Minamata Convention: analysis of the socio-environmental impacts of a long-term solution

Convenção de Minamata: análise dos impactos socioambientais de uma solução em longo prazo

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ABSTRACT The objective of this study was to estimate and to analyze the extent of the socio-environmental adverse impacts during the moratorium period provided in the Minamata Convention for two mercury emission sources: the industrial sectors of chlor-alkalis and of fluorescent lamps. The application of the conceptual integrated model DPSIR, of the case study and calculations utilizing available sectorial data has found an estimated total emission of 18.6 thousand tons of mercury, which will impact several environmental compartments and life in them. The moratorium period granted by the Minamata Convention is not justified because alternative technologies already exist that replace both electrolytic cells and bulbs without producing mercury pollution.

KEYWORDS Mercury poisoning. Environmental impact. Health.

RESUMO *O objetivo do presente estudo foi estimar e analisar a magnitude dos impactos socioambientais adversos durante o período de moratória previsto na Convenção de Minamata para duas fontes de emissão de mercúrio: os setores das indústrias de cloro-álcalis e das lâmpadas fluorescentes. A aplicação do modelo conceitual integrado Driver-Pressure-State-Impact-Response (DPSIR), do estudo de caso e de cálculos a partir de dados setoriais disponíveis encontrou a emissão total estimada de 18.6 mil toneladas de mercúrio, que impactará os diversos compartimentos ambientais e a vida neles inserida. O período de moratória outorgado pela Convenção de Minamata não se justifica, porque já existem tecnologias alternativas que substituem tanto as células eletrolíticas, como as lâmpadas, sem causar poluição de mercúrio.*

PALAVRAS-CHAVE *Intoxicação por mercúrio. Impacto ambiental. Saúde.*

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Introduction

Mercury is a noble liquid metal that is in the elemental metallic species, in organic and inorganic compounds and in the oxidation states Hg^{o}, Hg^{1} and Hg^{2}. The metal is toxic and vaporizes even at zero degree Celsius. It is persistent in the environment and is still widely used in society.

The deleterious effects of mercury have been observed for decades, especially in the workplace. Goldsmiths and hatters, for example, had signs and symptoms of chronic occupational mercurialism, due to their constant contact with the mercury vapors in their elemental form (the expression 'mad hatter' comes from the workmanship of the hatters in the 19th century). Going further, in the roman empire, christians and slaves were forced to work in the mercury mines (ZAVARIZ, 1994).

The awakening of public awareness of the consequences of mercury and its compounds widened in the 1960s with the environmental disaster in Japan, where, for more than twenty years, an industry has released in its liquid effluents the mercury in its organic form directly into the Minamata bay.

The bay, located in the southern archipelago of the Country, was contaminated by the residues of the Chisso company, which contaminated the marine fauna and, through the trophic chain, reached man. In addition to the sequelae in the body and mind of the victims, Minamata is also a history of the political struggle of the population for the recognition of 'Minamata Disease' or 'Minamata Harm'.

Despite technological modernity, the advancement of laws protecting the working environment, mercury and its compounds are still used in processes and products around the world, especially in peripheral countries. Therefore, exposure to metal vapors in the workplace is difficult to control. Although naturally existing trace amounts in the crust of the earth, the anthropogenic emissions of mercury are higher and, on the other hand, have increased significantly since the beginning of the industrial period (POULIN; GIBB, 2008).

The chemical reactions of mercury in the environment are complex, and, once released by anthropic action, considering its volatility, its biogeochemical cycle, providing circulation between soil, air and water, added to circulation and atmospheric phenomena, mercury can be found in most remote locations of planet Earth. The metal mercury when released is a pollutant that tends to remain in suspension from 4 months to up to a year in the atmosphere, react with other substances present and suffer deposition, and can, in this cycle, become organic by biotic factors (WATKINS III; KLAASSEN, 2012). Although the organic form of mercury is considered the most toxic (methylmercury), elemental mercury and inorganic mercury are also toxic.

Recent research has shown that mercury causes changes in the sexual behavior of birds (CONDON; CRISTOL, 2009), however, other species that feed on fish also already have detectable levels of methylmercury (FREDERICK; JAYASENA, 2011). Although scarcer, there are still cases of children diagnosed with mercury contamination (acrodynia), emphasizing that the diagnosis can be confused with other diseases (KHODASHENAS; AELAMI; BALALI-MOOD, 2015).

Mercury is considered an endocrine disrupter. Studies indicate that, in its organic form, it can cause male infertility (DUARTE, 2008). Mercury was found in higher concentrations in breast biopsies of women with breast cancer (INCA, 2012). Genotoxic tests reveal mutations, responsible for the emergence of cancers. There is a possibility that the emergence of cancer by exposure is related to the ability of mercury to affect the immune system (CARDOSO, 2001).

The behavior of mercury in nature, with

its characteristic of reacting and transforming, increasing toxicity, is a threat to the various life forms in the environment, especially considering that there is no control once it is emitted. In 2002, the United Nations Environment Programme (Unep) stated that mercury levels are already high both in freshwater and saltwater fish and in people whose fish is part of the regular diet. These levels may be responsible for adverse health effects (UN, 2002).

From evidence that public and collective health is at serious risk with the disorderly release of mercury into the environment, discussions began in the international political scope, lasting for about six years, resulting in a legally binding international treaty which aims to protect human health and the environment from the anthropogenic emissions of mercury and its compounds. In October 2013, the Minamata Convention for mercury had the final text approved and signed by 92 countries, among them, Brazil. Currently, it has 128 signatures and 28 ratifications, noting that only after the 50th country has submitted to the Convention secretariat the ratification document is that it becomes formally effective at the international level.

The purpose of the Convention is to protect, mainly, populations considered to be most vulnerable to mercury, such as fetuses, children and pregnant women. Organic mercury can overcome the placental barrier with greater efficiency, and it is possible to find the inorganic species in amniotic fluid and in breast milk (AZEVEDO, 2003). Mercury devastates the neurological system at the moment that the human being is still developing, including fetal development. Mercury damages vary, ranging, for example, from attention deficit, blindness, deafness, muscular atrophy, mental retardation, to death.

Although the international treaty is a breakthrough for the protection of human health and the environment, it brings long moratorium periods to mercury-containing processes and products. For example: products such as batteries, computers, switches, fluorescent lamps, cosmetics, barometers, hygrometers, manometers, thermometers, sphygmomanometers, pesticides, biocides and antiseptics will have a moratorium of use by 2020; the production of chlor-alkalis with mercury cells, by 2025; and the production of acetaldehyde, by 2018. The Convention excludes from prohibition many other mercury products and activities, such as those for: civil protection or military use, research products, instrument calibration, cultural and religious practices, and vaccines with thimerosal.

There are other activities and other products of which the Minamata Convention does not provide for elimination, but suggests control, such as: power plants and boilers operated with mineral coal, foundry and roasting processes used for the production of non-ferrous metals, waste incineration plants, cement production plants, artisanal and small scale gold mining, production of vinyl chloride monomers, sodium or potassium methylate or ethylate, production of polyurethane, using mercury-containing catalysts, and dental amalgam.

Due to the wide range of sectors and products containing mercury covered by the Minamata Convention and the difficulty of obtaining data for a comprehensive analysis of the overall impacts, this study made a cutout to evaluate two critical activities considered in the Minamata Convention. The first one, in view of the spread of mercury with the commercialization of lamps in all national and world territory, and the second, considering the use of expressive volumes of mercury, as in the production of chlor-alkalis. Chlorine is used in the manufacture of polyvinyl chloride (PVC), chlorinated solvents and agrochemicals and for sanitary purposes. Alkalis, mainly caustic soda, are used in the manufacture of soaps, detergents and in various industrial uses, such as metallurgical, textile, food, pharmaceutical, among others.

In this way, the objective of the present work was to analyze the impacts of the moratorium period of these two sectors, that of fluorescent lamps, through the integrated conceptual model DPSIR (Driver-Pressure-State-Impact-Response), and the chlor-alkali sector, by case study and by means of calculations of emissions.

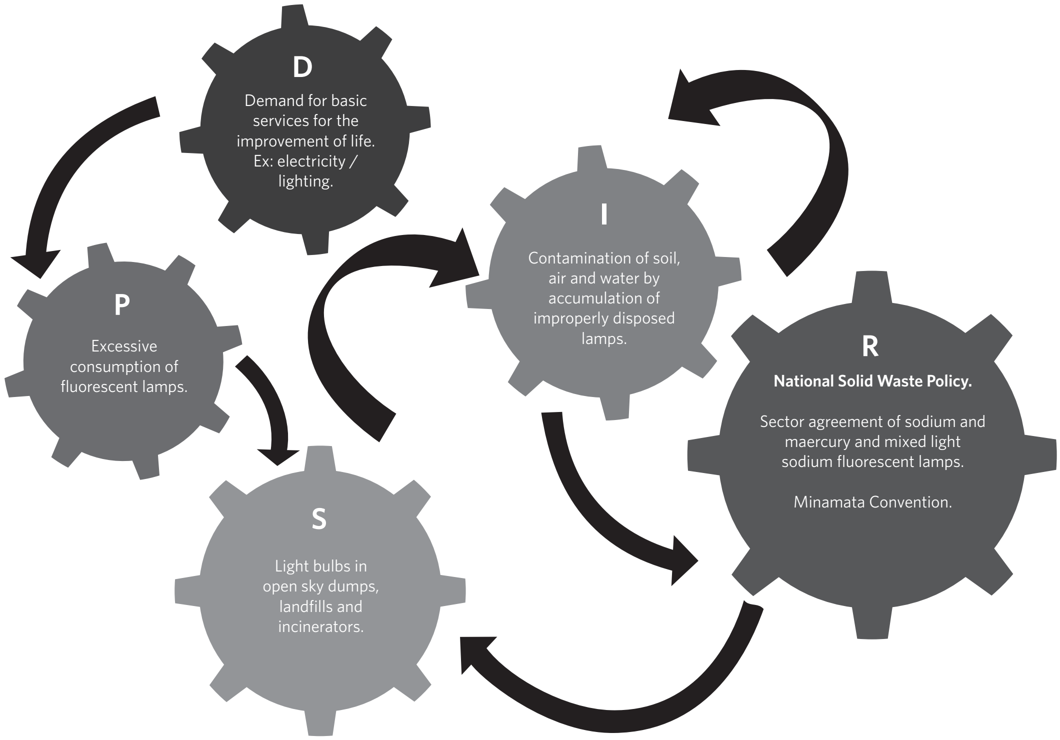
The totals of national and international emissions of these two productive sectors during the moratorium period proposed in the treaty were calculated from data collected from various sources, such as the Brazilian Association for the Chlor-Alkali and Derivatives Industry, the Ministry of Environment and the World Chlorine Council (WCC) for chlor-alkali; the Brazilian Association of Lighting Industry (Abilux) and the China Association of Lighting Industry for the lamp sector.

Analysis of the impacts caused by mercury lamps through the DPSIR model: Driving Forces, Pressures, State, Impact and Response

The DPSIR model, an acronym that, in Portuguese, means: Driving force – Pressure – State – Impact – Response, developed by the European Environmental Agency (EEA), helps to organize the analytical thinking about an environmental problem. The model makes it possible to analyze a given problem from its origin, its ramifications, to measures aimed at mitigating the impact, considering the ecosystem management that seeks interaction between environment, economy and society and sustainable development.

In DPSIR, driving forces are human needs that put pressure on the environment, and the result of these pressures is reflected in the state of the environmental condition, which, in turn, affects social and economic conditions, resulting in the impact, which, in what concerns it, demands answers from the society that generated it (PEREIRA, 2015) (*figure 1*).

Figure 1. Example of element interaction in the DPSIR analytical model for fluorescent lamps



Considering that the destination of fluorescent lamps after their useful life becomes an environmental problem, since their disposal is, most often, done in an inappropriate place or in an inappropriate way and in massive quantities, the DPSIR was used to analyze this context as an environmental conditioner.

From the increase in population consumption, which is geometrically larger than the population growth, even though it does not reach the whole of society, it is observed as driving force the demand for light electric energy and, by pressure, the excessive consumption of fluorescent lamps, mainly after the energy crisis of 2001 in the Country. The response of the brazilian government and energy sectors was to adopt the policy of replacing incandescent lamps with fluorescents, which culminates in 2016 (MONTEIRO; MEIRIÑO, 2015). As an impact, there was an 80% reduction in luminous energy consumption (CAMBESES POLANCO, 2007), but no strategy was used to adjust the increase in the use of fluorescent lamps due to the inherent risks.

Fluorescent, compact, tubular and mixed lamps, after use, are listed as class 1 hazardous wastes, listed in the annex B of the NBR 1004 of the Brazilian National Standards Organization. Due to environmental pressure, we have the inadequate storage of the post-consumption lamps, the lamp breaks at disposal in landfills and dumps, and there is no control of these impacts.

After the end of their useful life, lamps are considered an 'externality' for producers, who do not get involved in the result of their product after use. There is no way to know precisely the amount of mercury in the lamps entering the market. And, completing the framework, there is no effort to raise public awareness about environmental and health risks, related to the post-use of fluorescent lamps and other mercury models.

In the sphere of impacts, during the elaboration of the DPSIR, it was considered that people are sensitive to the exposure to ultraviolet rays of the lamps and their scintillation, involving skin, eye, neurological problems and even the immune system (EUROPEAN COMMISSION, 2012). Another impact of the lamp sector comes from the productive sector, with workers intoxicated by mercury in the workplace.

LED lamps (light emitting diodes) have higher energy efficiency. Although they can be considered as a response, that is, an alternative to fluorescent lamps, they also have harmful substances, such as lead, so that their after-use handling requires care. As a response, we also have the National Solid Waste Policy (NSWP), which has been in force since 2010, and, also, the sectoral agreement on fluorescents, sodium vapor (mercury) and mixed light lamps, signed in 2014 between The Ministry of Environment and the lamp sector. The international response to the environmental problem of mercury-containing lamps is the Minamata Convention.

To better qualify the possible environmental health impacts that the moratorium period will entail, indirect data were collected from the companies and associations of lamps and calculations were made to estimate the amount of emission from this sector in the period.

Estimated cumulative emission of the mercury lamp industry due to the moratorium offered at the Minamata convention

Brazil imports, on average, 313.000,000 lamps per year (BRASIL, 2016). Tubular fluorescent lamps have, on average, inside, 15 mg/Hg, the compact 4 mg/Hg, the mixed 17 mg/Hg, the mercury vapor 32 mg/Hg, the sodium vapor 19 mg/Hg and metallic vapor 45 mg/Hg (AMBIENSYS, 2014).

In 2014, 250 million compact lamps, 100 million tubular lamps and 11 million sodium/metal lamps were commercialized, which also contain mercury (ABILUX, 2015) *(table 1)*. And, still, 300 million incandescent lamps. After the prohibition of the production and commercialization of these lamps, in 2016, other lamps, such as LEDs, LFCs and tubular lamps (the last two of Hg), are consumed in their place. Considering that these mercury lamps have, respectively, 4, 15 and 32 mg, a rate of 8 mg per lamp is reached, on average.

Table 1. Estimated average amount of Hg per lamp

Consumption by Type of Lamp and Total Hg - BRAZIL		
Amount of lamps	**Amount of Hg**	**Total of Hg**
250 million of compact	4 mg	1.000.000.000 mg
100 million of tubular	15 mg	1.500.000.000 mg
11 million (sodium/metallic)	32 mg	352.000.000 mg
Total	Average of 8 mg/lamp	2.852.000.000 mg

The Minamata Convention introduced a moratorium to produce lamps by 2020, and the signatory countries may, still, with justification, extend this moratorium by 2030. Considering that, in Brazil, are used, each year, 313.000,000 lamps, it may be estimated that these lamps at the end of their cycle introduce into the environment about 2.504 kg/Hg/year.

With the moratorium period being extending for 17 years (2013-2030), will be introduced in the environment by Brazil 42.568 kg of mercury, without considering the rate of 6% of recycling. Worldwide, with a production of 6,69 billion (BEIGL, 2016) of lamps, considering a rate of 8 mg of mercury per lamp, we will have an estimated emission of 909.840 kg of mercury, without considering the 20% of recycling *(table 2)*. The *table 2* below, presents the estimated calculations of mercury introduced into the environment, considering that recycled mercury will not be released into the environment.

Table 2. Estimated emission of Hg by total discarded lamps

ESTIMATION OF EMISSION AND RELEASE OF HG BY DISPOSAL OF LAMPS			
Scope	**Production of lamps**	**Mg/Hg per lamp**	**Total/Kg/Hg/year**
Brazil	313.000.000 per year	8	2.504
World (China)	6.690.000.000 per year	8	53.520
Estimated emission in the worst Hypothesis with Production and Disposal until 2030			
Brazil (17 years)	42.568 Kg	World (17 years)	909.840 Kg
Brazil (6% of recycling)	40.014 Kg	World (20% of recycling)	727.872 Kg

Case study of a chlor-alkali industry that uses mercury electrolytic cells

Through the case study, it was analyzed the issue of the environmental impact of mercury in a brazilian chlor-alkali industry that still uses the metal in the electrolytic process. One of the arguments in relation to technology change in outdated processes that harm the environment is the high cost of restructuring, which is a threat to employability. This way, it is created among the people a conservative thinking and behavior of acceptance of practices harmful to the environment, in which it is understood that care for the environment would be a way of containing economic development and progress. Thus, in society, there is a massification of a linear, immediate thought that does not consider the finiteness of natural resources, nor its contamination and degradation, which puts pressure on ecosystems, as well as the well-being of workers and the urban population.

The industry analyzed in the study is the market leader in chlorine and derivatives. It produces liquid chlorine, caustic soda in flake and liquid and derivatives of the production, as sodium hypochlorite, hydrochloric acid and dichloroethane. It is a supplier of raw material for the national industrial production of varied products, ranging from food to other chemicals, such as chlorinated solvents. The main products of the company, such as chlorine, are used in sanitation. The Company has around 700 employees, both fixed and outsourced, and is in a city that has one of the largest industrial parks in the Country.

Despite the great wealth produced by the industrial complex of the metropolitan region, of which the study industry is a part, the distribution is deficient, since the municipality that houses this industry has one of the highest poverty, violence and crime rates in the region (murder, robbery and theft of vehicles), as well as the lack of adequate sewer system, among other precarious health indicators. It is from the developmentalist dictatorial package the growth without the proper urban, socioeconomic and environmental planning of the territory of the city that houses this chlor-alkali industry, due to the industrial expansion.

Since the 1960s, this producer of chlorine and derivatives has been active at the industrial pole, and among the seven industries of the fertilizers and petrochemical industries studied by the Environmental Sanitation Technology Company of the State of São Paulo (Cetesb) in the 1970s, was the one that contributed most to the mercury pollution of the river of important use for the region where it is located (HORTELANNI, 2003). In the 1975s, it consumed 440 grams of mercury per ton of chlorine produced, with an estimated loss of 40 tons/year. Like the others in the same segment, the industry develops projects of social and environmental responsibility and, this way, explores green marketing with the image of a company that is environmentally friendly, concerned about the health and quality of life of the local population, despite maintaining polluting activity.

The chlor-alkali company is located on the left bank of the Perequê river, at the confluence with the Cubatão river, where it launches its 'treated effluents', and in the right bank of the Cubatão river, about 300 meters away, there are five residential districts. Research with children fed on fish from the Cubatão river showed differences in the concentration of mercury in the blood, compared to the concentration found in children of the same place that did not consume any type of fish (SANTOS FILHO *ET AL.*, 1993).

The industry has caused environmental impacts related to mercury and other pollutants and, since 2003, is in the relation of contaminated areas of the environmental organ of the state in which it is. In these documents, there are several sources of contamination: storage, discard, disposal, production, infiltration, maintenance. Impacted environment are surface waters, surface soil and subsoil (within the property), groundwater and sediments (outside the property). Due to these notes, the company is in environmental recovery (SÃO PAULO, 2015).

The industry studied was fined for not carrying out complementary examinations in workers exposed to Hg. There were cases of intoxication of workers by metallic Hg, however, the industry did not allow in-depth tests, such as, for example, a set of neuropsychological tests for the detection of symptoms and signs of hydrargirism in people whose urine test was between 5 and 35 ug of Hg/g.

In 2013, analyses of atmospheric emissions of the chlor-alkali industries showed that there are atmospheric mercury emissions, including that of the case study, which presented a constant emission and greater than the other industries analyzed (CASTELO BRANCO, 2013). What is verified is the absence of rigorous and constant atmospheric evaluation (transparent, public and enlightened) with industries that launch, through steam, effluent and waste, complex behavioral pollutants such as Hg.

This trend is repeated in several regions of the world, where data are scarce and dispersed. To obtain an estimate value, both at a national and worldwide level, of emissions during the moratorium period of the chlor-alkali activity in Brazil and in the world, the present study completed and compared the data obtained in the Country with those from international sources.

Cumulative emission estimate of the chlor-alkali industry due to the moratorium offered at the Minamata Convention

Although there is no transparency in all information on quantity, use, disposal and loss of mercury in the chlor-alkali industries, an emission of 127 gr. of mercury per ton of chlorine produced is estimated (BRASIL, 2013). Using this data and multiplying it by the brazilian production of chlorine, which is 217.000 tons/year, a loss of 27.559 kg/year of mercury can be inferred. Multiplying 127 gr. by the world production of mercury cells, currently, around 6,4 million tons of chlorine (UN, 2011), there is an annual loss of 812.800 kg of mercury by the chlor-alkali industries *(table 3)*.

Table 3. Estimated emission of Hg by chlor-alkali cells

ESTIMATION OF EMISSION AND RELEASE OF HG BY ELECTROLYTIC CELLS			
Scope	**Production of Cl2**	**GrHg/TonCl2**	**Total / year**
Brazil	217.000 Ton. /year	127	27.559 Kg
World	6.400.000 Ton. /year	127	812.800 Kg
Estimated emission in the worst Hypothesis with Production until 2035			
Brazil (22 years)	606.298 Kg	World (22 years)	17.881.600 Kg

For the chlor-alkali industries that use mercury cells, the Minamata Convention introduced a moratorium by 2025, enabling the signatory countries, through justification, to apply for a five-year exemption, renewable for a further five, and being able to, thus, extend this moratorium by 2035. If it happens, the industry will have a total of 22 years to continue polluting. Considering this possibility, only Brazil will emit a total of 606.298 kg of mercury, and, globally, these numbers will reach 17.881.600 kg.

Discussion

One should not ignore the toxic potential of Hg and its compounds, because once mercury is released, control is lost, and its consequences can appear in many ways, some of which are still not fully understood, with the permanence of its effects for long periods. The disorderly release of mercury by anthropic action is a risk to mankind.

The release of mercury and its compounds, in Brazil, as well as its illegal entry into the Country, for activities such as mining, or even legal, but not even considered, through products containing mercury, such as electronics, are not yet properly controlled, which makes it difficult to detail the measurement of impacts.

The Minamata Convention provides long deadlines for the termination of activities and products that already have substitute technologies. This shows that there is still the dependence of the society on harmful substances, especially the resistance of these business sectors to acting at the forefront of environmental protection.

There are several specific sources of mercury emission from activities and products that already have mercury-free alternatives, but which are still in circulation, such as those mentioned in annex 'A' of the Minamata Convention. Multi-dose vaccines (which are more economical for governments) are still in circulation, mercury fumes in the open sky mining, thermometers and lamps whose vapors, in the case of a break in homes, cannot be considered harmless.

The membrane electrolytic cell is a mercury-free technology that has been available in the market for more than 20 years. Moreover, the chlor-alkali industries that use mercury cells have already adopted substitute technology, but they resist banning obsolete activity. Although they seek, on the one hand, to 'sell' the image of a company that is friendly to the environment and society, they are one of the continual sources of mercury pollution, especially mercury in metallic elemental form, which is very volatile. Thus, the mercury vapors of this activity can reach long distances, and their residues and effluents pollute rivers and soils.

Although they are a hazardous waste after use, mercury lamps are normally handled without proper care, being discarded in the streets, sidewalks, yards, empty lots and in the common garbage, where they will end up massively in landfills and dumps, since the culture of recycling in Brazil is inefficient. And, although we have as reference the laws of national scope, such as the NSWP and the sector agreement of lamps, they still have little effect on the global problem of mercury for this sector, since they are in the initial phase and they need the political will for their accomplishment.

The data presented represent only two sectors selected for study, among the various sectors covered by the Minamata Convention, and have considered 10 years beyond the moratorium period, established by the Convention, that is, 2030 for lamps and 2035 for chlor-alkalis, since the parties may request an exemption of 5 years, which may be extended for another 5 years, in accordance with paragraphs 5 and 6 of article 6 of the Minamata Convention.

Even if countries do not apply for exemption when ratifying the treaty, mercury emissions into the atmosphere will remain, the working environment will remain unhealthy, the rivers will, in turn, continue to receive water with significant doses of mercury, traditional population, as the riverine and indigenous, will present mercury content in their bodies.

If the adoption of tolerance values for the release of mercury effluent remains, the continuity of its entry into the environment may cause it to accumulate and make it organic in aquatic organisms. Thus, it is observed that the permanence of the current conditions implies the continuity and the aggravation of the impacts of the mercury in the environment and in the human health.

Conclusions

The Minamata Convention recognizes the impact of mercury and its compounds on public and collective health, especially on the most vulnerable populations. Studies have, gradually, shown deleterious effects on the body, such as neurological, endocrine and reproductive systems.

Mercury is still widely used in products and processes. Nowadays, there are many activities that depend on mercury, and political and economic aspects cause mercury to remain in various activities, such as, for example, in dental amalgam, although there are alternatives.

Considering the dimensions of the emissions, the Convention should be more rigid with known sources and that cause various environmental, health and social impacts. Only the lamp and chlor-alkali sectors will be responsible for a possible total emission of up to 18,6 thousand tons of mercury during the total moratorium period. Regarding these activities, as well as the activities of dental amalgams, vaccines and mining, there is a historical commitment of the Country with the society in the mitigation of the resulting impacts.

Thus, the present work considers that the extension of deadlines granted by the Minamata Convention is not fully justified, especially for activities that already have alternative technologies, such as electrolytic cells, lamps, vaccines, amalgam, mining, among others.

Collaborators

Rafaela Rodrigues da Silva is the author of the study that originated the article. Jeffer Castelo Branco contributed to the analysis, interpretation of the data, preparation of the text and approval of the final version. Silvia Maria Tagé Thomaz contributed to the critical revision of the text and participated in the approval of the final version. Augusto Cesar is the author of the study that originated the article, contributed to the critical revision of the content and participated in the approval of the final version of the manuscript. ■

References

AMBIENSYS. *Alternativa eficiente e segura para destinação de lâmpadas fluorescentes*. 2014. Disponível em: <http://www.mma.gov.br/port/conama/processos/0E732C8D/ApresBULBOX%20R1_AmbiensysAlexandre_11nov09.pdf>. Acesso: 10 jan. 2016.

ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DE ILUMINAÇÃO (ABILUX). *Projetos*. 2015. Disponível em: <http://www.abilux.com.br/portal/institucional/3/projetos>. Acesso em: 28 nov. 2016.

AZEVEDO, F. *A Toxicologia do mercúrio*. Rima: São Carlos, 2003.

BEIGL, P. *China Fluorescent Lamps collection and treatment demonstration project (Project CFL)*. Vienna: University of Natural Resources and Life Sciences, 2016. Disponível em: <https://forschung.boku.ac.at/fis/suchen.projekt_uebersicht?sprache_in=en&menue_id_in=300&id_in=9925>. Acesso em: 20 jan. 2016.

BRASIL. Ministério do Desenvolvimento, Indústria e Comércio Exterior. *Sistema AliceWeb*. Disponível em: <http:aliceweb.mdic.gov.br>. Acesso em: 2 maio 2016.

______. Ministério do Meio Ambiente. *Diagnóstico Preliminar sobre o Mercúrio no Brasil*. Perfil do Gerenciamento de Mercúrio no Brasil, incluindo seus Resíduos. Ministério do Meio Ambiente. Brasília, DF, 2013. Disponível em: <http://www.mma.gov.br/images/arquivo/80037/Mercurio/Diagnostico%20preliminar%20do%20mercurio%20no%20Brasil_FINAL%20_2013.pdf >. Acesso em: 10 jan. 2016.

CAMBESES POLANCO, S. L. *A situação da destinação pós-consumo de lâmpadas de mercúrio no Brasil*. 2007. 119 f. Dissertação (Mestrado em Engenharia de Processos Químicos e Bioquímicos) – Escola de Engenharia Mauá do Centro Universitário, Instituto Mauá de Tecnologia, São Caetano do Sul, 2007.

CARDOSO, P. C. S. *et al*. Efeitos biológicos do mercúrio e seus derivados em seres humanos: uma revisão bibliográfica. *Rev. Paranaense. Med.,* Curitiba, v. 15, n. 4, p. 51-58, 2001.

CASTELO BRANCO, J. *Emissões Atmosféricas de Mercúrio da Indústria de Cloro-Álcalis no Brasil*. 2013. Disponível em: <http://www.mma.gov.br/images/arquivo/80037/Mercurio/RELATORIO%20LUMEX%20CLORO-ALCALIS%20FINAL%202013.pdf>. Acesso em: 25 dez. 2015.

CONDON, A. M.; CRISTOL, D. A. Feather growth influences blood mercury level of Young songbirds. *Environmental Toxicology and Chemistry,* Nova York, v. 28, n. 2, p. 395-401, 2009.

DUARTE, P. A. F. *Novos poluentes:* principais impactos de compostos desreguladores endócrinos na saúde pública. 2008. 125 f. Dissertação (Mestrado em Engenharia do Ambiente) – Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Lisboa, 2008.

EUROPEAN COMMISSION. Scientific Committee on Emerging and Newly Identified Health Risks: SCENIHR. *Health Effects of Artificial Light.* European Union, 2012. Disponível em: <https://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_035.pdf>. Acesso em: 3 maio 2017.

FREDERICK, P.; JAYASENA, N. Altered pairing behavior and reproductive success in white ibises exposed to environmentally relevant concentrations of methylmercury. *Proceedings of the Royal Society,* Londres, v. 278, n. 1713, p. 1851-1857, 2011.

HORTELANNI, M. A. *Avaliação da contaminação por mercúrio dos sedimentos do estuário Santos:* São Vicente, no período de 1996-2000. 2003. 137 f. Dissertação (Mestrado em ciências) – Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo, São Paulo, 2003.

INSTITUTO NACIONAL DO CÂNCER (INCA). *Diretrizes para a vigilância do câncer relacionado ao trabalho.* Rio de Janeiro: INCA, 2012.

KHODASHENAS, E.; AELAMI, M.; BALALI-MOOD, M. Mercury poisoning in two 13-year-old twin sisters. *Journal of Research in Medical Sciences,* Isfahan, v. 20, n. 3, p. 308-311, 2015.

MONTEIRO, F. T.; MEIRIÑO, M. J. Análise comparativa de programas nacionais de eficiência energética na eliminação das lâmpadas incandescentes no mercado sul americano. In: CONGRESSO NACIONAL EM EXCELÊNCIA EM GESTÃO, 11., INOVARSE, 3., Rio de Janeiro, 2015. *Anais*... Rio de Janeiro: Firjan, 2015.

PEREIRA, C. D. S. *et al.* Metrópole e meio ambiente: aplicação do modelo DPSIR na RMBS. In: BRANDAO, M. V. M.; MORELL, M. G. G.; SANTOS, A. R. (Org.). *Baixada Santista:* transformações na ordem urbana. Rio de Janeiro: Letra Capital: Observatório das Metrópoles, 2015. p. 355-373. Disponível em: <http://web.observatoriodasmetropoles.net/new/images/abook_file/serie_ordemurbana_baixadasantista.pdf >. Acesso em: 3 maio 2017.

POULIN, J.; GIBB, H. *Mercurio:* Evaluación de la carga de morbilidad ambiental a nivel nacional y local. Genebra: Prüss-Üstün, 2008. (Serie Carga de Morbilidad Ambiental, n. 16).

SANTOS FILHO, E. *et al.* Concentrações sanguíneas de metais pesados e praguicidas organoclorados em crianças de 1 a 10 anos. *Rev. Saúde Pública*, São Paulo, v. 27, n. 1, p. 59-67, 1993.

SÃO PAULO. Companhia Ambiental do Estado de São Paulo (Cetesb). *Relação de áreas Contaminadas.* 2015. Disponível em: <http://areascontaminadas.cetesb.sp.gov.br/wp-content/uploads/sites/45/2013/11/ordem-alfab%C3%A9tica-1.pdf >. Acesso em: 5 jan. 2016.

UNITED NATIONS (UN). United Nations Environment Programme. *Chloral Li Partnership Area. International Conference on Mercury as a Global Polluant*. 2011. Disponível em: <http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/Chloralkali/

Mercury-Poster-Chlor-Alkali.pdf>. Acesso em: 2 maio 2016.

______. United Nations Environment Programme. *Global Mercury Assessment*. Genebra: UNEP Chemicals, 2002. p. 258.

WATKINS III, J. B; KLAASSEN, C. D. *Fundamentos em toxicologia de Casaret e Doull*. 2. ed. Porto Alegre: AMGH, 2012.

ZAVARIZ, C. *Avaliação da utilização industrial de mercúrio metálico no estado de São Paulo e aplicação de metodologia de intervenção nas condições de trabalho*. 1994. 200 f. Dissertação (Mestrado em Saúde Pública) – Universidade de São Paulo, São Paulo, 1994.

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