applications, from high power transmission to high frequency signal transmission. Fiber brush slip rings have an excellent volume to current ratio and are relatively maintenance free.[1] They also have a high frequency electric signal transmission and do not make a lot of noise. These are more costly than conductive block type slip rings but have comparable costs to mercury slip rings. Wireless slip rings lack standard mechanical parts meaning they are more resilient in harsh operating environments and require less upkeep and maintenance. However, the amount of power that can be transmitted between coils is somewhat limited compared to mechanical-type slip rings. Wireless slip rings are generally less efficient than other slip rings and the loss of efficiency is proportional to the distance between the two components. One benefit of wireless slip rings is that there are many possible configurations for their placement. They are well suited for applications that need high rotational speeds and where there is poor access for maintenance.[1] Wireless slip rings are more costly than mechanical types of slip rings; however, slip ring manufacturers are investing most in developing and refining wireless slip ring technologies.[2] As this technology grows, costs will likely decline. Fiber optic rotary joints enable continuous rotation of one or more optic fibres without affecting the signals transmitted along them. These are most beneficial for applications where a twist-free cable is needed. Single channel rotary joints are relatively simple and can be very compact while permitting high rotational speeds, good reliability, and little loss of performance over time. Multi-channel rotary joints can be very complex and need to be manually aligned when very high performance is required.[1] Often fiber optic joints are incorporated into other rotary components as the centre of the rotary assembly. These are quite costly, and costs are related to the overall size of the complete rotary joint assembly. Mercury slip rings are limited by temperature since mercury solidifies as -40 C. The other types of slip rings do not have this limitation.
Risks and benefits:	No negative environmental or health impacts are known to be caused by the other types of slip rings.

1. Servotechnica. (2017) What is a slip ring. Available from: https://www.servotecnica.com/en/resources/motion-blog-en/what.is-a-slip-ring/
2. Research and Markets. (2019). Global slip rings market 2019-2023. Available from: https://www.researchandmarkets.com/reports/4760888/global-slip-rings-market-2019-

2023?utm_source=BW&utm_medium=PressRelease&utm_code=dhnqkk&utm_campaign=1233188+-+Global+Slip+Rings+Market+Forecast+Study%2c+2019+to+2023&utm_exec=joca220prd

Button zinc silver oxide batteries and button zinc air batteries	
Description:	Small batteries used for powering high drain devices such as watches, calculators, and hearing aids
Alternative:	Mercury-free silver oxide batteries, mercury-free zinc air batteries, lithium batteries
Availability:	Mercury-free alternatives have been available from major battery manufacturers since the late 1990s and early 2000s (E.g. Sony, Panasonic, Duracell, Rayovac, Energizer, Maxell). It was reported that representatives of the battery industry agreed that mercury-free alternatives would be widely available in the US by 2011 and would have comparable prices.[1] Mercury-free alternatives come in the same shape and size as both mercury-containing zinc air and silver oxide batteries.
Technical and economic feasibility:	Panasonic reports that their mercury-free zinc air batteries have up to a 20% increased capacity compared to their previous zinc air batteries. They also note that zinc is much lighter and cheaper than lithium, and that their mercury-free zinc air batteries contain twice as much energy as a lithium-ion battery.[2] Seiko has also suggested that their mercury-free silver oxide battery has better leakage resistance and discharge characteristics in low temperatures compared to those containing mercury. [3]
Risks and benefits:	While recycling of batteries is the preferred option, in some jurisdictions, mercury-free zinc-silver oxide, mercury-free zinc air batteries can be disposed of as household waste as their components are relatively inert and pose little risks to the environment or human health; whereas mercury containing batteries are hazardous waste and require special treatment for disposal.[4, 5] Mercury-free zinc air and silver oxide batteries can be recycled with other alkaline battery types and would not need special equipment for processing such as a mercury retort oven.[6]

1. Maine Department of Environmental Protection. 2009. Mercury-free button batteries: their reliability and availability. Available from: http://www.retailcrc.org/RegGuidance/Lists/RNGList/Attachments/661350/GME00087.pdf
2. Panasonic. (N.D.) Zinc air batteries: for hearing aids of the next generation. Available from: https://www.panasonic-batteries.com/en/specialty/zinc-air
3. Seiko Instruments Inc. (2020). Seizaiken (mercury-free silver oxide battery). Available from: https://www.sii.co.jp/en/me/battery/products/silver-oxide/
4. Buchmann, I. (2020). BU-705: How to recycle batteries. Available from: https://batteryuniversity.com/index.php/learn/article/recycling_batteries

5. Recycle Smart. (2019). Mercury (batteries) rising. Available from: (https://recyclesmartma.org/2019/10/mercury-batteries-rising/
6. Aevitas. (2017). Battery recycling. Available from: http://www.aevitas.ca/battery-recycling.html

Reference electrodes for calibration of pH measuring devices	
Description:	An electrode with a stable and known electric potential that is used in electrochemical measurements. The reference electrode allows control of the potential of a working electrode or the measurement of an indicator electrode[1] Mercury-containing reference electrodes include calomel (Hg/Hg_2Cl_2), mercurous sulphate (Hg/Hg_2SO_4) and mercuric oxide (Hg/HgO) electrodes. The calomel electrode is widely used for pH measurements, while mercurous sulphate is used for other measurements e.g. for silver halides and chemical oxygen demand titrations.[2]
Alternative:	The mercury-free alternatives are made of glass and contain potassium chloride (KCl) with silver/silver chloride ($Ag/AgCl_2$). [3, 4, 5] Other alternative electrodes can be made of epoxy (stronger design for field use or demanding environments) and be gel or liquid filled. [4, 5, 6]
Availability:	Uses of mercury-containing electrodes appear to have been largely phased out in Canada due to a movement away from this type of electrode, likely due to the human health risks, extra handling precautions, and disposal costs associated with mercury. Mercury-free electrodes are available from all major scientific equipment suppliers in Canada and some no longer have mercury-containing electrodes available.
Technical and economic feasibility:	Mercury-containing electrodes show the most stable potential in the presence of potassium chloride; however, the reliable temperature range of mercury chloride is narrow. Above 60°C, it begins to degrade. Mercury-free electrodes can work in a wide range of temperatures (up to 140°C) and are therefore able to be heat-sterilized.[7] Electrodes made of silver/silver chloride can be affected by sulphides and cannot directly be used as a reference electrode for chemical analysis of chloride or silver concentrations. However, a barrier can be put in place and allow the silver/silver chloride electrodes to be used in sulphide environments and environments with other metal ions. Mercury-free alternatives are generally marginally more expensive than mercury containing electrodes but come in a variety of body styles (where mercury-containing electrodes are limited) and are refillable.[8] A newer iodine/iodide system has also been developed and is much less sensitive to temperature fluctuations.[7, 12] The iodine/iodide system is metal ion-free, which is useful when measuring Tris buffers and protein solutions, since reference electrodes using silver/silver chloride would require the use of barriers.[7, 11] This system is considerably more expensive than other alternatives, but is one of the only options suitable for analyses with chloride ions and is more accurate and precise than silver/silver chloride reference electrodes.[12]

Risks and benefits:	Handling and disposal are less of an issue with silver/silver chloride systems since silver is non-toxic to humans. For example, the safety data sheet for mercury chloride electrodes list them as having acute toxicity due to inhalation risks, reproductive toxicity, and repeated exposure toxicity.[9] Whereas silver/silver chloride solutions used in electrodes are listed only as causing skin and eye irritation.[10] Iodine/iodide systems would not be subject to strict handling or disposal procedures since iodine/iodide solution is not toxic to humans but could cause skin or respiratory tract irritation.[13]

1. Kahlert, H. (2005). Reference electrodes. In: Scholz F. (eds) Electroanalytical Methods. Springer, Berlin, Heidelberg. Available from: https://link.springer.com/chapter/10.1007/978-3-662-04757-6_14
2. COWI (2008). Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society. Final report for the European Commission prepared by Lassen, C., Holt Andersen, B., Maag, J & Maxson, P.
3. Fisher scientific. (2020). Fisherbrand accumet glass body Ag/AgCl reference electrodes – mercury-free. Available from: https://www.fishersci.com/shop/products/fisher-scientific-accumet-glass-body-ag-agcl-reference-electrodes-mercury-free-4/p-2903565
4. Sensorex. (2012). Product specification sheet: Sensorex new 'calomel free' epoxy and glass body pH and reference electrodes. Available from: https://www.sensorex.com/docs/specs/SpecsCalomelFree.pdf
5. Autolab electrochemical instruments. (N.D.) Autolab application note: reference electrodes and their usage. Available from: http://www.autolabj.com/appl.files/appl%20note/Appl038.pdf
6. Fisher scientific. (2020). Fisherbrand accumet epoxy body mercury-free reference electrode. Available from: https://www.fishersci.com/shop/products/fisher-scientific-accumet-epoxy-body-mercury-free-reference-electrode/p-4950075#?keyword=mercury+sulphate+reference+electrode
7. YSI (2019). Anatomy of pH electrodes. Available from: https://www.ysi.com/ysi-blog/water-blogged-blog/2019/02/anatomy-of-ph-electrodes
8. ThermoFisher Scientific. (N.D.) Essentials of pH measurement. Available from: http://www.ohiowea.org/docs/1500_pH_Seminar_Meirose.pdf
9. Koslow Scientific. (2015). Kit product number: Saturated calomel electrode (SCE), Safety data sheet. Available fromhttps://www.ameteksi.com/-/media/ameteksi/download_links/documentations/supportcenter/princetonappliedresearch/safety_data_sheets/g0115_saturated_calomel_electrode.pdf?la=en
10. ThermoFisher Scientific. (2014). Safety data sheet, Filling solution: 4M KCL saturated with Ag Cl. Available from: https://www.fishersci.com/shop/msdsproxy?productName=SP135500&productDescription=POTASSIUM+CHLORID+SOL+4M+500ML&catNo=SP135-500&vendorId=VN00033897&storeId=10652
11. Engineer Live. (2013). Innovative pH electrodes with iodine/iodide reference system. Available from: https://www.engineerlive.com/content/innovative-ph-electrodes-iodineiodide-reference-system
12. Fisher scientific. (2020). Sartorius GoldLINE electrodes. Available from: https://www.fishersci.ca/shop/products/goldline-electrodes/p-5295538

13. Home science Tools. (2018). Safety data sheet: iodine-potassium iodide solution. https://www.homesciencetools.com/content/reference/CH-IODINE.pdf

Mercury-containing lamps including: compact fluorescent lamps, cold cathode fluorescent lamps and external electrode fluorescent lamps, induction fluorescent lamps and automotive headlamps	
Description:	Lamps that are dependent on mercury to product light
Alternative:	The primary mercury-free alternative to mercury-containing lamps are Light Emitting Diodes (LEDs). LEDs use a semiconductor as a light source and have very high energy efficiency and significantly longer lifespans than fluorescent lamps. LEDs also appear to be the main replacement component for lamp components in infrared light detectors and radiation detectors.[1]
Availability:	LEDs have been on the market for 30 years but have seen a dramatic rise in demand in the last 5 years.[1] Large lighting manufacturers are phasing out the production of traditional lighting products in favour of greater production of LEDs.[2] Major companies such as GE and Philips are actively promoting the shift from CFL to LED and North America's lighting market is predicted to be 70% LED and 4% CFL by 2020.[3]
Technical and economic feasibility:	**All lamp types:** LEDs achieve 50-70% energy savings vs traditional lighting technologies and have lifespans of 50,000 to 100,000 hours. The 'catastrophic' failure rate of LED products over 6,000 hours is about 1%.[4] Estimates made in 2012 predicted that the global lighting market would expand to US$160 billion by 2020, primarily due to growth in demand for LEDs as their prices decline. The price of LEDs was expected to fall by more than 80% and reach a global penetration of around 60% across all lighting applications by 2020.[4] Additional information was available for the following specific lamp types: **CCFL and EEFLs:** Over the last decade LEDs have largely replaced CCFLs and EEFLs in the backlighting of flat panel displays such as liquid crystal displays (LCD).[1] LEDs allow for thinner and lighter designs in displays, use less power as they are more energy efficient and enable higher brightness and illuminate the screen more evenly.[5] In addition, LEDs illuminate instantly whereas previous CCFL-backlit displays at first appeared dim and then gradually increased in brightness. LEDs also have longer life spans than CCFLs and EEFLs.[1] Previously, LEDs for backlighting displays were more expensive than CCFLs and EEFLs but this is no longer the case as the price of LEDs has fallen. LEDs were predicted to completely replace CCFLs in TVs by 2014.[6] By 2016 LEDs had almost completely replaced CCFLs and EEFLs in most applications including smartphones, tablets, notebooks, tabletop monitors and TVs.[7] LEDs are also the main alternative for cold cathode/neon lamp uses including signage applications.[8]

	Induction lamps: the costs of LEDs have continued to decline in recent years while the costs of induction lighting have not. Improvements and new technologies for LEDs continue to be made, whereas similar innovation in induction lighting is not expected. As a result, LEDs have become increasingly cost-competitive with induction fluorescents.[1] LEDs are much more energy efficient than induction lamps.[9] Induction lamps often cannot be dimmed, and induction lamps that can be dimmed are only able to go a few settings below 100% compared to a full range of dimness available for LEDs. In addition, induction lights are much larger than their LED equivalents and when several lights need to be mounted on poles for lighting large spaces (such as parking lots) the smaller size of LEDs can be a significant advantage.[10] **High pressure sodium lamps:** LED lights provide much better colour rendering compared to high pressure sodium vapour lamps. LEDs provide an even white light, which is especially important for obtaining clear security camera footage.[1] Sodium lamps have the worst colour rendering of all lamps on the market with objects illuminated by them appearing shadowy black rather than the colour seen in daylight. LEDs are also much more energy efficient that high pressure sodium lamps resulting in lower operating costs.[11] High pressure sodium lamps typically require a "warmup" period which can take up to 10 minutes. As the light heats up it needs more voltage to operate which is balanced by a ballast (a magnetic or electric device designed to provide the light constant current). Over time, high pressure sodium lamps require more and more voltage to produce the same amount of light. Eventually, the voltage exceeds the fixed resistance provided by the ballast and the light goes out (fails). The lights become less efficient over time because they need more and more voltage to produce the same lumen output (brightness). In general, high pressure sodium lamps are usually able to maintain fairly good brightness (roughly 80% of original brightness) at their typical end-of-life (24,000 operating hours).[1] High pressure sodium lamps are particularly useful for outdoor lighting (such as municipal street-lighting or other common areas like parking lots). Compared to incandescent bulbs, fluorescent bulbs, and most high intensity discharge lamps, high pressure sodium lamps are much more efficient and last longer. It is only recently that LED lighting has become more affordable and prevalent enough to surpass high pressure sodium lamps in terms of energy efficiency and lifespan. The upfront costs of installing high pressure sodium lamps can still be lower than LEDs however the lifetime costs (including consideration of reduced maintenance and energy efficiency improvements) are lower for LEDs.[1] High pressure sodium lamps have higher maintenance costs and are more fragile than LEDs – several sodium vapour bulb replacements would be expected within the typical lifetime of an LED.[11]

	Metal halide lamps: Metal halide lamps can be very useful for high intensity applications like vehicle headlamps, athletic facility illumination, or for photographic lighting. The main advantage of metal halide lamps is their high-quality light output generating a very cool white light. LEDs also produce high quality light output with a very broad spectrum available depending on the light; ranging from warm 'yellow' to cool 'blue' light. Metal halides may still be the best source of high colour-rendering index white light on the market.[12] LEDs have longer lifespans than metal halides (50,000 to 100,000 hours or more compared to 6,000 to 15,000 hours). In the past, the costs of LEDs were higher, however with the prices of LEDs declining in recent years the upfront costs of LEDs and metal halides are now very close.[1] Metal halide lamps have the longest warmup period of any lamp on the market (between 15-30) and must therefore be operated for longer periods than LEDs and cannot be quickly switched on and off on demand. This results in lights often being left on when not needed to avoid the long warmup period. Due to the long warmup period for metal halides, there must be some anticipation of when light is required. LEDs have the advantage that they turn on immediately. Both LEDS and metal halides can be dimmed. However, dimming metal halides alters the light characteristics and reduces the efficiency of the light. LEDs are more energy efficient than metal halides. Metal halides emit about 15-20% of the total energy consumed is emitted as heat. LEDs emit very little heat. Metal halide lamps usually start switching on and off unexpectedly as they reach their end- of-life before failing completely. LEDs fail by gradually dimming over time. In many applications (e.g. stadium lighting) a sudden unexpected loss of light would not be acceptable and hence metal halides are often proactively changed out before the end of their useful life. Metal halides are also more fragile than LEDs. LEDs are solid state lights and difficult to damage with physical shocks.[12] **Automotive headlamps:** LED lamps have become much more widely used in the global automotive lighting market in recent years. However, their upfront costs are still higher than the alternatives such as halogen bulbs.[1] LED costs continue to fall; however, one market research report on the global automotive lighting market 2016-2020 expects that the cost of LED lighting may slow the growth of the market during this period.[13] LEDinside predicts that the value of the exterior automotive LED market will increase by 6% per year 2016-2020, continuing to replace traditional lamps in this application.[14] Data from recent IMERC reports indicate that major automakers (e.g. Honda, Nissan, BMW, Subaru, Mitsubishi, Mercedes-Benz) are phasing out uses of mercury-containing headlamps more rapidly than the LEDinside report predicts as many vehicle models had phased out mercury headlamps by the end of 2017.[1]
Risks and benefits:	LEDs are preferable to mercury-containing lamps from an environmental perspective since they are mercury-free and have higher efficiency and longer lifespans. However,

	a group of researchers questioned the hazards of certain types of LEDs that contain hazardous substances such as lead.[15] After conducting leachability and other tests, researchers found that LEDs are not hazardous (according to US federal standards) except for the low-intensity red LEDs that were tested, which leached lead at levels exceeding regulatory limits (186 mg/L; regulatory limit: 5).[15] The researchers found that LEDs, had levels of copper (up to 3892 mg/kg; limit: 2500), Pb (up to 8103 mg/kg; limit: 1000), nickel (up to 4797 mg/kg; limit: 2000), or silver (up to 721 mg/kg; limit: 500) making all LEDs except low-intensity yellow LEDs, hazardous according to California standards. This research study was based on a very small sample of an older generation of LEDs and more up to date content data for commonly used current LEDs would be useful. In this regard, a review of Safety Data Sheets for current LEDs from major suppliers indicates that current LEDs do not contain lead or any hazardous materials in reportable quantities and "there are no substances contained within an LED lamp that would cause the lamp to be classified as hazardous waste".[16] More recently, and specifically in the context of street lighting, the American Medical Association (AMA) noted the following advantages of LEDs: "The main reason for converting to LED street lighting is energy efficiency; LED lighting can reduce energy consumption by up to 50% compared with conventional high pressure sodium (HPS) lighting. LED lighting also has no warmup requirement with a rapid "turn on and off" at full intensity. In the event of a power outage, LED lights can turn on instantly when power is restored, as opposed to sodium-based lighting requiring prolonged warmup periods. LED lighting also has the inherent capability to be dimmed or tuned, so that during off peak usage times further energy savings can be achieved by reducing illumination levels. LED lighting also has a much longer lifetime (15 to 20 years, or 50,000 hours), reducing maintenance costs by decreasing the frequency of fixture or bulb replacement. That lifespan exceeds that of conventional HPS street lighting by 2-4 times. Also, LED lighting has no mercury or lead, and does not release any toxic substances if damaged, unlike mercury or HPS lighting. The light output is very consistent across cold or warm temperature gradients. LED lights also do not require any internal reflectors or glass covers, allowing higher efficiency as well, if designed properly"[17] However, the AMA also suggested that there could be health issues related to the cool light (blue light) of LEDs vs the warm light of traditional lamps with regard to disruptions to the circadian cycles in humans and nocturnal wildlife. With regards to concerns about blue light, it should be noted that most white light LEDs used today have 'blue-pump' LED chips that convert most of the light output into longer wavelengths, typically in the green, yellow, orange, and red parts of the spectrum to produce a white light.[18] There are other less common technologies that can produce white light and offer greater flexibility for adjusting the light output colour. One method is to combine LEDs of different colours or to combine multiple LEDs of various colours, in order to produce the desired light output colour. Systems offering dynamic adjustability tend to be more expensive and have been employed less often in street lighting and other outdoor applications to date.[1]

	Using shorter wavelengths (wavelengths associated with blue light) has some important advantages over using longer wavelengths. For example, they generally render nighttime colors more similarly to daylight, aid in identification (e.g., of vehicles, clothing, people), and improve contrast between an object (e.g., road debris) and its surroundings.[18] However, there can be times where using longer wavelengths is necessary, for example, in areas with endangered species that may be affected by short wavelengths. In these situations, the wavelengths of the light source can be engineered to match the wavelengths required. In this context LEDs are particularly useful because the wavelengths they emit can be more easily manipulated than those of most conventional light sources.[18] For example, the output of LEDs can be modified to emit particular wavelengths, allowing engineers to design lighting systems that produce cool light while minimizing the narrow range of wavelengths that affect sleep cycles. Since cool lighting is more effective, lights don't need to be as bright and streetlights can be dimmed late at night to save energy and reduce the impact on circadian rhythms.[19]

1. ToxEcology Environmental Consulting Ltd. (2018). Technical background study on products containing mercury in Canada with reference to the recently ratified Minamata Convention on Mercury.
2. For example: 'LEDVANCE to Shut Down Two Facilities to Focus on Solid State Lighting' Jan 23, 2018. Available from: https://www.ledinside.com/news/2018/1/ledvance_to_shut_down_two_facilities_to_focus_on_solid_state_lighting
3. Nunez C. (2016). An unloved light bulb shows signs of burning out. National Geographic: https://news.nationalgeographic.com/energy/2016/02/1602016-cfl-phase-out-light-bulb-leds/
4. The Climate Group. (2012). Lighting the clean revolution. Available from: https://www.theclimategroup.org/sites/default/files/archive/files/LED_report_web1.pdf
5. EDN Network (2015). LEDs for liquid crystal display (LCD) backlighting. Available from: https://www.edn.com/design/led/4438213/LEDs-for-liquid-crystal-display--LCD--backlighting---Part-1
6. LEDinside. (2013). Direct-type LED TV penetration rate surpasses 60% in 2014. Available from: https://www.ledinside.com/node/19148
7. LEDinside. (2016). Overview of micro-LED history and current developments. Available from: https://www.ledinside.com/outlook/2016/8/overview_of_micro_led_history_and_current_developments and refer to footnote 40 for perspective on EEFL as well as CCFL uses in displays
8. For example: A sign of the times, LED is replacing neon (2016). Available from: http://www.eastoregonian.com/eo/business/20160819/a-sign-of-the-times-led-is-replacing-neon; Replacing glass neon with flexible LED. Available from: https://blog.1000bulbs.com/home/neon-sign-repair
9. LEDs Magazine. (2014). Finally light challenges LED lighting with induction replacement lamp. Available from: http://www.ledsmagazine.com/articles/2014/05/finally-light-challenges-led-lighting-with-induction-replacement-lamp.html

10. Buildings Smarter Facility Management. (2015). LED vs Induction lighting: Which Illumination Solution is Right for Your Facility? Available from: https://www.buildings.com/article-details/articleid/18718/title/led-vs-induction-lighting/viewall/true
11. Stouch lighting. (N.D.) LED versus high pressure sodium (HPS) and low pressure sodium (LPS). Available from: http://www.stouchlighting.com/blog/led-vs-hps-lps-high-and-low-pressure-sodium
12. Stouch lighting. (N.D.) LED versus Metal Halide Lights. Available from http://www.stouchlighting.com/blog/led-lights-versus-metal-halide
13. ASD Reports. (2015). Global Automotive Lighting Market 2016-2020: Sample Report. Available from: https://www.automotive-iq.com/events-autoadvancedlighting/downloads/global-automotive-lighting-market-2016-2020
14. LEDinside. (2016). Automotive LED market has a bright future with the rise of replacement products. Available from: https://press.trendforce.com/press/20160707-2544.html#kuqIg3KvXdEWq2xL.99
15. Lim et al. (2011). Potential environmental impacts of light-emitting diodes (LEDs): Metallic Resources, Toxicity, and Hazardous Waste Classification. *Environ. Sci. Technol.*, 2011, *45* (1), pp 320–327; DOI: 10.1021/es101052q
16. Example Safety Data Sheets for LEDs from GE and Philips. Available from https://products.currentbyge.com/sites/products.currentbyge.com/files/document_file/LED-Lamp-Material-Sheet_0.pdf and http://www.usa.lighting.philips.com/support/support/literature/msds-sheets#
17. American Medical Association (2016). Guidance to Reduce Harm from High Intensity Street Lights Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting. Report of the Council on Science and Public Health CSAPH Report 2-A-16.
18. US Department of Energy. (2017). Street lighting and blue light FAQs. Available from: https://www.energy.gov/sites/prod/files/2018/04/f50/Street%20Lighting%20and%20Blue%20Light%20FAQs.pdf
19. Lombardo, T. (2017). Are LED Lights bad for your health? Available from: https://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/14607/Are-LED-Lights-Bad-for-Your-Health.aspx

Photographic film/paper	
Description:	Film and photographic paper that contains mercury as part of the developing process
Alternative:	Digital cameras and prints are available as well as mercury-free film and photographic paper
Availability:	Alternatives are widely available and appear to have been available since the 1970s. Little information is available on the current use and availability of mercury containing film and photographic paper.

Technical and economic feasibility:	Mercury-free photo papers perform just as well if not better than mercury-added photo papers[1]. Alternatives for mercury added photographic film and paper are most widely used and are therefore assumed to be economically and technically feasible.
Risks and benefits:	Mercury-free photographic film and paper do not require special treatments for handling or disposal.

1. https://imaging.kodakalaris.com/sites/uat/files/wysiwyg/pro/Silver_Halide_White_Paper.pdf

Infrared detectors	
Description:	Infrared detectors are detectors that react to infrared (IR) radiation. IR detector products can be highly specialized and have many uses in the military, scientific, security, medical, industrial and automotive areas. For example, IR detectors can be used in: rail safety, gas leak detection, flame detection, medical applications, petroleum exploration, space operations, temperature sensing, water and steel analysis, as well as motion detectors for alarm systems. There are two major types of IR detectors: thermal detectors and photon-sensitive detectors (photodiodes). Thermocouples, bolometers, thermistors, Golay cells, and pyroelectric devices such as those based on deuterated triglycine sulfate (DTGS) are examples of thermal detectors; while silicon photodiode, indium gallium arsenide (InGaAs), lead selenide (PbSe), mercury cadmium telluride (MCT), and indium antimonide (InSb) are examples of photon-sensitive semiconducting detectors.
Alternative:	Depending on the detector and application, several other types of IR detectors are available including (but not limited to): InGaAs (indium gallium arsenide), InAs/GaInSb (indium arsenide/gallium antimonide), InSb (indium antimonide), SiAs (silicon arsenide), PbSe (lead selenide), InSb (indium antimonide) and SiSb (silicon antimonide), and SiGe (silicon germanium).[1] Detectors may also use a combination of the different types of technologies. New high-performance IR detectors are also using emerging technologies based on nanomaterials including graphene.[2] The alternative most suitable for the reported IR detector products will depend on the exact product type and the nature of the mercury-containing component.
Availability:	The 2018 report by ToxEcology indicated that although some MCT-based detectors were imported into Canada in 2016, other companies are using mercury-free alternatives. [1] This indicates that in Canada, mercury-free alternatives are available.
Technical and economic feasibility:	The non-mercury alternatives can provide comparable performance to MCT-based detectors for all applications and are used by major IR detector manufacturers.[3, 4]
Risks and benefits:	Substitution of mercury with lead compounds would not be recommended from a human health or environmental perspective. Further investigation on the

	appropriateness of substituting mercury compounds with arsenic compounds may be needed to fully assess the health and environmental risks and benefits of these alternatives.

1. ToxEcology Environmental Consulting Ltd. (2018). Technical background study on products containing mercury in Canada with reference to the recently ratified Minamata Convention on Mercury.
2. Tan, C.L & Mohseni, H. (2017). Emerging technologies for high performance infrared detectors. Nanophotonics, 7(1): 169-197: Available from : https://www.degruyter.com/downloadpdf/j/nanoph.2018.7.issue-1/nanoph-2017-0061/nanoph-2017-0061.xml
3. Rogalski, A. (2012). History of Infrared detectors. Opto-Electron. Rev. 20, no.3. 279-308: DOI: 10.2478/s11772−012−0037−7 (e.g. see Table 3) https://doi.org/10.1088/0034-4885/68/10/R01;
4. Hamamatsu Photonics. (2011). Infrared Detectors – Technical Information. Available from: https://www.hamamatsu.com/resources/pdf/ssd/infrared_kird9001e.pdf

In addition to the products above, Canada is considering removing the exemption in the *Products Containing Mercury Regulations* for the following product categories due to the fact that there were no imports of these products in 2016: radiation light detectors; very high accuracy capacitance and loss measurement bridges, high frequency radio frequency switches and relays; and composite resins and adhesive resins used in the aerospace industry.

Canada has been made aware of potential uses of mercury in rocket propulsion systems in other jurisdictions[1]. This is a concern to Canada because of the atmospheric fallout and distribution of mercury into the air. Most atmospheric mercury deposited in Canada comes from foreign sources, and the addition of rocket fuel to existing mercury sources would only exacerbate this issue. Alternatives to mercury-based propellants are available and have been used for many years.

[1] https://www.bloomberg.com/news/articles/2018-11-19/this-space-startup-could-lace-the-atmosphere-with-toxic-mercury