TECHNICAL NOTE

JULY 2023

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MERCURY CONTAMINATION IN THE AMAZON

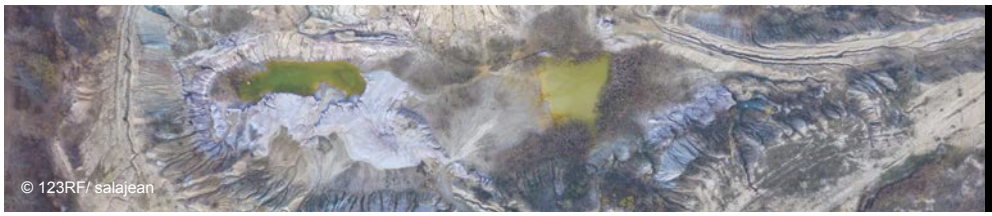
José Seixas Lourenço, the former president of the Association of Amazonian Universities-UNAMAZ, issued a warning in December 1989 regarding the “serious situation” of mercury (Hg) contamination in the Amazon. According to an article published 33 years ago, it was already possible to detect mercury levels above the permissible limit in water, fish, and humans (through blood, urine, and hair samples). The situation has worsened since then.

Illegal mining is an activity undertaken in all countries within the Amazon Basin, and it causes serious environmental, economic, and social problems in the region. This activity sets up a violation of the rights of populations that directly depend on this ecosystem for their subsistence.

Since 1994, 2,300 metric tons of Hg have been dumped in the Brazilian Amazon. However, this number, which was already high, has been growing steadily. Today, according to a series of analyzed studies, 150 tons of Hg are presumably being dumped in the region each year. Each square kilometer of excavated area in rivers due to illegal small-scale gold mining releases, on average, 24 kg of mercury (according to the same studies). According to data published recently by the Amazon Regional Observatory (ORA) of the Permanent Secretariat of the Amazon Cooperation Treaty Organization (SP/OTCA), there are 4,114 illegal mining sites throughout the region[1]. These data were systematized by the Amazon Network of Georeferenced Socio-Environmental Information (RAISG, 2020) based on official data[2].

[1] (https://oraotca.org/recursoshidricos/filter/?indicatorSelectionTerritory=5&indicatorSelection=10).

[2] National Service of Geology and Mining Technician (SERGETECMIN, 2013); DNPM, 2020; Digital mining cadastre of the Republic of Colombia (National Mining Agency, 2019); Mining Regulation and Control Agency, (ARCOM, 2019); Geological, Mining and Metallurgical Institute (INGEMMET, 2019); Ministry of Energy and Mines, 2017.



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HEALTH IMPACTS OF MERCURY

The World Health Organization (WHO) has declared mercury as one of the six most dangerous substances to human health owing to its high toxicity and the risks it poses to both human health and the environment.

Its effects are serious and sometimes irreversible. Mercury contamination in humans affects the nervous system, digestive tract, immune system, lungs, and kidneys. Pregnant women exposed to mercury can give birth to babies suffering from irreversible brain damage, motor paralysis, and hearing and vision problems (Rice *et al*., 2014).

FORMS OF CONTAMINATION

Mercury is a naturally occurring element that is used in a wide range of processes and products. In Latin America, particularly in the Amazon Basin, small-scale gold mining is the primary source of human exposure to the metal. This is because mining pollutes surface waters significantly, contaminating them with leached pollutants, such as oils, greases, sludges, clays, and heavy metals, with mercury being particularly prominent. Furthermore, petroleum and gas as well as urban effluents are also significant anthropogenic sources of Hg emissions in the atmosphere, soil, and water bodies (UNEP, 2017).

Contamination occurs in two ways in the gold extraction process:

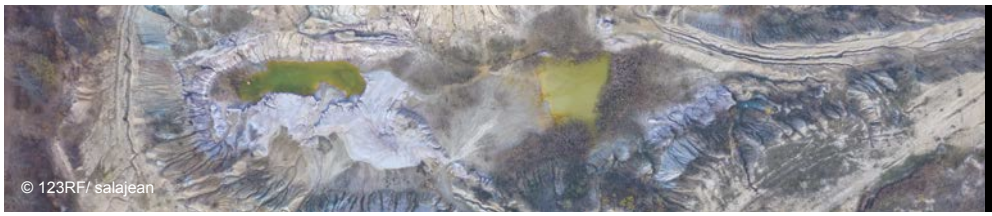
- During the process, when mercury is burned to separate and refine gold, it is vaporized and released into the atmosphere. Unlike many other metals, Hg can exist in a stable gaseous form (HgO), which enables it to remain stable in the atmosphere for approximately one year and disseminate over long distances, thus reaching remote areas far from the small-scale mining site.
- During the disposal stage, a portion of the Hg used in small-scale gold mining is released into the water bodies of the region, thus accumulating in the aquatic food chain and ultimately affecting the fish and other species that rely on them for sustenance.

Environmental contamination is first perceived when humans are affected. However, contamination can often occur through other routes, not just the direct ones. As mercury cannot be degraded, its harmful effects can impact ecosystems for decades.

Another reason mercury is particularly concerning in relation to public health is that heavy metals have a cumulative nature, which means their concentration increases along the food chain. Thus, mercury contamination affects not only those who work in small-scale mining, but also thousands of people who frequently consume fish (Meneses *et al*., 2022). Hence, it creates a complex social, environmental, economic, cultural, and public health problem.

TRAFFICKING OF MERCURY

Although mercury mining has historically existed in the region, currently, most of the mercury used in the Amazon is sourced from Mexico (Inda *et al*., 2022) . It is illegally trafficked across the borders between Amazonian countries and distributed through poorly known illegal routes, which are intercepted by command and control agencies (InSight Crime & Igarapé, 2022). The mercury used in illegal mining can also be obtained domestically by diverting legal stocks of mercury from the chlorine, alkali, dental, and manufacturing sectors or by acquiring mercury generated as a byproduct of large-scale polymetallic mining.



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INDIGENOUS AND RIVERINE POPULATIONS SUFFER THE MOST

One of the main concerns regarding mercury is its concentration in historically vulnerable populations (Castilhos *et al*., 2015). Currently, there is no established safe minimum limit of Hg in humans, which means that anyone with a certain level of mercury in their body can experience the adverse effects of contamination. However, the maximum limit is already known: 10 ppm (parts per million) of Hg in any body part. According to WHO, the adverse health effects of Hg are predominant and even irreversible above this level (WHO, 1990).

Data from the Mercury Observatory portal shows that riverine and indigenous populations in the Amazon already have contamination levels higher than the safe limits (Figure 1), with different contamination patterns in each country.

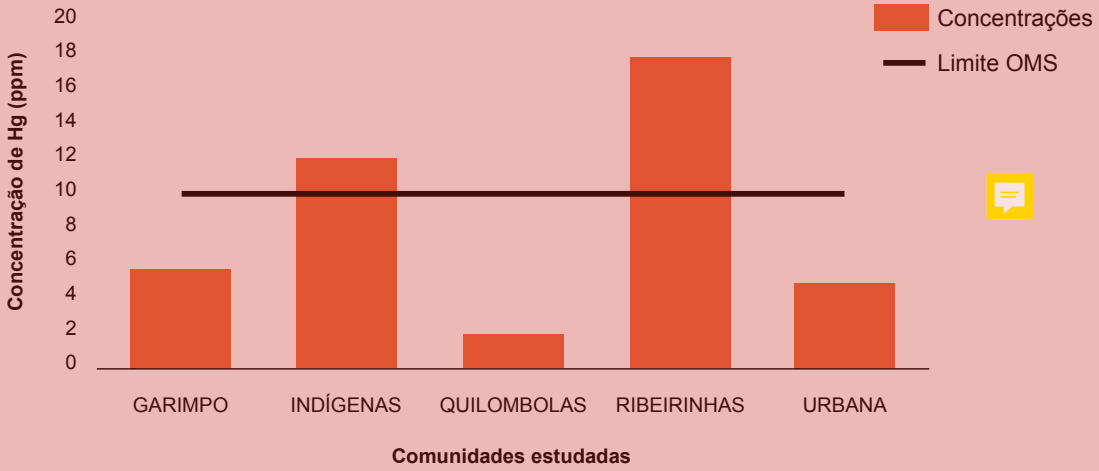


FIGURE 1.
Concentrations of Hg in the studied human communities and safe concentration limit of Hg according to WHO (WHO, 1990).

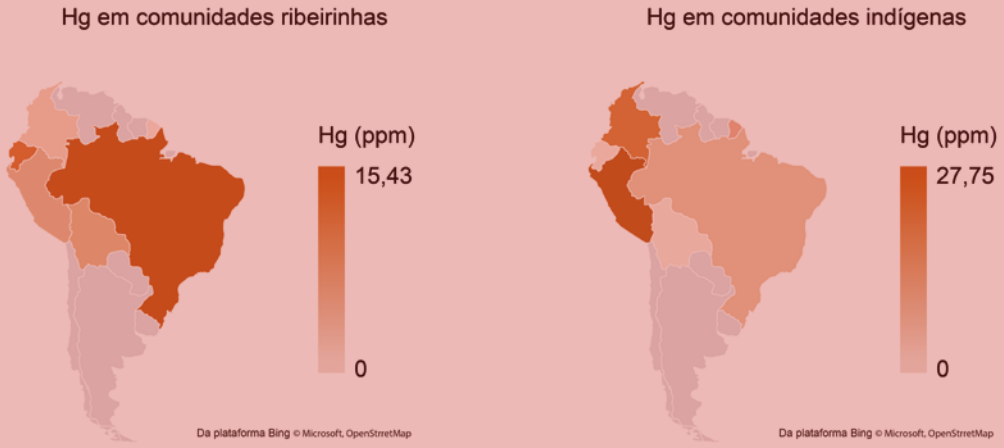
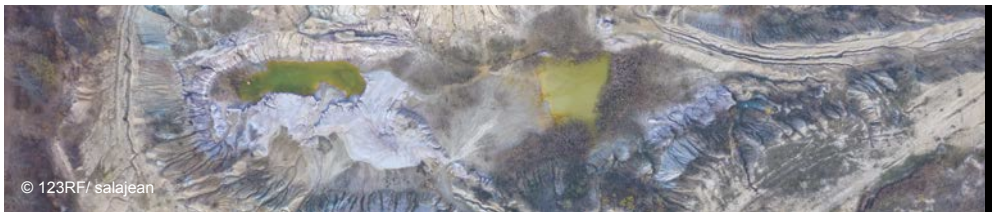


FIGURE 2.
Concentrations of Hg in the human communities studied by country, without considering biometric limits (gray areas do not have data).

- In Brazil and Ecuador, riverine communities are the most affected, with average concentrations of 15.43 and 12.3 ppm, respectively.
- In Peru and Colombia, the highest priority should be given to indigenous communities, as their average metal concentrations are 27.5 and 23.1 ppm, respectively (Table 1).



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Even with the differences, it is important to emphasize that in Brazil, Colombia, and Peru, in which the highest number of studies have been conducted, the concentration of mercury in riverine and indigenous populations is very high, close to or exceeding the maximum limit set by WHO.

TABLE 1.
Number of studies and mercury contamination values in Amazonian countries and studied human communities—values in red are above the limit established by WHO (10 ppm); values in orange are dangerously close to the reference value.

COUNTRY	NUMBER OF STUDIES	AVERAGE CONCENTRATION (PPM) IN THE COMMUNITIES STUDIED				
		RIVERINE	INDIGENOUS	QUILOMBOLA	URBAN*	SMALL-SCALE MINES
BOLIVIA	3	3.0	—	—	—	—
BRAZIL	61	**15.4**	**16.3**	2.1	6.3	3.2
COLOMBIA	16	**9.3**	**23.1**	—	5.3	3.9
ECUADOR	2	1.3	—	—	—	—
FRENCH GUIANA	3	—	**8.2**	—	**8.6**	—
PERU	13	**8.3**	**27.5**	—	2.4	2.8
SURINAME	2	—	—	—	0.8	4.5

* População urbana da Amazônia

BRAZIL HAS THE HIGHEST NUMBER OF STUDIES

The analysis of the available studies reveals a disparity among countries in scientific production on the topic. Brazil has the highest number of published studies (61 studies, or approximately 66% of the total), followed by Peru (13 studies, representing 9.5%) and Colombia (16 studies, representing 8%). It is important to emphasize that these disparities in the number of studies could also be reflected in the study results. Furthermore, as can be seen on the side of the figure, despite the studies covering the main rivers of the Amazon region, there are still significant gaps, especially in the Andean region and the northern part of the biome (Figure 3).

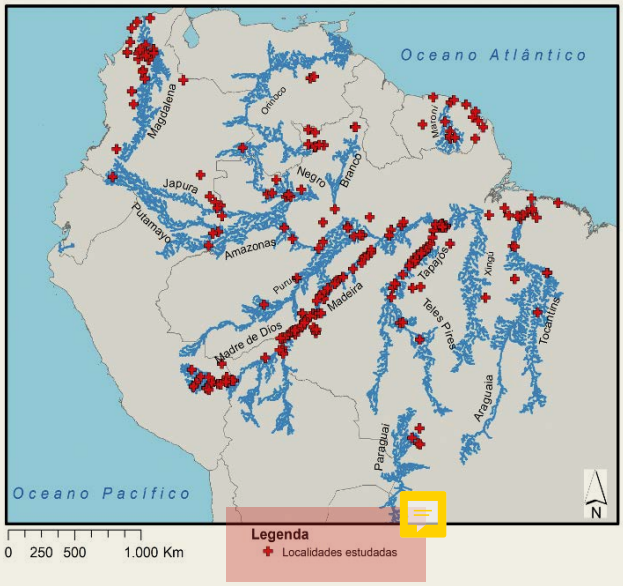
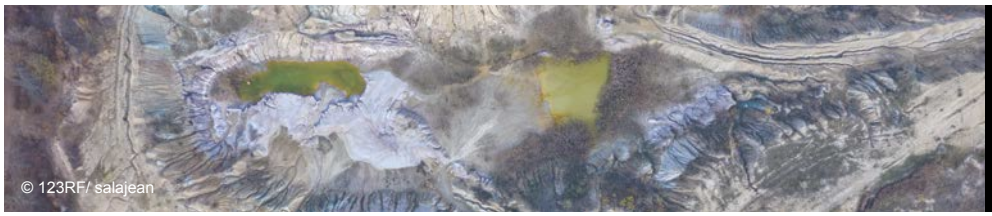


FIGURE 3.
Spatial distribution of the study areas in the Amazon region.



CONCENTRATION OF Hg IN FISH

In the context of environmental analyses of Hg contamination, the contamination in fish can serve as a means to assess the exposure of human populations, particularly in relation to their diet.

According to WHO, the maximum concentration of Hg in fish should be 0.5 ppm. The United States Environmental Protection Agency (USEPA), one of the largest authorities in the field, establishes even lower values, with their maximum being 0.3 ppm (Buck et al., 2019). According to the 94 studies compiled by the Mercury Observatory, 40% of the analyzed fish showed an Hg concentration higher than the limit allowed by the USEPA, and 31% showed values higher than the limit recommended by WHO. The results showed significant variation among species, trophic levels, and regions.

According to the compiled studies, Brazil has the highest levels of Hg concentration found in various fish species (Figure 5). Once again, it is worth noting that the high number of studies conducted in Brazil may have contributed to this result, highlighting the need for expanded monitoring in Amazonian countries.

FIGURE 4.

Schematic drawing showing the maximum concentration of Hg in the species with the highest concentrations of the metal.

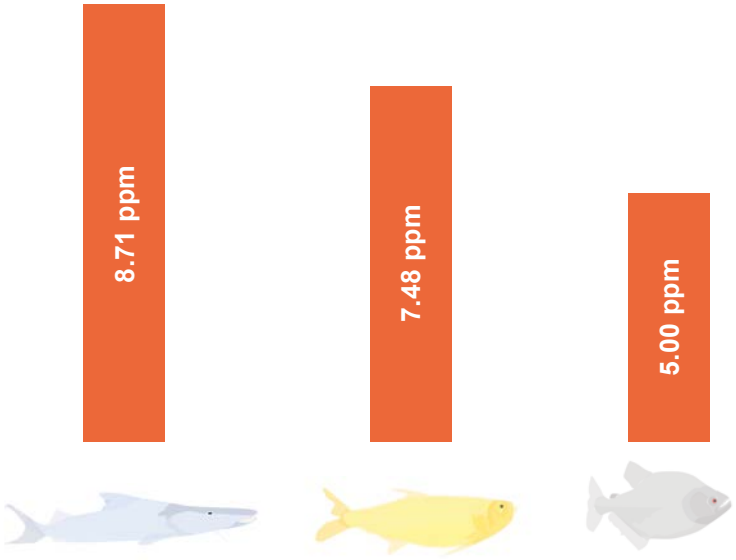
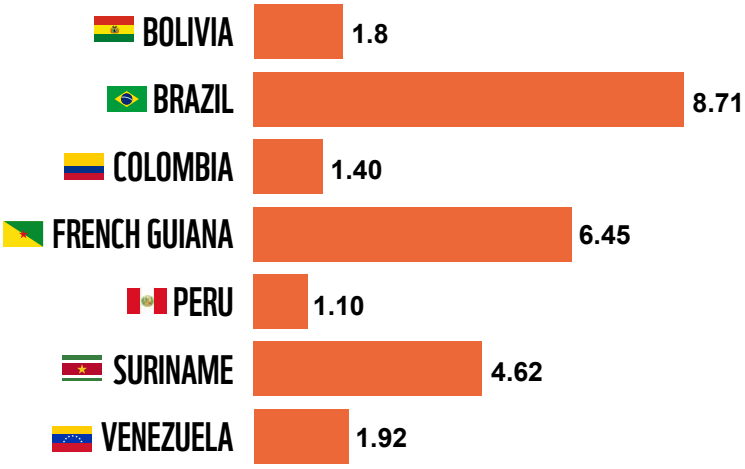


FIGURE 5.

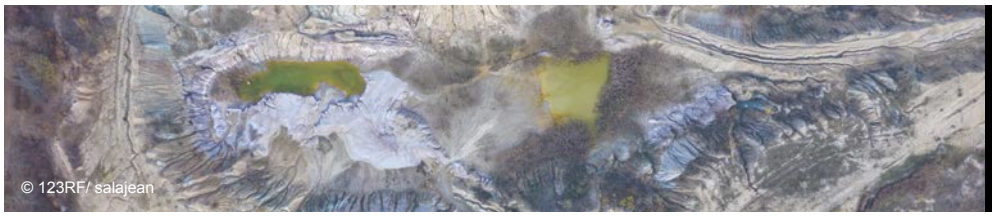
Maximum concentration of Hg in the countries included in the platform.



EVERY MINING OPERATION HAS AN IMPACT

Mining activities can occur in three distinct ways, all of which impact water resources in some way. A summary of the forms of mining activities and their characteristics is provided below.

	PIT	ALLUVIAL EXPLORATION	DREDGING BARGES
EXPLORATION	This is the most popular form, and it can be either manual or mechanized. A specific territory is excavated for mineral exploration, causing its devastation.	Generally, exploration is carried out in river or stream beds.	Barges are installed on mobile floats, and they search for minerals by stirring the riverbeds.
IMPACTS	It contaminates all the water involved in the process with metals used in the gold industry, such as mercury.	It causes the devastation of riparian forests, contributes to the loss of local biodiversity, and accelerates soil erosion processes, thus creating the ideal condition for the transportation of toxic substances into rivers.	The movement of dredges and rafts can also contribute to erosive processes in the beds of water bodies and alter fluvial geomorphology.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MINAMATA CONVENTION AND CHALLENGES FOR CONTROLLING MERCURY

The Minamata Convention, which has been adopted by more than 140 countries, aims to protect human health and the environment from the adverse effects of mercury. This international treaty, which was ratified in 2013, establishes a series of measures to reduce global emissions and releases of mercury at the global level. These measures include the adoption of safe alternatives to Hg and measures for monitoring and controlling its emissions. Among the Amazonian countries, only Venezuela is not yet a member country of the Convention.

In addition to the global effort to reduce the impacts of mercury, controlling Hg emissions depends on command-and-control policies, socio-environmental conservation actions, the development of sustainable economic alternatives for those who depend on small-scale mining for income generation, the improvement and control of the gold supply chain, and the provision of appropriate transparency tools and decision-making support. However, the significant lack of official information limits the reach and effectiveness of State policies in dealing with illegal and informal mining.


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Added to this reality is the heterogeneity of criteria between countries to define and measure the problems of illegal and informal mining. Both factors are among the main barriers to initiating regional efforts to enable a coordinated approach to address the problems arising from informal and illegal mining.

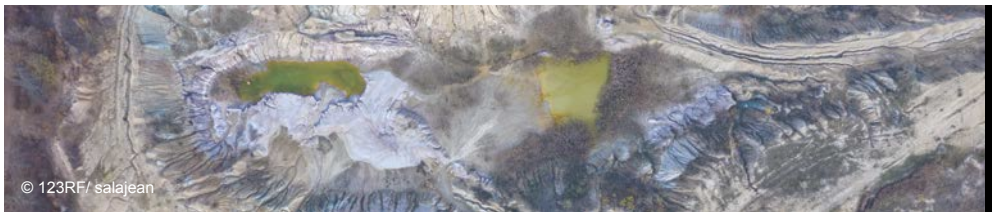
One direct method of measuring the negative impacts of small-scale gold mining, whether legal or illegal, is to map Hg contamination on a landscape scale and combine the information into a decision support tool. Therefore, to enable public access to information and data, provide more accurate and up-to-date understanding of the extent of the problem, and promote transparency, engagement, and public awareness, the Mercury Observatory, which is a portal for georeferenced data on mercury contamination studies in Amazonian countries, was established. Currently, it has documents from eight countries in the region.

ABOUT THE MERCURY OBSERVATORY

Available on an open online platform, the Mercury Observatory is the largest initiative for compiling and georeferencing environmental data and data regarding mercury contamination in humans and fish in the Amazon region. The database includes 139 studies from 1990 to 2022 regarding contamination levels in human populations and 94 studies from 1992 to 2022 regarding contamination levels in fish.

The platform was constructed by a group of experts in mercury contamination from the School of Public Health—Fiocruz, the Center for Amazonian Scientific Innovation—CINCIA, Peru, and WWF-Brazil and other experts. To achieve this objective, a systematic review was conducted using the PRISMA methodology, and it included a total of 233 scientific studies conducted in Bolivia, Brazil, Colombia, Ecuador, French Guiana, Peru, Suriname, and Venezuela.

Data from the study were included (type; year of



study publication; authors; title; year of collection; study target), as were information about the mercury measurement (mean and/or median of Hg; standard deviation (SD); unit of measurement; sample size) and the geographical location of the study. The documents presented include indexed articles, reports, and theses and dissertations that provide information on mercury levels in humans or fish in the Amazon, which are published in Portuguese, English, or Spanish.

The data presented were obtained by querying the following databases: PubMed, Web of Knowledge, and American Chemical Society Legacy Archives. The primary descriptors used were Amazon, Mercury/Hg, and Contamination and the secondary descriptors were humans, fish, and each of the countries that comprise the Amazon.

If the georeferencing information of the site was not provided in the publication, georeferencing was performed using the coordinates obtained from Google Earth for the name of the locality mentioned in the study, if available. It should be noted that one of the advantages of georeferencing is that it facilitates the exploration of geographical trends and knowledge gaps as a management tool.

By providing accurate, time-bound, and georeferenced information on pollution events related to small-scale mining, the Mercury Observatory can directly inform and support actions to reduce these impacts by actors from the public, private, and civil society sectors.

RECOMMENDATIONS FOR CONTROLLING Hg

Reducing and mitigating the impacts of mercury contamination in the Amazon is a complex challenge. It involves quantifying the amount of Hg released in each country and transported to neighboring countries and making a serious political commitment to reduce metal emissions through anthropogenic actions, such as deforestation, construction and operation of hydroelectric power plants, changes in land use, and illegal and irregular small-scale gold mining. Therefore, some actions are critical to curb this threat:

1. Control of the gold supply chain and illegal and irregular small-scale mines that contribute to increased mercury emissions in the environment

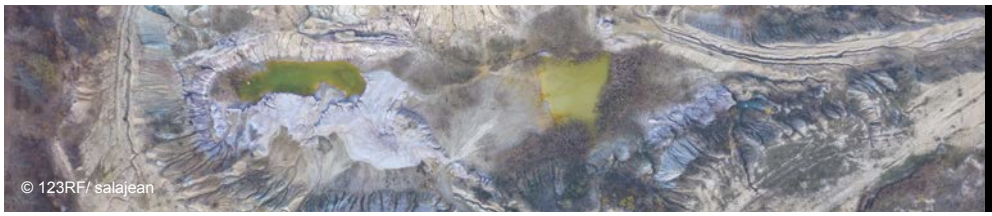
Measures aimed at controlling and reducing the supply of mercury to small-scale mines

- Suppression of illicit supply chains of trafficked mercury across borders.
- Effective regulation of legal mercury supply chains is necessary to prevent the “leakage” of mercury into the illicit sector of artisanal and small-scale gold mining (ASGM).
- Promoting actions to eradicate illegal mining and convert irregular small-scale mines into responsible and monitored models, which would lead to a reduction in the demand for mercury by the informal gold mining sector and encourage the use of mercury-free technologies.
- Establishment of effective control and proper disposal of mercury, which is produced as an industrial byproduct, in order to reduce its diversion to illicit sectors of gold mining.

2. Identification and measurement of mercury pollution events, with characterization of associated risks

It is a critical stage for Amazonian countries to understand the scale and magnitude of the risks posed to vulnerable populations. To make it possible, it is necessary to establish a capacity for rapid environmental monitoring in environmental agencies at various levels of the government.

- Identification and confirmation of the presence and extent of mercury pollution events associated with gold mining with the use of appropriate and reliable environmental field sampling methods, laboratory-based analytical methods, and standardized data analysis methods.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- Evaluation of the risks posed by the identified mercury pollution events to human communities and wildlife using appropriate and robust methods of characterization, assessment, communication, risk reduction, and impact mitigation.
- Communication of identified mercury pollution events and related risks to the public through official government notification processes—including the listing of mining-related mercury pollution events—in a georeferenced national database, which is available to the public and capable of tracking pollution events and related mitigation actions—including expected events and achieved results—over time.
- Support for the establishment and strengthening of analytical capacity in the academic and civil society sectors to provide multiple and parallel means of identifying mining-related mercury pollution events.

3. Development and implementation of measures to reduce the risks of mercury contamination to exposed and vulnerable human populations and wildlife species and its impacts

Once the risks associated with mining-related mercury pollution events have been characterized and communicated to relevant government agencies and the public, effective and timely actions should be taken to reduce and mitigate these risks. To achieve this, the use of “One Health” approaches is recommended. These approaches integrate assessments of both humans and wildlife to develop risk reduction and mitigation measures

- To assess the exposure of the human population to risk, relevant public health agencies must have the mandate and technical capacity to understand and assess the risks associated with Hg and develop mitigation strategies appropriate for the nature and scale of the pollution event, considering other health priorities in the affected communities. Special considerations for events exposing indigenous peoples and traditional communities should be included in standard practices to reduce any unintended additional cultural impacts of implementing Hg risk reduction measures.
- To assess the exposure of wildlife to risk, relevant environmental and natural resource agencies must have the mandate and capacity to understand and assess the risks associated with Hg exposure that affect wildlife populations and communities and the extent of the impact on the ecosystem. They must also possess the technical capacity to develop mitigation strategies that are appropriate for the nature and scale of the pollution event.


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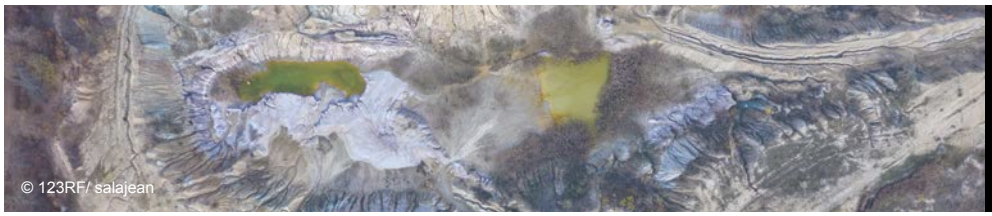

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FICHA TÉCNICA

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DIAGRAMAÇÃO

Laboota