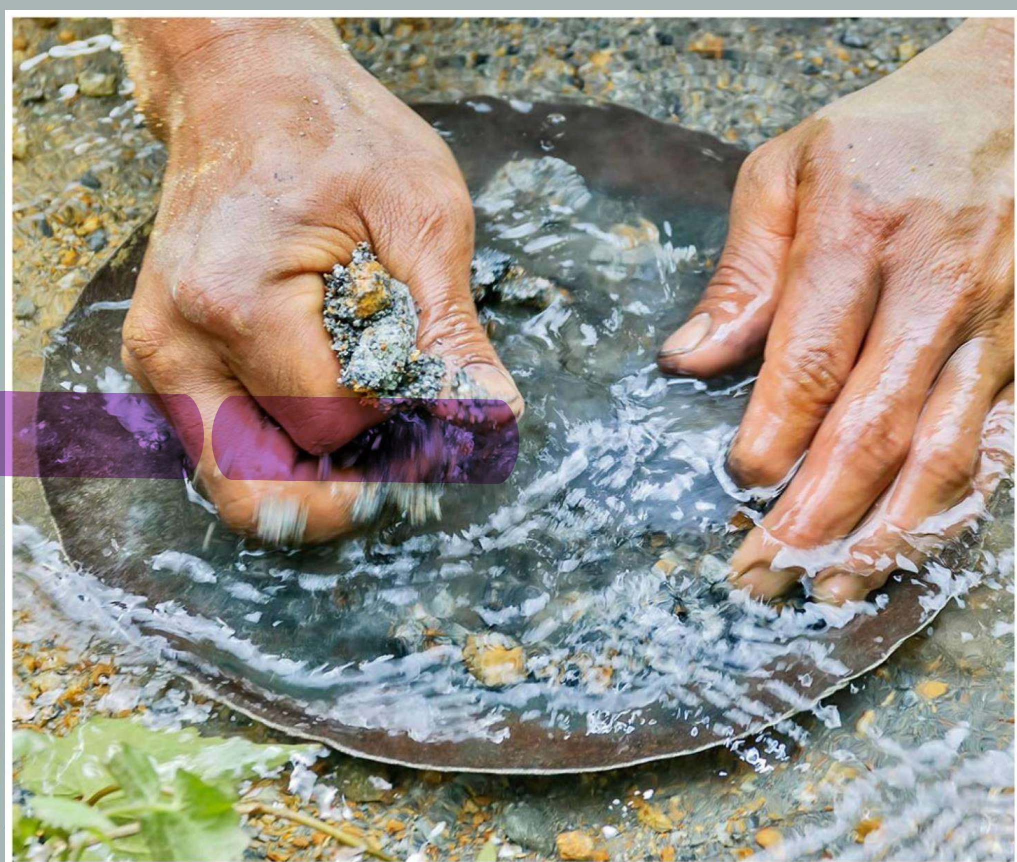
ACADEMIA BRASILEIRA DE CIÊNCIAS

MCMXVI

Contamination by mercury

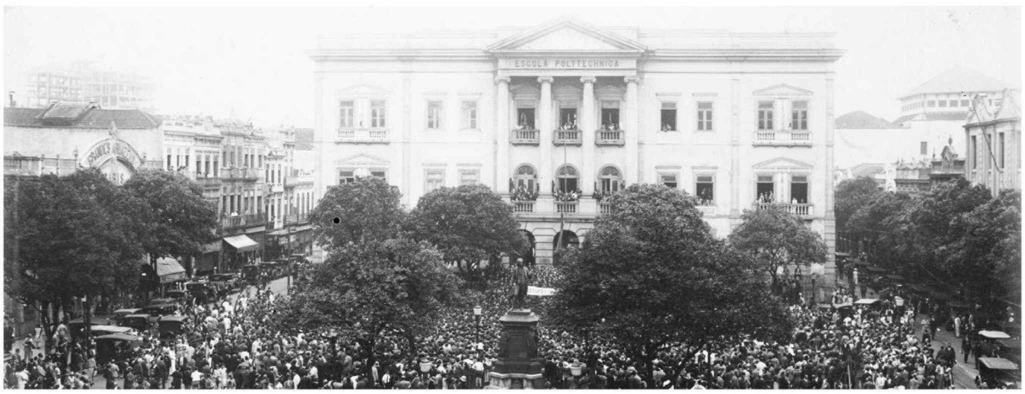


FEBRUARY
2023

Brazilian Academy of Sciences

The Brazilian Academy of Sciences (ABC) was founded on May 3, 1916, with the aim of recognizing the scientific merit of great Brazilian researchers and contributing to the promotion of the development of science and education. In these 106 years, ABC has established itself as a defender of science, education, and innovation as structuring axes to leverage the development of Brazil. This process is known to depend on the ability to produce knowledge and apply it in socioeconomic development. To this end, quality education and advanced scientific and technological research are crucial and decisive factors.

ABC believes that the dissemination of new discoveries knows no boundaries and that science and the scientific community should be a link, both between the peoples of the world and the regions of our country. Thus, the Academy seeks to contribute to studies on topics of primary importance to society, as well as to propose public policies with a strong scientific basis. It is in this sense that ABC works and dedicates itself with all its efforts, both nationally and internationally, whether in person or virtually, for more than a century.



The Brazilian Society of Sciences (first name of ABC) was founded in 1916 at the Polytechnic School of Rio de Janeiro, located at the Largo de São Francisco. Photo: Museu da Imagem e do Som.

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Introduction

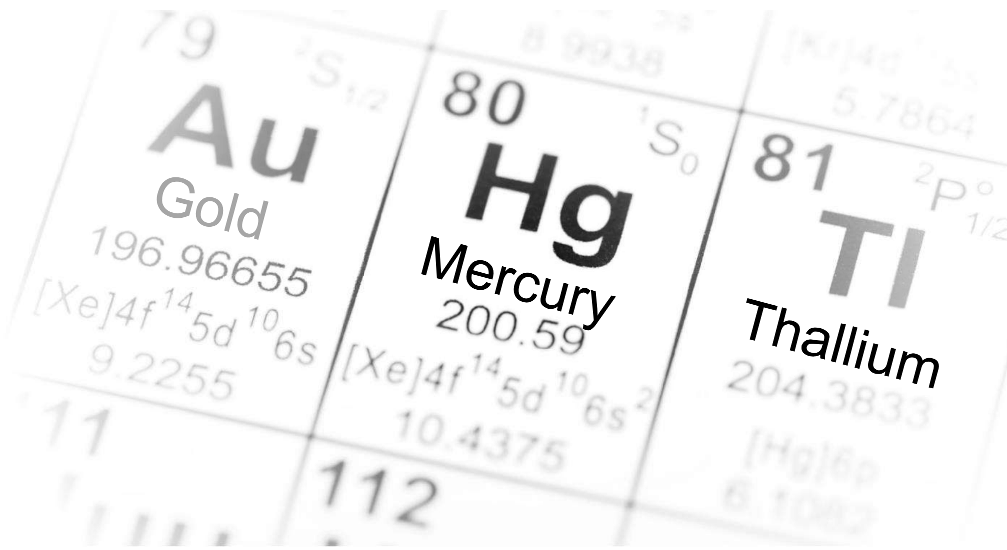
In recent years, the world has turned to environmental issues – mainly the consequences of human action, with some effects already irreversible. Despite the discussion gaining increasing space in the public debate, one topic still has little prominence: mercury (Hg) emissions in the biosphere.

A global problem with serious repercussions on human and planetary health, Hg emissions are easily distributed through the atmosphere, covering long distances. Although several Brazilian locations are affected by the contamination, Hg is strongly associated with Artisanal Small-scale Gold Mining (ASGM), mostly illegal, where Hg is used in gold extraction. These processes have a direct impact on public health, especially of indigenous, traditional, and riverside populations, also altering their territories and making it impossible for them to continue their ways of life and cultures.

The Brazilian Constitution is clear in prohibiting mining on indigenous lands. However, what has been seen lately is the systematic invasion of prospectors in these territories, without the State fulfilling its role. The result is the murder of local populations and intense environmental destruction. In addition to Hg, which affects fishing by contaminating fish and their consumers, mining disrupts social organization by including the search for gold in the dynamics of communities.

It is known that indigenous and traditional peoples play a fundamental role in the conservation of forests, being true guardians of the Amazon. Analyses by the Instituto Socioambiental[1] show that indigenous and traditional peoples are responsible for protecting one-third of Brazilian forests. Over the past 35 years, indigenous lands have protected 20% of the country's total forests.

Due to the significant impacts of the presence of Hg in toxic concentrations in the atmosphere, hydrosphere, pedosphere and, in particular, in the biosphere, the Brazilian Academy of Sciences (ABC) created a Working Group to organize this document, which addresses the most relevant issues about the subject. The objective is to mitigate the impacts of the release of this element on the environment, caused by trade (legal and illegal) and the use of Hg in ASGM and industrial activities. ABC also highlights the consequences of the presence of Hg in the air and food, initiating a debate on Hg management in Brazil.



[1] Instituto Socioambiental (https://www.socioambiental.org/noticias-socioambientais/estudo-comprova-que-povos-indigenas-e-tradicionais-sao-essenciais-para).

Mercury – extraction, circulation, and impacts

The chemical element mercury (Hg) occurs in nature mainly in the form of mercury sulfide (HgS), also known as cinnabar. Because it is the only liquid metal at room temperature, Hg is widely used in electrolytic cells, mercury-vapor lamps, gold extraction (as amalgam), as fungicide and in thermometers and some medical equipment.

The commercial extraction of Hg is done by heating cinnabar ore in an air stream. The Hg vapor is then condensed. Being toxic, this vapor, if inhaled, can cause dizziness, tremors and damage to the lungs and brain. Organic mercury compounds, such as methylmercury $HgCH_3$, are even more toxic and can cause mental disorders and even death.

The circulation of Hg in the environment is well known to science. It occurs especially in the atmosphere, in the form of elemental Hg vapor (Hg^o), associated with inhalable atmospheric particulate matter and/or rainfall. Inhalable Hg can reach the pulmonary alveoli and enter directly into the bloodstream. The fundamental mechanism of the biological toxicity of Hg is its high reactivity with the sulfhydryl of an amino acid called cysteine – present in all proteins and in enzymes essential for the metabolism of human cells. When Hg binds to enzymes and other proteins, they are irreversibly inactivated, which generates serious clinical complications. In humans, Hg is found mainly in the hair, blood, breast milk and brain, and is also transferred to fetuses[2].

In addition to the impacts on human health, Hg contamination affects other living beings (such as fish, crustaceans, corals and sediment-associated organisms – like polychaetes and mollusks) and accumulates in compartments of natural and managed ecosystems (such as soils, sediments and water sources). Contamination may also be associated with other pollutants, such as micro and nanoplastics, potentializing its harmful effects on the environment.

[2] Mercury Observatory (https://panda.maps.arcgis.com/apps/Cascade/index.html?appid=da3337387cac4449bf8ca3c15b95f225).

Material facts

1. Sources of mercury in Brazil

The most updated inventory for Hg sources and emissions in Brazil was released by the Ministry of the Environment (MMA)[3] in 2019, based on 2016 data. Some information deserves attention. First, although typical in studies of this nature, the variability between the scenarios of minimum emissions is quite significant: between 69 and 913 tons. Gold production through ASGM has the highest relative contribution, ranging from 28 to 64% of the total. Subsequently, there is the production of alkalis (1 to 15.3%), dental uses (4.7 to 15.5%), cement production (4.1 to 5.7%) and release of solid and urban liquid waste (10.3 to 14.9%), among other uses.

In view of the inventory, we emphasize that the great variability in emission estimates is the result of ASGM. For the year 2016, for example, the MMA estimated emissions ranging from 11 to 161 tons, given the uncertainty of illegal mining that, at the time, could involve up to 75 thousand prospectors in the Amazon. Such numbers require updating in face of the advance of illegal practice in the region[4].

In addition, the contribution of sources involving products containing Hg (dental amalgam, batteries, lamps, and manometers, among others) is significant. Since 2020, such products have been under controlled manufacture, import and export, as regulated at the 3rd Conference of the Parties (COP-3) to the Minamata Convention[5]. In this sense, it would be important to observe the impact of such measures on the Brazilian inventory.

Finally, emissions from the burning of fossil fuels and the production of cement and steel are subject to significant reduction, which could be done through the development of technologies aimed at reducing Hg emissions.

2. Remobilization of mercury: a legacy of our environmental irresponsibility

Several environmental contamination problems by Hg that we face today do not involve new emissions. They are, in fact, due to changes in the use of soils and sediments. In the Amazon, for example, except for the last six years (of which no data are yet available), several studies have shown that, although the total emission has decreased dramatically, concentrations in key organisms (such as fish and humans) have been increasing over the last 20 years[6]. This phenomenon is associated with the alteration of land use, particularly in the conversion of forests for wood extraction and agriculture, which increases the emission of Hg to rivers and the atmosphere, making the metal bioavailable. Geographically, the Amazon and the Cerrado are the most sensitive biomes, due to their past mining and rapid deforestation of their natural ecosystems. Similarly, along the Brazilian coast, dredging actions associated with ports and navigation have also been releasing high concentrations of Hg previously accumulated in these sediments. Finally, robust evidence begins to emerge that the mobilization of Hg's legacy also results from vectors associated with climate change.

[3] Ministry of the Environment (http://diretoriopre.mma.gov.br/index.php/category/69-gef-001062-03-01-desenvolvimento-de-avaliacao-inicial-da-convencao-de-minamata-sobre-mercurio-no-brasil?doc=1).
[4] Mapbiomas Brasil (https://mapbiomas.org/en?cama_set_language=en).
[5] Minamata Convention on Mercury (https://www.mercuryconvention.org/en/meetings/cop3).
[6] Annals of the Brazilian Academy of Sciences (https://doi.org/10.1590/S0001-37652012000100007).

3. Large-scale circulation

As with other gases in the atmosphere, the global Hg cycle is directly affected by atmospheric conditions and ocean-atmosphere interaction. In this sense, distal changes end up generating local impacts. An example is the increased fugacity of Hg due to changes in temperature, salinity, and acidity of the oceans[7]. This dynamic explains why regions of the planet, such as the Arctic and semi-arid coasts, have witnessed increases in bioavailable Hg concentrations, even considering the absence of significant anthropogenic sources of Hg in these environments. The result is an elevated contamination of the biota and increased human exposure to Hg[8].

4. Fish contamination, economic impacts, and human exposure

The main route of human exposure to Hg is fish intake. Studies on the impacts of fish and seafood consumption on public health show that risks exist even when Hg is present in low concentrations. It is important to highlight that Hg has a large bioaccumulation capacity and, therefore, can reach levels higher than the limits established by environmental legislation – which occurs even in regions without specific sources of Hg. Contamination of fish and aquaculture products is an obstacle to achieving the economic potential of the sector in the country, in addition to posing risks to public health and food safety.

5. Health hazards

All humans are exposed to some level of Hg, mostly in low concentrations and, in general, in a chronic way. Some populations, however, are exposed to high levels of Hg, either by the occupation and use of particularly contaminated areas, by their eating habits and/or by occupational exposure.

[7] Science (https://www.science.org/doi/epdf/10.1126/science.1242838).

[8] Frontiers in Earth Science (https://www.frontiersin.org/articles/10.3389/feart.2020.00093/full).

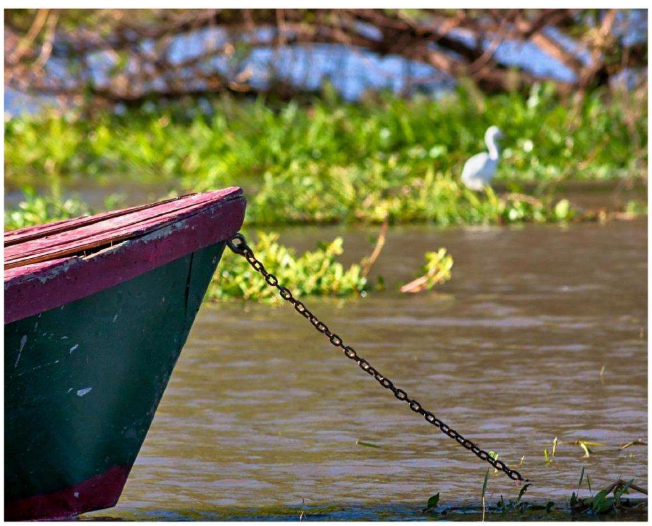
The effects of exposure also depend on its duration and route (inhalation, ingestion, or dermal contact), the chemical form of Hg, the age and socioeconomic and health conditions of affected people and other biological and anthropological vectors that intensify human exposure[9]. Thus, in Brazil, the health risks are higher in riverside populations of the Amazon and in artisanal fishermen of the Brazilian coast.

6. Cross-border interaction in the Amazon Basin and multilateral agreements

In all countries of the Amazon Basin, ASGM (legal or illegal) uses Hg in the investigation process. Therefore, it is impossible to identify the source of all the Hg circulating in the Amazon rainforest and in its hydrographic network. For example, between 1995 and 2005, mining on the Madeira River (in Rondônia) was almost extinct. Despite this, the region's watershed maintained high Hg concentrations, mainly due to contributions from Bolivia and Peru.

Within the United Nations, Hg pollution is one of the few environmental events that have generated an international commitment to controlling and reducing contamination. A treaty signed in 2013, the Minamata Convention, reveals the importance of Hg: a worldwide ubiquitous metal that, although naturally occurring, is released into the atmosphere, soil, and water by a variety of sources and anthropogenic activities on a global scale. Thus, the Convention unites several countries in the commitment to control anthropogenic emissions of Hg[10].

In 1999, Brazil hosted the Conference on Mercury as a Global Contaminant and therefore played a key and leading role in the construction of the Minamata Convention, with significant participation in its Conferences of the Parties and thematic meetings. The country's initiatives in relation to this cause, however, have been drastically reduced. A basin-wide initiative mirrored in the Minamata Convention is urgent to upscale research, management, mitigation, and adaptation to Hg pollution of the Amazon Basin.



[9] Science (https://www.science.org/doi/10.1126/science.1245924).

[10] Minamata Convention on Mercury (https://www.mercuryconvention.org/en/documents/minamata-convention--mercury-text-and-annexes).

7. Development of new technologies for gold mining and extraction

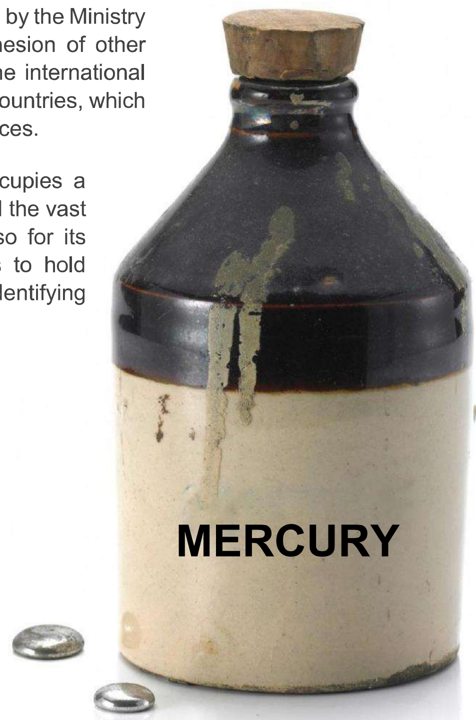
Most gold extraction processes (artisanal or industrial) are based on amalgamation with mercury. Alternative methods already exist: they dispense with the use of Hg[11], but are still incipient. This is a challenge of great complexity and requires actions beyond the development of new technologies. It is also necessary to stimulate cultural and behavioral changes of the agents of gold extraction, particularly in ASGM, and society in general. In this sense, education, scientific dissemination, events, and actions involving all areas of knowledge – **humanities, exact sciences, biological sciences (including health) and agronomical sciences** – are as relevant as the development of new technologies.

Recommendations

Hg contamination is a national challenge that demands the mobilization of all levels of government (municipal, state, and federal), the private sector and social organizations. It is also necessary to mobilize organized research structures with relevant performance in education, science, technology, and innovation. Such structures are present in all regions of the country and can be an important starting point for forwarding some of the recommendations listed below.

Expressive support for an integrative project to be initiated by the Ministry of Science, Technology, and Innovations, with the adhesion of other ministries and regulatory agencies, is also essential. The international scenario requires attention to the involvement of border countries, which can contribute to contamination and suffer its consequences.

In this context, the Brazilian Academy of Sciences occupies a favorable position, not only for its representativeness and the vast experience of Brazilian science on the subject, but also for its experience in regional issues[12]. Thus, ABC proposes to hold regional, national, and international meetings, identifying bottlenecks and proposing solutions.



[11] ScienceDirect (https://doi.org/10.1016/j.exis.2020.06.023).
[12] ACS Publications (https://doi.org/10.1021/acs.est.5b00215).

Recommended actions

- Resume Brazil's active engagement in the Minamata Convention, participating significantly in the drafting and dissemination of Global Assessments on Mercury[13], as well as accountability for actions carried out in the country.
- Update Hg emission inventories, with emphasis on ASGM.
- Eliminate and replace products containing Hg and for which there are already alternative technologies independent of the use of Hg, since it is a reality of practically all health and dental instrumentation and industrial sources, such as the production of paint alkalis.
- Ban illegal mining, both for its impacts on the environment and health and for the challenges it poses to the assessment of emissions. Reinforcing punitive actions and measures related to the illegal import of Hg — since Brazil does not produce Hg, it becomes easier to efficiently control imports, which can be effective in reducing emissions.

[13] United Nations Environment Programme (https://www.unep.org/explore-topics/chemicals-waste).

- Promote the recuperation of degraded areas by illegal as well as legal mining operations, particularly in the Amazon and Cerrado biomes.

- Develop multidisciplinary research projects focused on decontamination of affected areas and tailings to avoid or mitigate Hg remobilization.

- Encourage the development and implementation of technologies and innovation aimed at reducing emissions from incidental sources, where Hg occurs as an impurity.

- Develop multidisciplinary research projects focused on health, including environmental toxicologists who know the biochemistry of Hg, ecologists who trace Hg pathways in the food chain, physicians who address the effects of chronic and acute exposure to metal, public health specialists who analyze patterns of large populations and sociologists and anthropologists who study the impacts of the main source of Hg on the planet (prospecting and extraction of gold).

- Formulate future scenarios free of exposure to Hg and subsidize measures to improve the sustainability of the fishing sector regarding food security. In the short term, improve the information available to the sector and government as a result of fish quality audits, such as the most recent conducted by the European Community[14]. Continuous monitoring of Hg contamination of fish and other aquatic products and human risk analysis of metal exposure by consumption of such products is essential.

- Articulate mechanisms provided for in regional government organizations, such as the Union of South American Nations (Unasur) and the Amazon Cooperation Treaty Organization (OTCA), and non-governmental organizations, such as the InterAmerican Network of Academies of Sciences (IANAS) and the InterAcademy Partnership (IAP), to participate in this effort and expand its scope.

[14] European Commission (http://ec.europa.eu/food/audits-analysis/audit_reports/details.cfm?rep_id=2911).

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