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Toxic residues and amalgamated injustices:
A political ecology of mercury and gold extraction in Colombia

By

Sebastián Rubiano-Galvis

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Environmental Science, Policy, and Management

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Nancy Lee Peluso, Chair
Professor Kate O'Neill
Professor Javiera Barandiaran
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Abstract

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Professor Nancy Lee Peluso, Chair

Mercury is a metal that has recently gained global visibility and notoriety as a toxic pollutant due to the environmental and human health effects of its past and present use in artisanal and small-scale gold mining (ASGM). Present in more than eighty countries in Latin America, Asia, and Africa, ASGM employs between 15 and 20 million people and has been deemed the most significant contributor to global mercury emissions. After decades of interventions and millions of dollars spent, many have asked why it is still a challenge to deal with pollution coming from ASGM. In many countries, the problem of mercury pollution is typically seen as the transgression of toxicity thresholds or laws, the inevitable outcome of environmentally irresponsible miners, or as the governance of another commodity or supply chain.

In recent years, Colombia has been labeled the largest mercury per capita emitter in the world, as some twenty percent of all global mercury flows in the atmosphere are emitted from the country's ASGM activities. This makes the South American nation the third-largest absolute emitter of mercury after China and Indonesia. It has also been shown to be the second-largest mercury importer in Latin America in the past decade, despite bans on the mercury trade. Colombia has been a top gold producer since colonial times and is in the top sixteen world gold exporters, a status that state-sanctioned mercury use in the metal's extraction helped make possible. Today, the country sustains a significant ASGM sector of around 500,000 people. ASGM globally produces between fifteen to twenty percent of the entire gold supply; in Colombia, ASGM miners extract an estimated eighty-six percent of the nation's gold. Therefore, the country is one of the eight prioritized sites of the Global Environment Facility (GEF) Planet Gold initiative (formerly GEF GOLD), the flagship project launched in 2019 under the UN Minamata Convention to eliminate mercury from the supply-chain of gold produced by ASGM.

Drawing on concepts from political ecology, science and technology studies, and the social studies of toxicity, this dissertation provides a relational history of gold mining in Colombia and its entanglements in global efforts to first promote and then phase out the mercury amalgamation technique. Specifically, I provide situated histories of mercury's chemosocial lives and trajectories in Colombia and the broader context of the Americas to provide a nuanced

interpretation of the contemporary persistence of a technique and a metal that the international community wants to eradicate. I conceptualize mercury as a chemosocial substance embedded in complex bundles of social and ecological relations and infrastructures of knowledge, technology, and power. From that perspective, the work situates mercury use in ASGM as a toxic residue within broader political ecologies of knowledge, technology, and colonial, corporate, and nation-state practices and power relations. Said conceptualization supports an understanding of the mercury problem in ASGM as a practice that indexes the intersection of power and control over resources and people, changing markets, and histories of extraction, rather than something to be blamed on individual miners' behavior.

To achieve this, I weave qualitative and archival work done in Colombia, California, Spain, and UN meetings on global mercury management in Geneva between 2017 and 2019. Across six chapters, I demonstrate how historical practices have interacted with mercury's biophysical characteristics, specifically its irreversible persistence in the environment, to co-produce the current "problem" of global pollution. I examine the connections between contemporary science and scientific work and the colonial era's long-term residues in mining environments and beyond. I explain how policies of the nation-state have flip-flopped from support of mining and mercury use to their condemnation when conducted by small scale miners, and failed to recognize the needs of people pushed into small-scale mining as they lose access to other forms of livelihood.

The chapters demonstrate how external narratives of history, disciplinary practice, selectively deployed science, and of mercury as part of ASGM, conceal the long and sedimented histories of colonial, corporate, and state power and knowledge production that have characterized mercury's chemosocial life in the region and globally. These inequities have epistemic, technical, political-economic, and representational dimensions in mining policy and practices, as expressed in the scientific community and bureaucratic institutions studying and regulating it. I argue that the persistence of mercury use in ASGM in Colombia and elsewhere has to do with the persistence of past practices, policies, and privileges in the present.

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CHAPTER 1. Introduction: mining and the chemosocial life of mercury

Opening vignette 1: Towards a mercury-free world

Mercury is a natural element, which exists in soils and varied forms in the Earth's crust, and can also be extracted from cinnabar rocks (Chaline, 2012). It has been used for millennia for multiple purposes - the Romans and various indigenous peoples of the Americas used it for pigments; Chinese emperors ingested it hoping it would grant them immortality; and European alchemists tried to use it to turn other metals into gold. But one of its most prominent uses has been as a processing agent in silver and gold mining. Between the sixteenth and the nineteenth century, silver was processed using mercury, and since the mid-nineteenth century, the gold mining industry started using it widely as well (Robbins, 2011). The mines of Almadén (Spain) and Idrija (Slovenia) led cinnabar extraction for producing mercury from 2500 years ago until new mines were found at the end of the nineteenth century in California, Mexico, and Peru. An estimated third of all the mercury in the above-ground world was extracted from Almadén (Rojas 2013). UNEP (2018) reports that human activities have increased total atmospheric mercury concentrations by about four-hundred and fifty per cent above natural levels. With the rise of postwar industrial chemistry in the twentieth century, mercury became widely used in industries like cement production, chlor-alkali production, fungicides, and measuring devices (UNEP, 2013).

Although mercury cannot be eliminated, biodegraded, or metabolized due to its persistent nature and global reach (Fino, Strincone, & Pirrone, 2013)[1], the promise of a future world where this toxic substance is "made history" has been widespread in meetings under the UN Minamata Convention, the international treaty signed in 2013 regulating the lifecycle of mercury. The delegates, experts, activists, consultants, and victims of mercury exposure attending the First Conference of the Parties (COP1) of the Convention in Geneva in September 2017 were able to observe an intervention installed by UNEP and the Plastique Fantastique collaborative in front of the UN *Palais des Nations* representing a future with only 'one last drop of mercury in the world' (*Photo 1*). People could 'enter' the drop, sit in improvised couches and watch short clips meant to raise raising awareness of mercury pollution (UNEP, 2017b). Outside, installed around 'the drop,' an exhibit by Pulitzer winner Larry C. Price depicted 'the human face' of mercury pollution through photographs of artisanal miners using mercury in countries like Peru, Philippines, Colombia, and Ghana. The image of a half-gold, half-quicksilver fish has become an iconic branding of the Convention, visible across the COPs on banners, podiums, wall projections, video content, and publications This messaging stresses the desire for a mercury-free world, which the treaty aims to achieve through technology transfer and capacity building in large-emitting countries. The quicksilver motif within the fish represents "*a visual 'flash' of mercury (...) 'dissolving' as the dominant gold motif moves into the future, representing the positive progress of the Convention".* In turn, the golden portion of the fish is a *"subtle reference to artisanal gold mining and the global gold sector, but gold is also a universal color of celebration* (UN Minamata Convention Secretariat 2017).

[1] Mercury is a highly volatile heavy metal that can be present in two chemical forms: its inorganic form (elemental mercury) or its organic form when it is methylated and bioaccumulated through trophic chains (methylmercury) (UNEP 2018).



Photo 1. "The last 'drop' of mercury in the world" installation by UNEP in Geneva's *Place des Nations* during Minamata Convention COP1. Photo: UNEP (2017).

Similar to other global initiatives advocating for a "detoxified future" or a "chemical-free world" (Khan, 2021), the goal of a zero-mercury world raises the question of what landscapes and bodies will be detoxified, through what means, with what consequences, and who would bear the burden of "the last drop", that is, any remaining uses, exposures, or past legacies of pollution. The staging of rituals and spaces like these in international meetings like COPs offer opportunities to address such questions, as they let us see into the processes of framing, translation, and sense-making of global environmental problems (Death, 2011; Suarez & Corson, 2013, p. 69). These symbols stressed that the 836 tons of mercury emitted by ASGM annually to the atmosphere (thirty-eight per cent of the total emissions) are the main target of global mercury governance – more so than all other emission sources including stationary combustion of coal (twenty-one per cent), non-ferrous metals production (fifteen per cent) and cement production (eleven per cent) (UNEP, 2019b). Through the drop and the photographs, UNEP attempted to enroll attendants to the main global decision-making forum on mercury (including country delegates, activists, scientists, and consultants) into particular ways of seeing the issue—one that stresses ASGM's contribution to it by symbolizing the object of concern (the mercury drop), the main culprits (miners in the Global South), and the desired future (the swimming fish celebrating gold-laden and mercury-free futures).[2] Instead of depicting mercury, for instance, through bioaccumulation or atmospheric travel diagrams, the symbols chosen depicted the undesired substance in the literal hands of its main users.

[2] While the drop and the photo installation were not replicated in the subsequent COP2 and COP3, they remained as memorable symbols for subsequent COP participants. In turn, the fish and the motto did become permanent in content and publications associated with the Convention.

Images 1-2. *The golden fish branding of the UN Minamata Convention. Source: UNEP (2017).*



This framing of a mercury-free future as a break from the past is not the only shiny depiction of mercury in international politics. The area around Almadén, a small town 300 km south of Madrid, has the world's most significant reserves of cinnabar, the mineral from which mercury is extracted. About a third of all the mercury that has ever been produced was mined at Almaden. The mine closed in 2002 and opened to the public in 2006 as the Almaden Mining Park, a "geotourism" park opening the industrial and geologic remnants of 2,500 years of cinnabar mining to tourists. In 2012, UNESCO declared the Park ~~as~~ a World Heritage Site, a denomination celebrating landmarks with cultural, historical, technical, or scientific significance. The declaration celebrates the "most important heritage left behind by the intensive extraction of mercury, particularly in the modern and contemporary periods." It recognizes that mercury extraction in Almadén had "international significance," as it played a key role in "the working of gold and silver mines in America" and the "economic and financial exchanges related to technical expertise."[3] When cinnabar extraction ceased in 2000, due to the European mercury ban, Almadén joined a growing list of former mines that since the 1990s have become tourist geoparks, memorializing the history of extraction and its associated knowledge and techniques (Idrija and Almadén, 2011, p. 5). But what was left out of this second meaning of the UN's moniker of "Make Mercury History" is that while these European mines certainly "made history" because of the massive volume of mercury production, the violent legacy of colonial precious metal extraction in the Americas – not to mention its lasting environmental effects – went without mention.

In November 2019, after attending the Minamata Convention COP3 in Geneva, I booked a tour to Almaden's geopark. While we walked through a former cinnabar mine tunnel 160 ft. underground, our guide described how the UNESCO declaration has given Almaden residents a

[3] https://whc.unesco.org/en/list/1313/ (accessed 30 July 2022). See also Lopez Avalos (2011, 5).

certain sense of pride, although it has not attracted the number of visitors they expected.[4] When we returned aboveground, our last stop was the Mining Park's Museum of Mercury. At the entrance, visitors were welcomed by an enclosed, non-functional mercury fountain surrounded by two large vertical photographs on the walls depicting mercury drops splashing in an empty background. On the main floor, there were rooms dedicated to the geology of cinnabar, a section on mercury sciences with interactive experiments on mercury physics and chemistry, and a human-sized installation of the molecular structure of mercury (Photo 1). In one of the rooms, a human-size structure of a mercury molecule (see Photo 11 in Ch. 3) portrays mercury in its elemental liquid form and as an isolated molecule, detached from its history, context, and chemosocial relations (Murphy, 2017). The giant mercury molecule, like the mercury drop in Geneva, conveyed that the substance's chemical form as detached (or detachable) from bodies and landscapes. However, mercury's multiple chemical forms,[5] as well as its social and political entanglements suggest the opposite. Despite that, the declaration of Almaden's toxic legacy as a positive heritage that is meant to instill both local and universal pride conveys only that certain segments of mercury's chemosocial life (primary extraction, and processing into liquid form, and transport) deserve to be universally appreciated.



Photos 2, 3, and 4. *Almadén Mining Park; UNESCO World Heritage Site; Mercury Museum's entrance. Photos: S. Rubiano (2019).*

The rest of the Museum's contents-the displays' privileging of some aspects of mercury's social life while downplaying others. A room off the main concourse detailed the history of mercury metallurgy, describing the evolution of the weighing and packaging systems that were used to ship quicksilver to the Americas between the sixteenth and the twentieth century. In the basement, a banner and a three foot wide bar graph hanging on the wall depict the estimated quantities of quicksilver produced in Almaden in the last three centuries. The environmental health effects of mercury in present times are displayed in the Museum's ground floor in vague and abstract terms. Even less is said about the political and economic consequences of mercury's colonial use – e.g. how it played a vital role in the massive extraction of silver and gold in the colonial Americas, sustained the Spanish empire's finances, financed the slave trade, and enabled the rise of capitalism by catalyzing trade with the Middle East and China (Brown, 2012a). Colonial practices resulted in irreversible environmental damages: preindustrial mercury releases still circulate globally through the atmosphere, oceans, and food chains (H. Selin & Selin, 2020; Selin & Selin, 2006). As I left the museum, I reflected on the irony that today,

[4] This is consistent with the literature on territorial heritages, which characterizes the case of Almaden's UNESCO declaration as an example of a top-down heritage site type of declaration, typically initiated by state or international institutions (Ruiz & Cañizares, 2020).
[5] See *supra* note 1.

artisanal gold miners who use mercury to amalgamate gold are blamed as the perennial culprits of a toxic global economy (Goldstein, 2021), while their extraction methods and the material infrastructures that make gold extraction and marketing possible are memorialized as World Heritage for being valuable contributions to science and technology.

Opening vignette 2: Toxic landscapes

These framings of mercury and mining knowledge and technology become even more puzzling by looking behind the representations and zooming into sites where global action against mercury use is focused. One of the photographs around the mercury drop in Geneva depicts the Colombian towns of Segovia and Remedios. These two towns are located in the mountainous region of Antioquia, the largest gold producer in Colombia, the site from which most of the mercury emitted by ASGM has come in the last two decades (Cordy et al. 2011). The Northeastern region of Antioquia produces forty per cent of Antioquia's gold, and Antioquia contributes forty per cent of Colombia's national production (Bernal-Guzman 2018: 77). Antioquia is the first site in Colombia that mercury amalgamation was first used, in the mid-nineteenth century. Antioquia has also been one of the laboratories for local and international efforts to address mercury pollution. This is thus, one of the sites where this dissertation is grounded.[6]

Colombia has been a top gold producer since colonial times (Kalmanovitz, 2010). After being part of Spain's colonial domains until the 1820s, the country hosted large foreign companies that extracted gold between 1852 and 1975. Many companies left the country due to the internal armed conflict that started in 1964 and continues today (Castillo, 2013). Since the 1970s, independent miners (nonaffiliated to companies nor dependent on armed groups) are responsible for the bulk of gold production (Castillo and Rubiano, 2019). Today, the country sustains a significant ASGM sector of around 500.000 people and is in the top 16 world gold exporters. The sector extracts eighty-six per cent of the country's gold, and it is estimated that twenty per cent of all global mercury flows in the atmosphere are emitted from Colombia's ASGM. Such a contribution makes the country the third-largest emitter of mercury after China and Indonesia and the largest emitter per capita (Cordy et al., 2011). Moreover, Colombia was also the second-largest mercury importer in Latin America in the past decade (WWF & Gaia Amazonas, 2019) and is also one of the eight prioritized sites of the GEF Planet Gold initiative (formerly, GEF GOLD), the flagship project launched in 2019 under the UN Minamata Convention.

Global imaginaries of a mercury-free world have also appeared locally in Antioquia.[7] Between 2018 and 2019, the province of Antioquia implemented the *Antioquia Sin Mercurio*

[6] Northeastern Antioquia is also an epicenter of Colombia's armed conflict. Every year since the mid-1980s, there have been 600 murders per 100,000 habitants in the gold mining centers of Segovia and Remedios; Colombia's national average is 27/100,000. Given the region's long history of armed violence–which can be traced back to the 1950s, time known as *La Violencia*, the bipartisan conflict between liberals and conservatives that precedes the current civil war (Botero 2003)–, it is perhaps not surprising that violence and toxicity are represented as entangled in Antioquia's more recent history.

[7] Antioquia has long been a hub of mining education and technoscientific innovation, as it hosts the largest and oldest school of mines of the country, la *Facultad de Minas* of the *Universidad Nacional de Colombia.* Founded in 1876 and

("Antioquia without Mercury"). This program offered training workshops and technical assistance programs as well as reiterating the mercury ban. *Antioquia Sin Mercurio* is the latest of a longstanding history of projects related to mercury and ASGM implemented since the 1990s (Garcia et al., 2015). In the same vein as the *Antioquia Sin Mercurio* program, the province of Antioquia-launched the initiative *Municipios sin Mercurio (Municipalities without Mercury),* which encouraged municipalities of the province to double the efforts to control mercury use in the mining sites in their jurisdiction. In 2018, Andes, a municipality in Southwestern Antioquia, was the first municipality that certified the transition towards mercury-free methods in the twelve processing plants in its jurisdiction.



Photo 3. *Scientist takes water and sediments samples from La Cianurada brooke - Segovia, Colombia. Photo: S. Rubiano (2019)*

Andes is an exception. Segovia, Remedios, and almost all other mining towns of Northeastern Antioquia have not been able to eliminate mercury use. But this is far from a new problem in the region, despite the recent visibility of it. Between 1853 and 1972, US and British mining companies used mercury to extract gold from El Cogote mine, the largest gold mine in the country operating continuously since its opening. As is still the case today, companies have worked the motherlode while informal miners have exploited secondary veins. In 2003, a Canadian mining company (today called Gran Colombia Gold Co) inherited the old colonial concession, which covers eighty per cent of Segovia's land. Gran Colombia Gold continues to exploit El Cogote mine alongside more than 30,000 informal miners that work in 200 informal extraction sites within the concession area. The company considers them illegal invaders.





*Photos 4 and 5. Scrap metal seekers (*chatarreras*) in Segovia. Photos: J. Alvarez (2019).*

The Canadian company's operation at El Cogote mine has had huge environmental impacts, which rest on a longer history of mercury-intensive processing or ores that does back until the 1850s. Large scale operations have dumped their tailings into La Cianurada Brooke (Photo 3), which runs between Segovia and Remedios and is one of the most polluted sites in the country (Corantioquia, 2018). Those mercurial waters are the worksite of around 150 *chatarreras* (women who work manually collecting gold scrap and tailings. Most of them came displaced from other regions fleeing the war) dig the tailings and *jaguas* in La Cianurada left by corporate extraction. They are even more precarized than the miners who have kept insisting to work in the company's concession areas and old tunnels from the colonial exploitation. Another type of informal miners are *machuqueros,* the moniker for miners who stealthily break into the

modeled after UC Berkeley's College of Mining, some of its researchers and private companies are increasingly, although slowly investing in research and development on mercury-free processing techniques (Nanotecol 2019; Universidad de Antioquia 2017).

thousands of underground tunnels of El Cogote mine and steal sacks of ores. These examples demonstrate that the toxic legacies of mercury preceded the region's armed conflict, persist until today, and are also mediated by other forms of structural exclusion of vulnerable actors in the Northeastern region like displaced women or seasonal miners without mine, little mining knowledge, and more willing to work in other segments of the extractive endeavor.

Since 1995, in several regions of Colombia, including Antioquia and the Northeast, government agencies, aid agencies, and NGOs have implemented dozens of capacity-building and technology transfer projects to discourage the use of mercury in gold mining and biomonitoring studies to document the reach of mercury toxicity (M. Jensen, Combariza Bayona, & Sripada, 2021; Vargas Licona & Marrugo Negrete, 2019). While consultants, officials, toxicologists, health professionals, and engineers have been taking fish, blood, or urine samples, writing reports, filling out spreadsheets with estimations of mercury emissions, and collecting the attendance sheets of the training sessions that few gold miners actually attend, many gold miners have interpreted the Government's framing of the biophysical research as a fight against the infamous toxic metal as another pretext to tighten the already draconian rules for informal mining. In Northeastern Antioquia, Bajo Cauca Antioqueño, and Sur de Bolívar, many mining workers complain that anti-mercury initiatives are designed from above, demands them to buy shaking tables, cyanidation tanks, and other equipment that cannot buy, aggravate criminalization. In general, toxicity research based solely on the biophysical manifestations and interactions, do not address the political-economic problems that the country's hundreds of thousands of small-scale gold miners face, from extortion by armed groups to the monopoly and concentration of access to gold by large companies, and the lack of access to technical assistance (Bernal-Guzmán, 2018).

Since 2011, eradicating mercury use in all industries, but especially in the so-called illegal mining sector, became a top national security priority with the twofold goal of cutting off a now lucrative source of income for criminal armed groups and curbing mercury poisoning in the country's rivers. The Colombian government launched a crusade against the so-called criminal gold mining but also against mercury itself, declaring it as another actor in the country's resource war (Rubiano-Galvis 2022a). President Juan Manuel Santos (2010-2018) declared that mercury contamination was "an obstacle" to the *post-agreement* peacebuilding efforts, seeing in the substance the manifestation of the criminal capture of gold mining supply chains by paramilitary, guerrilla, and narco-traficking groups. In 2013, Congress approved a National Mercury Law mimicking the core provisions of the Minamata Convention, with even more stringent timelines for phasing mercury out of ASGM and other industries and forbidding its use from 2018. Despite the ban, mercury keeps being imported and widely used in Colombia's goldfields. The right-wing government of President Ivan Duque (2018-2022) maintained a military approach to illegal mining and environmental crime more broadly. For instance, in 2019, he launched Operation Artemisa, a series of military campaigns cracking down on deforestation and, to a lesser extent, gold mining (Ministerio de Defensa Nacional, 2021).

Although the Government and large companies conflate informal miners with their criminal extorters, truth is the relationship between gold mining, violence, and mercury is far from straightforward. Like other kinds of extractive activities, gold mining can fuel rebellion or other forms of political violence (Massé & Le Billon, 2017). Moreover, not all mining is done by

drug lords, but since the mid-1980s, paramilitary and narco-trafficking groups have harassed informal miners in Antioquia, typically accused of having ties to the leftist guerrillas. Against that background, the state is making a war on illegal mining and using it to justify a fight against mercury pollution in small scale mining, and in the process amalgamating all kinds of violence into one ball and therefore mixing up the drivers of all those different kinds of violence, and responding with a militarized approach to the problem. Despite these simplistic views, small-scale mining is different from the capture of certain segments of the gold supply in Antioquia and elsewhere in Colombia (Castillo & Rubiano, 2019). In fact, such a view conceals that the mercury problem did not begin with small scale mining since 2012 when the global price went to about 1200$/ounce. It goes back way far, as well as into other types of mining, and involving different, actors besides criminal groups. In Antioquia, small scale miners whose families have mined gold and farming for generations, sometimes with the active support of the state, have only been criminalized within the last couple of decades due to lack of permits, lack of paying taxes and more recently the use of mercury (Bedoya 2017; Ferry and Ferry 2017).

Background: The problem of mercury use in ASGM

Mercury is a globally traded commodity that has come under increased scrutiny due to its harmful impacts on human health and the environment. Under the 2013 Minamata Convention, the parties committed to controlling the mercury trade, a process that had already started when the EU and the US banned mercury exports in 2001 and 2008, respectively. Such decisions took place in the context of an overall decline in mercury demand. For a large part of the twentieth century, mercury's uses expanded to produce pesticides, weapons, paints, chlorine, chlor-alkali, measuring devices, and other industrial products (López-Morell & O'kean, 2014). However, the increasing awareness of its health and environmental effects –epitomized by the now well-known events at the Minamata Bay in Japan in the 1950s (Buccella, 2014)– led to it being phased out in most of these industries as well as in most wealthy nations on the next two decades. This brought about a plummet in mercury prices, but the substance's lower price resulted in its continuing appeal to poorer nations and less rigid environmental controls (Davis 2019). In terms of economic sectors, since 1990, the global Chlor-alkali industry's demand for mercury has declined. However, since 2003, artisanal and small-scale gold mining (ASGM), predominantly in nations in the global South, has emerged as the new frontrunner of mercury use (Egan 2008: 48; UNEP 2013, 2018).

Present in more than 80 countries in Latin America, Asia, and Africa, the artisanal and small-scale gold mining (ASGM) sector employs between 15 and 20 million people and is the largest contributor (thirty-eight per cent) of global mercury emissions (UNEP, 2018). Miners use mercury because it is a relatively affordable, quick, and easy method to process their ores and earn an income. But this need for profits and survival has turned into a global environmental problem. Mercury binds to gold and liberates it from the rocks it inhabits, creating a gold-mercury amalgam.[8] Then, miners burn off the amalgam, turning the mercury into a vapor that is

[8] Depending on the type of mineral deposit, different processing technologies are more or less suitable. For vein deposits, milling, gravimetric concentration of ores, and leaching are more adequate, whereas alluvial deposits –which are already smaller after being eroded from vein deposits by water— are better processed with sluices, panning, and other techniques (UNEP 2013). Mercury amalgamation is a widely used method in both types of operations: mercury

emitted into the air. Miners add mercury to the ores before processing them, discarding mercury-containing tailings into water and land (UNEP 2017). These emissions and releases are transported through local and global environments. Between 2005 and 2010, mercury emissions from ASGM increased from 300 to almost 700 metric tons/year (UNEP 2013). According to the 2018 UNEP's Global Mercury Assessment report, the ASGM sector is the largest source of atmospheric mercury emissions (838 tons/year or thirty-eight per cent of the total), followed by coal combustion (twenty-five per cent), and production of non-ferrous metals (twelve per cent) (UNEP 2018).

Across the Global South, most small scale miners use mercury. In the last two decades, much environmental scholarship has stressed that interventions are urgently needed to deal with pollution coming from the ASGM sector (Veiga et al. 2014; Davies, 2014) Swain et al., 2007; (Sippl & Selin, 2012). Consequently, mercury used in ASGM has become the target of international action, both developing responsible gold markets and for the sake of global environmental health. The WHO (2016) declared mercury as one of the top ten most toxic substances for human health, and since 2001, the UN has been advocating for phasing it out in industry, especially in the artisanal and small-scale gold mining sector. Large gold mining companies extract eighty per cent of the global gold production each year. Some ninety per cent of the gold from these sources is processed using cyanidation (Li 2015).

UNEP (2016) has promoted abandoning practices such as whole ore amalgamation, open burning of amalgam without vapor capture systems or retort, and reprocessing of mercury-contaminated tailings with cyanide. Instead, they suggest processing ores with "gravity only" methods, direct smelting and safe chemical leaching. UNEP and UNIDO have prioritized the four 'bad practices' that need to be combatted: i) whole ore amalgamation (applying the mercury before separating ore from gold by milling); ii) burning or vaporizing amalgam in residential areas; iii) open burning of amalgam without vapor capture systems or retort; iv) and reprocessing of mercury-contaminated tailings with cyanide (which adds toxic mercury-cyanide to mining waste). Instead, for each of these practices they suggest alternatives, as in: i) milling and concentrating the ores (panning, sluicing, shaking tables, and centrifuges); ii) processing in designated areas far from vulnerable populations; iii) processing ores with "gravity only" methods or direct smelting; and iv) removing mercury before using cyanide to reduce toxicity (UNEP 2016; UNIDO 2017).

The suitability of these alternatives depends on the type of deposits, and ore size at each mining site, as well as on the use of multiple technologies that require capital, training, and careful monitoring (J. O'Neill & Telmer, 2017). Some claim that the times when technical solutions were considered the silver bullet of mercury reduction initiatives are past behind us, based on the acknowledgement that consultants, scientists, and engineers involved in those efforts make of the inefficacy of interventions and the need for new strategies.[9] However,

is added to non-concentrated ores or to ores that are too small to bind with mercury (UNEP 2018; Veiga 2018). It forms an amalgam with gold, and then gold is again separated from mercury using a torch, so mercury (the metal with the lowest boiling point) turns into vapor, and gold remains solid. Once the amalgam is split, mercury vapors can be recovered and turn into liquid mercury again using retorts and other types of artifacts and then reused.

[9] Interviews 5, 35, 37.

capacity-building and technical assistance have been designed and practiced with a top-down approach and have not led to significant industrial transformations (Hilson, 2007; Veiga, 2018).

In many countries the majority of miners do not have land titles or formal concessions (Echavarria 2014). In Colombia, as in other countries, lack of property rights limits access to technical assistance in reducing mercury use. In addition, machinery like shaking tables or the decision to relocate a processing plant require financial investments inaccessible to most miners or processing plant owners. In parallel and in contrast to the situation in the informal or small-scale sector, large companies worldwide have been able to substantially reduce their use of mercury – they extract eighty per cent of the global gold production each year and ninety per cent of it is processed using cyanidation (Li 2015). In contrast, ASGM across the Global South is still using mercury and remains the key target of intervention and concern in that regard.

After three decades of interventions and millions of dollars spent, many have asked why it has been so difficult to deal with pollution coming from mercury amalgamation in ASGM (Hinton, Veiga, & Veiga, 2003; Stocklin-Weinberg, Veiga, & Marshall, 2019). Overall, many recurrent explanations put an over-emphasis in miners' individual behavior as both cause *and* solution to the problem, which contrasts with the fact that miners' voices, aspirations, and experiences with mining technologies and experts have been largely overlooked in the literature and from mining policy in general (Hilson 2007; Castillo and Rubiano 2019). Most of the literature answers the question by adopting a narrative of instrumental failure, which attributes the sustained failure to reduce mercury emissions from ASGM to a set of local or cultural barriers that have blocked the well-intentioned initiatives of international and local agencies and consultants (*see* Hilson 2000; Veiga 2009; UNEP 2011). Some of these 'barriers' are miners' illiteracy and alleged aversion to technological change, lack of organization, mistrust to foreign interventions, states' inability or unwillingness to formalize the ASGM sector or to exert authority in convulsed environments, and miners' lack of access to finance or credit (Hilson 2000; Veiga and Telmer 2009; Fernandez et al. 2015). Other studies highlight corruption and the capture of gold supply chains by transnational criminal networks (Global Initiative against Transnational Organized Crime 2016; Siegel 2013). Others think that the failure responds to a problem of project design and slow institutional learning that could be corrected with greater coordination and consideration of local conditions (Selin et al. 2018).

As Selin and Selin (2020, p. 193) put it while discussing mercury reduction initiatives in ASGM in Madre de Dios, past interventions have emphasized incremental interventions without addressing fundamental questions of mining, have lacked the required multiscale coordination, and have eschewed issues of power and justice. In the same line, the heterogeneity of mining territories and modes of production complicates top-down interventions (Diaz, 2021). Moreover, these recurrent explanations take for granted the knowledge and technological interventions involved in trying to fix the problem. One of the reasons behind this disconnect may have to do with the fact that, by and large, anti-mercury programs in the past two decades have lacked robust methods for identifying who has benefitted and who was harmed (Koekkoek, 2013; H. Selin & Selin, 2020). In general,, the literature does not sufficiently connect the mercury problem in ASGM (and the attempts to counter it) with larger structures of power, including the state but also including international organizations, gold markets, and the global flows of mercury in the economic circuits of international chemicals trade (Maxson 2016) (Le Billon & Spiegel, 2022).

The global politics of "reducing and, when possible, eliminating" mercury use in ASGM

Mercury's environmental health harms are so dangerous that it is one of the few pollutants with its own international treaty – the UN Minamata Convention signed in 2013, a treaty that seeks to phase down and phase out mercury from all industries, especially ASGM.[10] Since then, mercury amalgamation technique for processing gold and silver is largely seen as a 'bad mining practice' that must be eliminated as miners are formalized and receive technical assistance and finance (UNEP 2017).

The mercury treaty does not establish time limits for mercury eliminations in ASGM, but it does do so for the other industries where short-term technological shifts are more feasible, especially in oligopolistic sectors like chlor-alkali production (Ovodenko, 2017).The Convention particularly stresses the close association between ASGM and mercury consumption, emissions, and releases. Article 2 defines ASGM as "gold mining conducted by individual miners or small enterprises with limited capital investment and production" (UNEP, 2013). While the Convention does not impose a complete prohibition on the use of mercury in ASGM, Article 7 requires parties "to reduce and where feasible to eliminate the use of mercury" and the emissions from ASGM activities. Each signatory country where ASGM activities are "more than insignificant" must present a National Action Plan to the Convention's Secretariat no later than three years after entering into the agreement and revise its progress every three years. The Plan requires parties to establish national emissions and mercury use reductions objectives for ASGM.[11]

For many observers, the Minamata Convention is a comprehensive and reasonably effective treaty that has already launched a global phase out of mercury in all industries, although at different paces (Buccella, 2014; Eriksen & Perrez, 2014). For others, it is a technical fix for the gold supply chains (Le Billon & Spiegel, 2022) or an excessively flexible instrument that leaves states too much leeway in directing the transition towards a mercury-free world (Bell et al., 2017), especially in the ASGM sector.[12] Despite these mixed views, what both the optimistic

[10] The UN Minamata Convention signed in 2013, which commits countries to reduce and eliminate mercury pollution, covering the entire lifecycle of the substance and explicitly promoting the formalization of the ASGM sector (Yang 2015; UNEP 2013). The Convention requires governments to establish actions to eradicate the four most hazardous practices of mercury usage in ASGM: whole ore amalgamation; open burning of amalgam or processed amalgam; burning of amalgam in residential areas; and cyanide leaching of ore or tailings to which mercury has been added (UNEP 2013). Although Annex C of the Convention lists measures to achieve these goals, the domestic implementation of these provisions is left to the states' will (Yang, 2015).

[11] Additionally, it requires parties to develop "(1) strategies for promoting the reduction of emissions and releases of mercury; (2) strategies for managing trade and preventing the diversion of mercury from both foreign and domestic sources to use in ASGM; (3) Strategies for involving stakeholders in the implementation and continuing development of the national action plan; (4) A public health strategy on the exposure to mercury including gathering of health data and training for health-care workers; (5) strategies to prevent the exposure of vulnerable populations, particularly children and women of child-bearing age; and (6) strategies for providing information to miners and affected communities" (Buccella, 2014)

[12] Instead of a radical ban, Article 7 encourages states with "more than insignificant" ASGM to reduce and, when possible, eliminate mercury use in ASGM. For all other sectors, the treaty establishes concrete deadlines.

and critics of the treaty share is an acknowledgement of the uncertainty how the Convention (which is the latest of a series of attempts to phase out mercury in ASGM) will impact the world's poorest populations who are disproportionately exposed to mercury's negative effects and at the same time most dependent on mercury for mining in small-scale operations (Le Billon & Spiegel, 2022). ASGM is the area of the treaty that raises more questions about environmental justice and human rights, as the UN Special Rapporteur on toxics and human rights Marcos Orellana declared recently (Orellana 2022). Moreover, how each state interprets how "significant" ASGM is in its territory and what that means for its response to it is not a self-evident fact nor a mere numerical description. Instead, it is a process mediated by history, politics, and culture.[13]

Therefore, a more nuanced and context-specific analysis of the persistence of mercury use in ASGM is required, one that recognizes the substance use in the past as part of the present circumstance. This is not least due to mercury's biophysical characteristics and the impossibility of eliminating them. Some political ecologists have argued recently that:

> "(…) *in Africa, Asia and South America, while governments have used foreign donor funding to hire consultants to diagnose mercury threats and promote medium-scale "business" models for entrepreneurial actors to phase out mercury in gold mining (sometimes using dangerous cyanide methods as a replacement), the uneven balancing of social and environmental goals in recent years has entailed a lack of careful contextual attention to marginalized and criminalized artisanal and small-scale miners and communities*" (Le Billon & Spiegel, 2022, p. 781).

Partly in response to this call for more contextual attention to the problem, this dissertation conceptualizes mercury and its use in ASGM not as an unruly molecule but as a chemosocial substance embedded in complex bundles of relations and infrastructures of knowledge, technology, and power. Instead of asking why small-scale miners continue to pollute or why two decades of regulations, military crackdowns, and project-based interventions have provided insufficient incentives, I ask the following: How have historical practices in extraction sites interacted with mercury's biophysical characteristics (its persistence in the environment) to produce the current problem of mercury pollution attributed to ASGM? What are the connections between contemporary science and scientific explorations and the colonial era's violence in mining environments? How have ideologies of the nation-state flip-flopped and failed to recognize the needs of people pushed into small-scale mining as they lose access to other forms of livelihood and become subject to overlapping forms of violence?

I point to multiple situated histories of mercury's chemosocial life in the extractive sector in the Americas, and the connections between them, to provide a more nuanced interpretation of the contemporary persistence of a technique that the international community wants to eradicate. I situate mercury use in ASGM as part of the residue of broader political ecologies of knowledge, technology, and colonial, corporate, and nation-state power. Drawing on concepts from political ecology, science studies, and the social studies of toxicity, I conceptualize mercury use in ASGM not as an individual behavior to be adjusted, but as a practice that indexes the

[13] I devote Chapter 5 to the numerical work involved in quantifying mercury use in ASGM and therefore determining its significance.

intersection of power, markets, and histories of extraction across various temporalities and imaginaries of the past and the future. Drawing on this conceptualization, I study the history of gold mining in Colombia and its entanglement in the global efforts to both develop and diffuse the mercury amalgamation technique, and then to eliminate it. Toxic landscapes like Segovia and Remedios in Antioquia illustrate the challenges ahead of the Minamata Convention and, more broadly, international efforts done to reduce or eliminate mercury use. But as I demonstrate, the Convention's efforts to prioritize ASGM index a deeper set of relations, practices, and histories that help explain the rise, later downfall, and stubborn persistence of mercury amalgamation.

In this dissertation, I demonstrate what conditions have made mercury amalgamation widespread in Colombia, and what kinds of social orders the persistence of mercury use in ASGM helps sustain. While I address the global efforts to eliminate mercury in ASGM, I ground my analysis in Colombia, a crucial node in the global biogeochemical and economic cycles of mercury and a site of intervention for international mercury governance. Across six chapters I argue that the persistence of mercury use in ASGM has to do with the persistence of past practices, policies, and privileges in the present. These inequities, I will show, have epistemic, technical, political-economic, and representational dimensions in mining policy and practices, expressed in the scientific community and bureaucratic institutions studying and regulating it. In the remainder of this introductory chapter, I expand the contextualization of the problem, introduce my research question and methods, and present an outline and brief summary of the rest of the chapters.

When I started talking to mercury-using gold miners as well mining engineers, toxicologists, and other scientists involved in mercury reduction efforts in Colombia, my initial assumption was that I would encounter, on the one hand, miners with little awareness of the environmental health harms they produce and are exposed to, and on the other hand, experts with little awareness of the complexity and structural violence that characterizes ASGM. Through my fieldwork, though, I encountered miners and experts with much more awareness of harm and violence than I expected, but also connecting the present problem to past mining practices, knowledge production and circulation, and policies at multiple scales. Many of them would refer to the mercury used by past mining operations – there was virtually no interview in Antioquia that did not refer to 120 years of extraction carried out by the Frontino Gold Mines Co (1853-1973) in Antioquia. In turn, engineers and consultants referred to the history of more than three decades of mercury reduction initiatives with frustration and nostalgia of times when the blurry frontier of legality did not limit their work with now called illegal miners. Such an attentiveness to the past, as well my engagement with the bodies of literature I review below, directed me towards the need to understand the role of contemporary ASGM in global mercury pollution as part of more complex historical political ecology of extraction and toxicity that required drawing on methods that allowed tracing past and present practices and ideas across scales, temporalities, and landscapes.

Methods[14]

[14] CPHS/OPHS Approval date: August seventeenth, 2018. Protocol ID: 2017-04-9807.

I started my data collection by compiling all the publicly available data on mercury reduction projects implemented in the ASGM sector in Colombia in the past three decades. Surprisingly, no international or local institution (not even UNIDO nor the Ministries of Environment and Mines) had a systematic record of their work on mercury in ASGM in Colombia, and was stark indication of how much knowledge about the problem is produced and forgotten on the desks of veteran consultants and retired government officers. I decided then to create and reconstruct the record myself: through information requests, interviews, and archival research, I compiled a database with data from 127 projects carried out between 1989 and 2019. The database contains basic information about each project (years of operation, funder, budget, implementing agency, aims, outcomes). Although the data is incredibly patchy and does not allow to see many clear patterns, I nevertheless used it as a guideline to identify potential interviewees and select Northeastern Antioquia as my field site given that is the region where most anti-mercury initiatives have been implemented between 1995 and 2019.[15]

I was initially going to work in the Amazon, an emerging mining frontier in which the question of mercury is beginning to become a priority of indigenous organizations. However, security conditions in the Northeastern Amazon after the 2016 Peace Deal deteriorated, as the region became one of the strongholds of the small but heavily powerful faction of the FARC guerrilla combatants who did not demobilize and continued in arms. While I have continued collaborating with indigenous organizations affected by mercury in Colombia and Peru and Brazil (see Chapter 4), I decided to change my main field site to Antioquia. Security in Antioquia is no better than in the Amazon, but there was an important factor: in Antioquia, a region with larger urban areas, I could do fieldwork without being in war zones or actively disputed territories. Since going to the mines in rural areas on Segovia and Remedios in Antioquia involved security risks that I did not want to assume, my visits to actual mines were reduced to a handful in each of my visits. This ended up having important implications, as I shifted my analytical focus to the *above-ground* politics of mining – in other words, to the work involved in taking minerals from processing centers in urban areas to global markets beyond mining areas, as well as on the distribution of the toxic burdens left by such process and the knowledge-making work for making them globally visible.

As stated above, Antioquia has the double status of being the most mercury-polluted and polluting region of Colombia while also being the most prepared and invested in addressing such a problem, although with unsatisfactory results on both fronts. The close involvement of UNIDO scientists in the emergence of Segovia as a globally known site for its contribution to massive mercury pollution made Segovia and Antioquia the ideal node to study mercury's chemosocial life in the gold mining sector and its intertwinement in global imperatives of detoxification. I focused on discussing atmospheric emissions as they have been the form of mercury pollution that had more prominence in the substance's globalization, and therefore it allowed to me "travel" physically and analytically across various sites. As Peluso claims, "the understanding

[15] I also built a database of the graduates between 1952 and 2012 from the mining engineering program of the *Facultad de Minas* of the Universidad Nacional de Colombia in Medellin, drawing on an annex on Vargas' (2012) history of the institution. Triangulating this data with other sources, I identified how many of these mining engineers are experts in gold processing. While I left the analysis of this database for a future project, having built it was useful as it gave me a sense of the workforce that has been available to implement mercury reduction initiatives in ASGM areas on the ground.

how history is told or remains untold is an essential part of the politics of knowledge production, but also of human experience and mobilization for change. It should be part of any political ecology analysis" (Peluso, 2012, p. 80).

With attentiveness to the fact that both local conditions and transnational forces shape ASGM, for carrying out this project, I have conducted a qualitative-historical study of mercury use and mercury reduction initiatives in ASGM in Colombia and followed several sites of decision-making about mercury and knowledge production and circulation during 18 non-continuous months of fieldwork. I used archival work, text analysis, participant observation, targeted interviews, and descriptive statistics to recount situated histories (cf. Peluso 2011, 2012) that weave together those various critical temporal and spatial contexts. I attended the 1st, 2nd, and 3rd Conferences of the Parties (COP) of the UN Minamata Convention in Geneva as an accredited observer through UC Berkeley's accreditation.[16] I also visited ministerial offices, metallurgic laboratories, ore-processing centers, and training on mercury-free techniques in the province of Antioquia. There, I observed in-depth three mercury-free technologies exhibitions/fairs (*Ferias subregionales de tecnologías limpias*) organized by the provincial government between 2018 and 2019. These were key sties of inquiry, as they gathered most of the actors concerned about mercury use in ASGM for several days, e.g., international aid agencies, national, regional, and local government officers, large companies, technology vendors, university researchers, military forces, and miners.

Being attentive to these multiscale dynamics in various sites (UN forums, processing plants, government offices, and archives) entailed limitations in terms of depth and engagement with each particular site. Therefore, I complemented my observations with 60 interviews with miners, mining engineers, and government officers during the fairs, all selected through snowball sampling (Ragin 2011) across all those sites: the COPs, government offices, and sponsored events on mercury, and mining and processing sites where mercury is used. I asked my interviewees about their experience and involvement with mercury reduction interventions in ASGM and their views on them, and the topic of mercury locally and internationally. Their responses and my visits to the mentioned sites led me to find reports and scientific documents on mercury relevant for mercury policy both globally and locally in Colombia. Through databases and libraries in Colombia and the US (e.g., UC Berkeley, Universidad Nacional de Colombia Sede Medellin, Universidad EAFIT, and Universidad de los Andes), I accessed plenty of materials on the history of mercury and mercury amalgamation in Colombia, the Americas, and Europe.

Chapter 2 on the situated practices of mercury production and trade during Spanish colonialism and the Colombian state's active support in supplying its mining sector draws on qualitative work in mining areas in Antioquia, Colombia, and archival research at the School of Mines of the Universidad Nacional de Colombia in Medellin, the New Almaden Museum in San Jose (California), and UC Berkeley's Bancroft Library Archive. I also drew on some of my interviews and participant observation in Antioquia and Nariño, two prominent gold mining regions in Colombia.

[16] Since 2017, UC Berkeley is an accredited observer of the Minamata Convention and Professor Kate O'Neill is the focal point.

Chapter 3 on the itineraries of the mercury amalgamation technique draws on archival research at the School of Mines of the Universidad Nacional de Colombia in Medellin, the New Almaden Museum in San Jose (California), and UC Berkeley's Bancroft Library Archive. I also drew on primary sources like mining and metallurgy manuals used in the Americas in the nineteenth century, and historical statistics of mineral imports in South America. My visits to the Almaden Museum and Mining Park in Spain in 2019 and the New Almadén Mining Park in Santa Clara in 2021, as well as my fieldwork at the Minamata Convention COPs, helped me expand, situate, and interpret the archival information.

Studying knowledge politics, as I do in Chapter 4, requires methods that can account for its circulation across multiple locations and centers of calculation (Latour, 1987), their evolution over time, their materiality, and the multiplicity and heterogeneity of participants and institutions involved (Karasti, Millerand, Hine, & Bowker, 2016). That chapter is based on 18 non-continuous months of fieldwork which included archival work, text analysis, participant observation, targeted interviews, and descriptive statistics. I observed the display of UNEP's Global Mercury Assessment reports at the Minamata Convention COPs 1, 2, and 3 between 2017 and 2019, a venue where I interviewed 12 mercury scientists (8 of them engaged in UNEP's GMA and ICMGP) and four consultants who have participated in various research initiatives on mercury. I also built and processed a database with information about the experts who have participated in the four UNEP Global Mercury Assessment reports between 2002 and 2018. Drawing on authorship information in the reports, on internet searches, and with the help of two of the most veteran experts in the DB, I found the institutional affiliation, country institution, gender, and area of expertise of the 127 experts.

Chapter 5 on the numerical work required to make mercury use in ASGM legible I draw on participant observation, critical text and data analysis, and interviews with experts, bureaucrats, and miners. The analysis is based on 18 non-continuous months of fieldwork which included archival work, text analysis, participant observation, and targeted interviews in various spaces, such as Minamata Convention COPs 1, 2, and 3 between 2017 and 2019; six processing plants in Segovia, Antioquia; and events and training on mercury led or co-sponsored by the Colombian government, the province of Antioquia, or the Minamata Convention Secretariat. The interviewees (listed in Annex A) were scientists, mining engineers, government and UN bureaucrats, and consultants involved in producing data about mercury use in ASGM in Colombia.

Positionality

I collected data about mercury after being involved in the discussion about policy, governance, and advocacy before my doctoral studies. In 2015, I coordinated a workshop organized by UNITAR and the Universidad de Los Andes in Bogota, the first enabling activity to promote awareness of the Minamata Convention in Colombia. I was in charge of drafting a report on what ratifying the Convention would mean for Colombia. While I wrote that report thinking in legal terms exclusively, since then, I have 'stayed with the trouble' of mercury (cf. Haraway 2016) and refined my approach to mercury's chemosocial forms. I could do this, partly thanks to wearing different hats: through the socio-historical analysis of its global, long-range

atmospheric transport, providing legal counsel to indigenous communities exposed to mercury, and consulting on mercury policy. Indeed, since 2018, I have worked providing legal counsel to indigenous organizations in the Lower Caquetá River in the Amazonian region seeking compensation from the Colombian state for its failure to prevent mercury contamination in their lands in the last two decades.[17] Also, in 2018 I worked as a consultant for UNEP, WWF, and the Gaia Amazonas Foundation for a project on how the countries of the Amazon Biome are dealing with mercury trade and pollution. I presented this report on side events during COP 2 and COP 3 of the Minamata Convention, wearing the hat of an activist and "knowledge communicator" and also as a way to fund my dissertation fieldwork. Finally, in 2021 and 2022, I helped organize a side event at the Minamata Convention COP4 with the UN Special Rapporteur on Toxics and Human Rights in which Amazonian indigenous women from Colombia, Brazil, and Peru discussed mercury exposure in their territories. All these activities contributed to my broader understanding of the problem and helped me identify interviewees and sites to visit.

This involvement in international mercury governance as an environmental and human rights lawyer, consultant, and field researcher has allowed me to engage not only with miners and communities exposed to mercury use but also with different levels of institutional action and knowledge production and circulation. I have been part of mercury's international and national apparatus myself and have firsthand witnessed its possibilities and limitations. Therefore, rather than an 'objective' or a 'view from nowhere', this vantage point has enabled me to occupy several differently situated perspectives (Haraway 1988; Peluso 2012). I had the chance to both 'study up' (Nader 1979) by attending glamorous UN meetings in Geneva and with innovators in the Silicon Valley in California, as well as discussing ASGM with marginalized actors (Harding 2015) such as small-scale miners, and Southern scientists and engineers in Colombia and other Global South countries. Although I had the privilege of circulating through various sites and vantage points, I am not neutral towards the problem – on the contrary, I acknowledge the profound injustices that characterize it and attempt to learn from and foreground the voices of two of the most vulnerable actors affected by them: the small-scale miners trapped in a Catch-22 of informality, and the exposed communities—miners and their families exposed to the substance.

Literature review and contributions

This dissertation makes three conceptual and empirical contributions to debates on the social dimensions of toxicity, expertise, and extractive industries in Latin America. First, the dissertation conceptualizes mercury use in ASGM foregrounding the histories of colonialism, state-building, technoscience, and mining policies in Colombia. Second, this work examines the question of miners' resistance to abandoning mercury use and highlights how their refusal rests on a sedimented history of structural violence and epistemic and technological injustices, and not merely on their alleged ignorance or their status of informality or illegality. Third, the dissertation expands studies on science and technology in the extractive sector focused on corporate mining expertise and opposition to it- by studying the work of scientists, engineers, and bureaucrats producing or collecting knowledge on ASGM's use of mercury not simply as

[17] After losing in the lower courts, the case was selected by the Constitutional Court and it seems like we will win.

cogs in a corporate or anti-mining machine, but as complex actors whose role in producing knowledge about the problem is far from merely descriptive but also productive of it.

For elaborating these contributions, the dissertation draws on two strands of discussion: the critical study of toxicity (in discard studies and political ecology) and its treatment of historical and contemporary trends, forces, and production practices in industrial capitalism, and debates about the politics of knowledge and technology referring to extractive industries. In this section, I present a general overview of these bodies of literature, making explicit how I engage with and contribute to each of them.

1. Orders, scales, and temporalities of toxicity

a. Toxicity and pollution as bundles of relations

The emergence of mercury as a global pollutant that needs to be eliminated through international cooperation raises questions raises the questions of what worlds will be detoxified, for whom, and through what means. Mercury and the efforts to eliminate it, then, can be better understood using the lens of the emergent, interdisciplinary field of *discard studies.* This field examines how certain objects, practices, and populations are rendered disposable through larger social, political, and economic processes (Liboiron 2017), and it is inspired by the questions of "how, why, and to whom do waste, discards, and disposal matter" (Moore 2012). Instead of the traditional focus on waste and trash, discard studies redefine the problem of waste and pollution as the manifestation of "wider complex social and political systems" like colonialism, capitalism, and patriarchy (Liboiron 2018). In the particular case of toxics, some authors have proposed the notion of *toxic politics*, seeing power struggles involved in chemical exposure as "not about 'how much' toxicant or even 'what' chemical, but the why and how it is encountered, by whom, and to what end" (Watts, 2013 cited in Liboiron, Tironi and Calvillo 2018, 341; *see also* Shapiro et al., 2017). It is worth noting that these questions resonates with and expands studies in political ecology and environmental sociology, for example, about environmental justice struggles against toxic exposure of vulnerable populations (Theriault & Kang, 2021), works on collective violence and inaction against toxic exposure (Auyero & Swistun, 2009; Lora-Wainwright, 2017), and the racialized politics of purity and pollution (Kosek, 2003).

From this critical point of view, toxicity is seen as "produced by and reproductive of different orders of life" (Liboiron, Tironi and Calvillo 2018). According to Liboiron, Tironi and Calvillo (2018: 3), toxic harm disrupts order and existing relations, while also sustains systems, including those that produce inequity and sacrifice: "more than just the contravention of an established order within a system, toxic harm can be understood as the contravention of order at one scale and the reproduction of order at another" (*see also* Shapiro and Kirksey 2017, 481). For example, "chronic low levels of arsenic in water interrupt the reproduction of fish, but maintain the ability of mining companies to store mining tailings in open air mounds" (Liboiron 2017). Similarly, even low levels of mercury pollution can disrupt social and ecological life in and around mining areas (through, for instance, political conflict and water pollution), but maintain the stability of gold markets or local structures of violence and dispossession. One of

the questions at stake would be who defines what "low levels" are and who 'repairs' them in case they are surpassed (like toxicologists and mining engineers do with mercury use in ASGM).

The cultural representations and productions of knowledge about a toxic substance play a key role in shaping what toxicity means, for whom, how much of it is acceptable, and who benefits from its production and permanence in certain bodies, landscapes, and supply chains. This is why social scientists have advocated for the use of ethnography and qualitative methods to go beyond this 'molecularization of life' and instead shed light on the shared, entangling, and extensive chemical infrastructures that alter life (Auyero and Swistun (2009), and Murphy (2017). These alterations are not merely bodies exposed to chemicals, but rather the illustration of chemical relations as "varied enmeshment and enfleshment in infrastructures" (Murphy 2017) in which life and death can be at stake frequently in slow and imperceptible ways (Nixon 2011). In line with recent efforts in social science to include non-humans in political theory (Braun and Whatmore 2008) and in social theory (Mol 2002; Latour 2004), the study of chemicals is becoming increasingly useful for researchers to "follow complex, multisite, and multiscale phenomena" (Shapiro and Kirksey 2017, 481). Ethnography and other interpretive methods can be useful to revel what Shapiro and Kirksey (2017) call *chemosociality* —the longstanding relationships and emergent social forms that arise from chemical exposures and dependencies. Using these methods, works in environmental sociology and anthropology have studied how marginalized exposed communities experience chemosociality and contest it in various ways that range from passive waiting to varied forms of activism and contestation (Auyero & Swistun, 2009; Lora-Wainwright, 2017; Silva, 2021)

Another key discussion foregrounds the fact that waste and pollution are only phases in the life of a thing. For instance, works that study the political economy of waste and recycling allow us to follow the transit of waste from and back into commodities" and the unequal consequences of this transit across global politics and markets (Clapp 2001; O'Neill 2019). Kao (2017) distinguishes two approaches to 'follow' objects: the "social life of things" (Appadurai 1994) approach concerns the shifting social and cultural meaning of an object through time, whereas the "follow-the-thing" (also known as commodity chain analysis) approach emphasizes the connections between economic practices that take place simultaneously in a different place (Egan 2000, 2010 (Sellers 2015), (Chen 2012) (Vogel 2008). For instance, Shapiro (2019) interrogates the category of persistent ephemeral pollutants (PEP) under which the US EPA's regulatory science has categorized chemicals like formaldehyde. Despite being chemically transitory in human bodies, formaldehyde, for example, is a sociotechnically persistent substance that circulates through the vessels of industrial petrochemical violence. Therefore, the relations that span this substance "do not start and stop where regulatory states think they do" (Shapiro 2019). Rather, they start and continue with social relationships that are always ongoing and always changing. Temporalities and materialities are thus both critical to the social analysis of pollution and toxicity, as I show below.

b. Temporalities and materialities of toxicity

In political ecology, recent works have-addressed the framings and epistemic violence of pollution and toxicity of industrial chemicals like PFAS (Fisher, Mostafanezhad, Nading, & Wiebe, 2021) or elements like mercury and cyanide in gold mining (Vélez-Torres, Vanegas,

McLamore, & Hurtado, 2018; Verbrugge, Lanzano, & Libassi, 2021) in the context of capitalist expansion and toxic dispossession. The slow nature of toxic violence (Nixon 2011) has ignited debates about the various temporalities of toxics and their chemosocial lives. In general, temporality is a key dynamic in natural resource politics as groups struggle over representations of the past and visions for the future (Mathews and Barnes 2016; Peluso 2011). In that sense, conflicts about extractive development are also "conflicts between divergent environmental imaginaries constructed through cultural frameworks for understanding the past and the future" (Kojola, 2020). For instance, recent accounts of gold mining in Colombia highlight how governments and corporations see and depict ASGM as actors anchored in the past, backwards, lacking futures, and as obstacles in the process of materializing neoliberal development imaginaries (Jaramillo 2020). In the last decade, various Ministers of Mines and presidents of mining companies in Colombia have claimed repeatedly that all forms of mining without license should not even be called mining but "illicit extraction of minerals", a rhetorical twist to further criminalizing narratives of the sector.

Here I review four concepts in the social studies of toxicity that address toxic materialities and temporalities and that are part of the conceptual framework I use throughout the dissertation: residues, infrastructures, baselining, and heritage. Boudia et al. (2018) propose the notion of *residue* as a theoretical and methodological tool to chart the chemical dispersions and transformations set in motion by industrial capitalism and as a multivalent conceptual device to theorize about the politics of toxicity and chemical environments. A residue has four properties: it is a *material object* that piles up over time (through bioaccumulation) and distributes harm and fortune unevenly, while sometimes appearing as immaterial, it is *irreversible*, not only because of its indestructible molecular nature but also due to the regulations that impede dealing with cleaning up the leftovers, it is *slippery* and *unruly* because it is unpredictable—i.e., it can escape regulatory systems and technologies of control; and it is *valued for the work it creates but much less for the work it accomplishes* (Boudia et al., 2018). In that vein, pollution and its residues are not side effects of colonialism but rather enactments of ongoing colonial relations to land and people; they embody colonial violence rather than being symptoms or side effects of it (Liboiron, 2021).

Recent developments in STS have paid greater attention to materialities and infrastructures as promising components of understanding the social orders at work in the production and control of chemicals and toxicity (Liboiron, Tironi, & Calvillo, 2018; Ureta, 2016). The concept of infrastructure has gained terrain in the social sciences to explain the co-constitution of material and social worlds and as an analytical window into statist and capitalist expansion (Jonkman & de Theije, 2022). Infrastructures are built networks that facilitate the flow of goods, people, or ideas and allow for their exchange over space (Larkin 2013, p. 328). We can think of infrastructures, not only as invisible material substrates (Star 1999), but also as those structures that are "supposed to become invisible" Hetherington (2017, p. 42)," Expanding on this notion, chemical infrastructures are defined as the spatial and temporal distributions of industrially produced chemicals that materially and unevenly shape human and non-human life (Murphy, 2015, 15). Chemical infrastructures are regulated and attended in uneven ways, which explains why certain chemicals become known, legible, or actionable and other do not. Toxicity, then, is infrastructural in the sense that its materiality can manifest (or not) in various registers of power.

Other scholars have characterized the confirmed and suspected toxic remnants of war as toxic infrastructures that become sedimented in the social lives of land and resources, and distribute war's lethal potential, even years after, for example, the last bomb was dropped (Touhouliotis 2018). The infrastructures needed to manage the air as a "commons" –also constitute toxicity by monitoring its thresholds (Calvillo 2019). Large-scale logistics infrastructure, like the Ports of Los Angeles and Long Beach, are other examples of toxic infrastructures in the sense that they threaten local and global ecologies through their massive material presence (De Lara 2018). Ports and other logistics infrastructures also enable the permanent circulation of goods and capital and serve the continued expansion of capitalism and the extraction of natural resources with its typical labor violations, pollution, and other harms (Dunbar-Hester 2023).

The third critical concept in the realm of toxics is baselines. Toxic ecologies are known, governed, and normalized through toxicity thresholds, risk assessments, and environmental impact assessments (Murphy 2017; Barandiaran 2017; Bond 2022). Baselines are epistemic and political practices that render environments and their components legible (whether species, ~~a~~ landscapes, or resources). They create both 'historical' references and normative benchmarks with which to assess any harms or impacts (Ureta, Lekan, & von Hardenberg, 2020; Craig 2014). Baselines are political: they create and enact modernist ideals of perfect and mythologically pristine pasts and serve as arenas to highlight specific temporalities and scales of harm to the detriment of others (Barandiarán, 2020). Baselines are at the center of current efforts to deal with some of the most pressing environmental issues of our time, including climate change, biodiversity loss, and toxic pollution (Ureta et al., 2020). For instance, building a pollution inventory (a case I discuss in Chapter 4) is a technology of quantification that *baselines* the best possible estimation boxed in a political and epistemic jurisdiction (Winickoff & Mondou, 2016). Surprisingly, the extractive industries are a sector in which baselining and the infrastructures of inquiry, evaluation, and intervention that support them have not been widely studied (Ureta, 2018).

The concept of toxic heritage responds to the question of how toxic sites are remembered in both the memory practices of communities and in official heritage narratives such as museums, historic markers, or sites under the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage. This concept is at the intersection of the history of substances and processes that have created physical harm or threats to their environments and the forms of life supported within them (plants, animals, humans, etc.). That history intersects with both formal heritage institutions and informal memory practices (Kryder-Reid 2021). Other questions that animate the overlaps and intersections between toxicity and heritage include: how are sites used, modified, and managed in the aftermath of contamination, what roles have corporations, governments, and individuals played in the creation and remediation of environmental harm, and how are toxic heritage sites are being deployed in broader projects of environmental and climate justice? (Kryder-Reid and May 2020).

A comparative study of toxic heritage sites in Europe and the Americas found three typical kinds of treatments of toxic heritage in those sites and exhibits: a sense of positivity or neutrality in which the impact of the industry is celebrated; a passive acknowledgment, usually

in the context of declining industries and greener work; and the inclusion of explicit statements of environmental and bodily harm (Kryder-Reid (2020). While the sample of sites is small, the differences in valuation of toxic sites reveal key aspects worth further studying, such as narratives of post-industrial sites (nostalgia, pride, community, home, histories of heroic workers, innovation, or progress), forms of positionality at the sites, and conflicts over which perspectives and voices are centered, especially those of former miners and other workers.

The history of mercury amalgamation in gold and silver mining in the Americas, like the history of other substances, is not linear but rather a more fluid ecology of power and knowledge, a fluidness that is concealed and de-politicized by UNESCO's declaration of such technology and knowledge exchanges as "horizontal" and universally beneficial. My analysis of mercury's toxic heritage enriches the framework by focusing on how knowledges produced in Almaden, the site of the mercury drop described in the beginning of this chapter, are differentially valued in global politics and simultaneously do multiple types of political work. I extend the concept of toxic heritage to encompass not only former extraction sites, but also their connection to the valuation of current ones like the mining landscapes in Northeastern Antioquia. This case expands Kryder-Reid's (2020) typology of the three treatments of heritage—Almaden's toxic heritage conveys a sense of positivity or neutrality about mercury mining and its associated knowledges, but at the same time, one of the technologies lauded in the UNESCO declaration is also targeted by the Minamata Convention. Thus, the knowledge produced about the toxicity of mercury at Almaden cinnabar mines does two kinds of political work: it justifies its history as "universally beneficial" and reinforces the present urge to phase it out of amalgamation processing elsewhere.

These insights are critical for my case, as I do not treat mercury as an isolated, unruly molecule devoid of social history and politics and only knowable through chemistry, atmospheric science, or environmental engineering. Instead, by situating mercury use in ASGM in larger historical and political contexts, I show its entanglements in varied networks and social relations. After being extracted from cinnabar and before being emitted as waste, mercury travels through global, regional, and local circuits of trade and exchange as a commodity before turning into mining waste and entering the environment as a "global pollutant" or human bodies as a toxic. Similarly, mercury has been memorialized as toxic heritage at the Almaden mines in Spain and the Idrija mines in Slovenia.

In sum, the social and political studies of toxicity literature provides four key ideas for my work. First, toxic harm can be decompartmentalized and rethought of as an indicator of larger -and conflicting- social orders at different scales. Second, the production of knowledge (and ignorance) about chemicals and toxicity is contested and has broader social, economic, and political implications at different levels of analysis. Third, chemicals and toxic substances have social lives that render them unruly and forbidden at particular moments and sites of their biogeochemical and economic cycles, which is why "following" them across varied social worlds can help unravel their entanglements in broader social networks and infrastructures. The fourth idea is methodological: ethnography and qualitative research can provide useful insights to illuminate how certain objects, practices, and populations are rendered disposable and how such decisions are connected to larger social, political, and economic processes.

2. STS Underground (and above-ground): the politics of knowledge, technology, and numbers in extractive industries

Recent works in political ecology have critiqued the framing of small-scale mining as a problem requiring interventions in the form of technoscientific fixes and have documented the heterogeneity of production modes and land politics in diverse and historical ASGM landscapes (Peluso 2017; Libbasi 2020; Diaz-Leiva 2021). This dissertation expands these critiques of technological framings and fixes of mining through-the STS literature on the politics of mining knowledge and technology. Specifically, I decenter the mine as the sole site of mining knowledge production, by examining the enrolling of engineers, scientists, and international organizations in the constitution of chemical infrastructures that enable mercury use in ASGM.

a. Infrastructures of knowledge in the extractive sector

The production of mercury as a global pollutant, as well as the efforts the counter it as such, has been possible in part thanks to the labor of scientists and engineers working at the intersection of international organizations, corporations, government agencies, consultancy firms, aid agencies, and UN agencies. These experts play a crucial role in co-producing the Colombian state agencies involved with mining and mercury use and marketing, gold markets, and international mercury policy. Given the prominence of these experts as architects, implementers, and commentators of the international efforts to eliminate mercury, I engage with an emerging literature highlighting the role of engineers and applied scientists in mining and extractive industries in general.

The role of engineers and scientists in accounts of extractive industries are scarce, with a few exceptions and most of them focused on the corporate sector (Li 2015). In response, recent studies have invited to call to question the knowledge, expertise, and power underlying appeals to science and technology in extractive industries. A recent body of literature under the label of *STS Underground* has advocated for the use of STS concepts and methods to make sense of the role of technoscientific work in the mining and oil industries. Kinchy et al. (2018), for example, argue that technoscientific expertise plays a key role in shaping decisions about two fundamental questions around extraction: what spaces are worth digging and for whom? How can exploited surfaces be reclaimed –e.g., restored, become habitable, repurposed for other uses– during and after extraction? A key point of this literature is the claim that scientists and engineers are not just 'cogs in the machine,' merely complicit to neoliberal ideologies of extraction (Hughes 2017), or external agents who sometimes can be perceived as 'parachuting in' determined scenarios (Cohen and Ottinger 2010), but rather active architects of the socio-natural landscapes they are bound to know and intervene (Bowker 1994; Gustavson 1954).

Indeed, scientists do not merely describe the underground and the consequences of mining it, in the same way that geologists and engineers are not only carriers of technical knowledge and artifacts for extracting and processing ores. These experts do much more than that, as they also help constitute extraction landscapes by pronouncing different representations of them to their employers, the miners, or the public in general (Richardson and Weskalnyz 2014). Scientists' and engineers' calls to attend or use their expertise when defining and

intervening the environmental health hazards posed by ASGM operations, shape and are shaped by the kinds of worlds in which we want ASGM to exist (*see* Bowker 1994). Experts' work is not monolithic and is fraught with internal conflicts. Even though the profession of engineering does have a history of reduced independence and close ties to corporate business (Layton 1971), the interests and values of experts do not necessarily match the ones of their employers and cannot be reduced to mere vessels of capital (Smith and Smith 2018, 72). In the same line, some work on STS has also highlighted alliances between technoscientific expertise and environmental justice movements (Fortun and Fortun 2005; Riley 2007; Cohen and Ottinger 2010; Kinchy 2019; Smith and Smith 2018 (Ottinger, Barandiarán, & Kimura, 2014)).

My work engages with these debates in two ways. Firstly, since most studies have focused on the role of experts in large-scale and formal operations of mining, oil, and fracking, I ~~will~~ shift the analytical and empirical focus to ASGM, a sector in which science and technology are often considered secondary due to the sector's marginality and its recurrent definition as 'low-tech' (ILO 2011; UNEP 2017). Despite the habit of thought that associates ASGM with the absence of technology skills and scientific literacy among miners, in practice, technology and knowledge do play key roles in the fortune of ASGM: different communities of experts (e.g. atmospheric chemists, mining engineers, geologists, and ecologists) frequently interact among themselves and with miners, engaging in varied types of relationships. Moreover, scientific knowledge is not the only relevant knowledge in mining. Miners' knowledge –both social and mineralogical– is often either dismissed as unscientific or non-credible or valued only in terms of its use for advancing corporate mining (Luning 2014), despite its importance to prospect deposits, exert territorial control, and develop mining technologies invisibilized by criminalization of the sector (Peluso 2018). Putting the spotlight on the role of scientists and engineers when studying the ASGM sector sheds light on a 'background infrastructure' (Star 1999) that so far has been largely overlooked in the extractive industries literature, but that is essential to keep gold supply chains running.

b. Numerical work, extraction, and pollution

A specific form of knowledge production and circulation I examine in one of my chapters is numerical work. In Chapter 5, I discuss what role do metrics, measurements, and numbers more broadly play in our understanding of a global environmental problem like mercury use in ASGM. Answering these questions entails widening the analytic focus for studying extractive industries towards the bureaucratic and technoscientific apparatus producing knowledge, doing technical interventions, and making the problem of mercury use in ASGM legible for local and global audiences. Studies of knowledge politics in extractive industries have focused on large companies' strategies of "corporate science" (Birkenholtz, 2018; Kinchy, Phadke, & Smith, 2018), but little has been written about the ASM sector, also known as non-corporate, informal, or illegal. Aside from being politically marginalized and legally and economically oppressed, by and large, the ASGM sector has been regarded as opaque and lacking data (Wade, 2013, p. 1448), a perception that has not shifted radically even in the last few decades when the sector has become more politically visible (Siegel, 2018) and has received more scholarly attention in the studies of extractive industries (Verbrugge & Geenen, 2020; Verbrugge & Geenen, 2019). And although there is a renewed interest in the governance of mining waste, most studies have

focused on corporate mining waste (Lepawsky, Liboiron, & Keeling, 2017; Ureta, 2016; Ureta & Flores, 2018). Against this backdrop, mercury use in ASGM has become a visible problem which is why, as I discuss in this chapter, a focus on the efforts to make it legible help better understand the co-production of epistemic and normative practices in the sector.

As I detail in the first section of Chapter 5, my analysis of the metrics, numbers, and narratives of environmental blame at stake in knowing about mercury use in ASGM is premised on two ideas about the relationship between science and politics in environmental matters that scholars in STS and political ecology have widely insisted on. The first is that science, far from being an apolitical or neutral representation of reality, reflects and, in turn, informs interests, values, and power relations (Ulrich Felt, Fouche, Miller, & Smith-Doerr, 2017). As constructivist STS scholars have shown, how the social and natural world is represented is intimately associated with how it is governed and intervened (Goldman, Nadasdy, & Turner 2014; Jasanoff 2004). Knowledge production about environmental problems influences and is influenced by political, social, and economic choices regarding the framing and responses to those problems (Jasanoff and Martello 2004; Jasanoff, Miller, & Mccarthy, 1998; Jabbour & Flachsland, 2017). The second is that since expertise is a highly politicized and contested phenomenon, we should be wary of the tempting assumption that what we need most is "better science" or less uncertainty to characterize better environmental problems, including those related to pollutants (Nash, 2008, p. 656). Instead, we should be attentive to how scientific knowledge often rests upon hidden, unchallenged, and problematic assumptions about people, landscapes, and their relations (Forsyth 2011). Such assumptions can, among other things, produce and circulate *narratives* or *storylines* in which ideas of blame, responsibility, and urgency become engrained (Forsyth 2011 in Death 2011).

A key component in the construction of narratives of blame and responsibility I want to focus on are metrics, measurements, and other practices of quantification that render environmental problems or conflicts (in this case, global mercury pollution) visible on the global stage. As has been widely discussed in historical and sociological accounts of numbers, the rise of infrastructures of calculation and measurement is a crucial trait of modern states, markets, and international organizations seeking to make populations and resources legible and governable (C. A. Miller, 2005; J. C. Scott, 1997), a process in which numbers, statistics, and measurements help stabilize ideals of objectivity and neutrality (Porter, 1995). Quantification is usually thought of as a disciplined discourse based on excluding judgment and subjectivity through numbers (Porter 1995). Numbers are thought to allow action at a distance, as they give the impression of allowing control of many settings at different times through quantitative inscriptions across networks (Robson 1992). Nevertheless, descriptive practices of classification, quantification, accounting, and representation are both performative and normative (Scott 1998; Anderson 1983; Peluso and Vandergeest 2011; Jasanoff and Martello 2004; Mahony 2014). Numbers are not only reflections of the phenomenon they help describe; they also contribute to establishing the object and what it is possible to count about it (Castillo 2017, 15). As Day et al. claim, numbers form "number ecologies" that involve participation and themselves participate in the composition of forms of social life" (Day, Lury, & Wakeford, 2014, p. 127).

Focusing on the metrics, measurements, and other inscription devices provides a window into the production of extractive landscapes and the social relations of toxicity that tend to

characterize them (Ureta 2021). My analysis denaturalizes the status of ASGM as the "world's largest mercury polluter" and problematizes the role of numbers and quantification in the configuration of the political economy of gold and mercury. Others have written about how toxic ecologies are known, governed, and normalized through toxicity thresholds, risk assessments, and environmental impact assessments (Murphy 2017; Barandiaran 2017; Bond 2022). Here I add to that literature by studying other devices like emission ratios, inventories, per capita emission rates, and more mundane forms of numeral work like percentages and rankings. The case of mercury use in ASGM illustrates how the numerical work of making global mercury emissions legible and actionable is co-produced with normative aspirations to control, formalize, and govern the sector altogether. Studying epistemic and numerical work in a sector typically considered illegible or characterized by 'data gaps' (World Bank 2019) helps denaturalize the politically and epistemically marginal status of the ASGM sector and extends the analytical focus toward silent but politically relevant forms of work like measuring or inventorying tons of toxic chemicals.

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In sum, these two bodies of literature – critical studies of toxicity and STS of the extractive sector are rich theoretical and methodological tools I draw on and that constitute the conceptual framework of my dissertation with which I interpret my empirics. While the dissertation as a whole draws on this general conceptual framework, each chapter privileges and expands some of these lines of analysis depending on the dimension of being addressed.

Outline of chapters

The dissertation proceeds in six chapters. Chapter 1 "***Mining and the chemosocial life of mercury***," which concludes with this outline of chapters, provided a contextualization of mercury use in ASGM and the mainstream approaches and explanations of its persistence (as discussed until now), described the research question and methods and situated the dissertation's conceptual and empirical contributions within specific bodies of literature.

Chapter 2, "***Toxic residues: Unearthing the colonial, corporate, and state traces of mercury in Latin America,***" discusses the current mercury boom in Central and South America that frames countries in the region as massive polluters or enablers of mercury contraband. Between the sixteenth and nineteenth centuries, toxic legacies left by the massive use of mercury in colonial silver mining accumulated; yet many contemporary scientists and UN officials have ignored this legacy in designing research and policy to understand and control contemporary mercury use. This chapter conceptualizes mercury as a colonial residue. This concept helps chart the substance's materiality and highlights the long-lasting legacies of its toxicity in the context of colonial, capitalist, and nation-state political economies in Latin America. Focusing on Colombia and Latin America, I first trace the massive use of mercury in colonial mining. I then examine the corporate use and state provision of mercury from the mid-nineteenth century to the present. Mercury use in Colombian gold mining illustrates that pollution and its residues are not just side effects of colonialism but also ongoing enactments of colonial relations. Though formal empire in

Colombia has ended, colonial relations continue to shape how the country participates in the UN-led efforts to improve ASGM.

Chapter 3 (***Mercury's toxic heritage and the itineraries of metallurgic expertise in the Americas*****)** counters common depictions of mercury amalgamation as a backward practice that ASGM has used since colonial times. The chapter reconstructs the itineraries of expertise of the mercury amalgamation technique – namely, the fluid practices of translation, adaptation, dismissal, and reuse of mining knowledge and technology on both sides of the Atlantic that shaped mercury amalgamation as we know it today.~~,~~ Euro-American networks of metallurgists, indigenous peoples, and mining engineers developed and encouraged mercury's use, making amalgamation a key component of empire, modernization, and state-building. I use the concept of toxic heritage to highlight how the international community committed to eliminating mercury use in gold mining in the name of global environmental health also lauds this technique when it is part of a universal patrimony of mining science and technology.

Chapter 4, "***Global toxics and global epistemic justice: the politics of knowing mercury as a global pollutant***," examines the politics of scientific practice in global mercury pollution between 2002 and 2019 and show that mercury's chemosocial life in the last two decades has been known through an epistemic apparatus characterized by acute disciplinary, geographic, and gender inequalities. Mercury science has worked to demonstrate environmental and health harms as global and to inform laws and policies. I demonstrate that knowledge production around mercury as a global pollutant is highly politicized and intimately entangled with the politics of scientific practice and its representation. I analyze UNEP's Global Mercury Assessment and the international network of mercury scientists since 1990. Based on my work with Amazonian indigenous peoples who live and work with mercury, I speculate on what an alternative framing of mercury as a global problem would look like if the inequalities discussed in this chapter were to be acknowledged, and if marginalized voices like miners, scientists, and indigenous peoples in mercury-emitting countries were included in the understanding of the problem.

Chapter 5, "***Inventories, spreadsheets, and the politics of environmental blame: Quantifying mercury use in artisanal gold mining***," dissects the numerical work required to make mercury use in ASGM legible both internationally and domestically. I critically analyze six devices of quantification (ratios of mercury use per gram of gold produced, inventories, pollution rankings, percentages, emissions per capita, and certified mercury-free gold) and argue that far from mere descriptions of a fixed reality, these devices have played an active part in the construction of the problem framing and are political processes in themselves. These quantification devices reflect and amplify representational injustices because they reinforce the framing of ASGM as the main culprit of global mercury emissions despite vast uncertainties and ignorance of past long-term uses of mercury. Not only are other mercury-emitting sectors reluctant to produce or disclose data that would nuance such a conclusion; a more fundamental politics of baselining through practices like inventories shapes what dimensions of the problem matter, to whom, and on what scales.

Chapter 6 (***Conclusions***) briefly recounts the work's conclusions, main contributions, and limitations, and outlines some possible research questions that could expand the present work in different directions.

CHAPTER 2. Toxic residues: Unearthing the colonial, corporate, and state traces of mercury in Latin America

Introduction

This chapter characterizes the materialities and temporalities of mercury in the context of mineral extraction in the Americas. Specifically, I discuss the situated practices of mercury production and trade during Spanish colonialism and the Colombian state's active support in supplying its mining sector with the substance in question. During Spanish colonial rule between the sixteenth and early nineteenth century, mercury was primarily produced in Europe, California, and Peru and used in silver and gold mining in Mexico and the Andes. This colonial mining left a massive toxic legacy that precedes current debates about mercury regulation but has received very little attention. While there is no certainty about the magnitude, spatial and ecological reach of colonial mercury use, there is consensus on the fact that toxic legacy boosted global anthropogenic mercury pollution significantly (Hylander & Meili, 2003; N. A. Robins, 2011). Also, once South American nations gained their independence in the 1820s, they actively promoted mining as an engine of development and modernity and, in doing so, enabled and promoted the import and use of mercury in gold mining. In the case of Colombia and Peru, state sanctioning and provision of mercury to small-scale miners continued until at least the 1960s.

A focus on these practices sheds light on the cumulative toxic legacies that precede current preoccupations with mercury as contraband and threshold transgressions, and that often go unnoticed in public debates on the topic. Thus, the chapter follows political ecologists' invitation to adopt more contextual perspectives in studying mercury use in artisanal gold mining and the contentious politics around the sector more broadly (Le Billon & Spiegel, 2022; Peluso, 2018; Vélez-Torres & Vanegas, 2022). A valuable concept for that purpose is Boudia et al.'s (2018) notion of *residue*, defined in Chapter 1 literature review. As described there, a residue is a theoretical and methodological tool to chart the chemical dispersions and transformations set in motion by industrial capitalism and as a multivalent conceptual device to theorize about the politics of toxicity and chemical environments. According to Boudia et al. (2018), residues are material objects that pile up over time in landscapes and bodies; they are chemically indestructible and leave harm and leftovers in their biogeochemical and economic transit. Moreover, they are slippery, unruly, and beyond the control of regulatory systems and technologies of control; they do political and economic work valued in different ways (Boudia et al., 2018).

This concept helps me foreground how the materialities of mercury have shaped and been shaped by circuits of power, international trade, and extraction along the lines of the residual materialities and temporalities of mercury, specifically in the Americas. In particular, the notion of residues helps me characterize mercury's materialities and highlight the long-lasting and vast legacies of mercury toxicity in the context of the political and economic structures of colonialism, capitalism, and state power. I develop said characterization through two sections that develop the two situated histories mentioned above: the massive use of mercury in colonial mining in the Americas and its continued use until the mid-twentieth century with active state and corporate involvement. Both stories support my main claim: though formal colonialism

finished long ago in Colombia, it continues to shape mining relations and policies. I conclude by highlighting that the case of mercury reaffirms that the persistent nature of mercury pollution and its residues are not just side effects of colonialism. Rather, they are enactments of ongoing colonial relations to land and people. Those relations, through which a socio-environmental order at one scale is sacrificed in the name of another, embody colonial and state-sanctioned toxic violence rather than being mere symptoms or side effects of them (Liboiron, 2021).

This claim interrogates and nuances current narratives about mercury as predominantly a problem created and enacted in Global South countries. Since the end of the twentieth century, we have witnessed a shift in the direction of global flows of mercury trade and emission, as well as in the sites of production – that is, cinnabar mining and processing. Over the past thirty years, OECD countries have produced and imported less mercury, whereas middle- and low-income countries, especially in Southeast and East Asia and Central and South America, have continued to import significant quantities despite bans and restrictions on mercury's international trade (UNEP 2017; Maxson et al. 2019). Countries with former mercury mines such as Spain, Kirghizstan, the US, or Germany have continued trading their available stocks extracted years before and shipping them to countries demanding mercury, mainly those with significant ASGM sectors. For instance, the Almaden mine in Spain closed in 2001 but kept producing mercury until 2003 and exporting it until the 2011 deadline set by the EU a decade before (MAYASA 2019). Even after the global restrictions on the mercury trade and the closure of the largest mercury mines, the mercury market is far from being dismantled – on the contrary, new centers of cinnabar extraction have emerged in countries such as Mexico and Indonesia. Cinnabar mining and the resulting mercury exports from these countries have continued to feed the demand for quicksilver in ASGM in Latin America and South-East Asia (UNEP 2017; Maxson 2019).

Indeed, on top of Mexico emerging as a new mercury exporter, other Latin American countries have become key actors in the international mercury trade – both legal and illegal. As discussed in Chapter 1, the scandalous and unprecedented levels of vaporized mercury in places such as Segovia and Remedios in Antioquia, Colombia (Bernal-Guzmán, 2018) and the thousands of deforested hectares and patches of toxic ponds straddling the rainforest in Madre de Dios in the Peruvian Amazon (Diaz, 2021), have been focused on by international mercury governance. This has been possible in part because mercury imports to Colombia and Peru between 2008 and 2015 were high relative to the regional totals. Moreover, Bolivia has also taken on a central role as a critical node in the regional redistribution of the illegal mercury trade. Sudden and unusual decreases and increases in Bolivia's mercury import records in the last decade (Gonzalez 2018), together with various records of police seizures of mercury on the border with Peru, suggest that Bolivia is an important route for the illegal mercury trade in Latin America, as has been documented by various journalists and activists (BBC 2020; InfoAmazonia 2022).[18] Even the UN Special Rapporteur on toxics and human rights, Marcos Orellana, called

[18] A 2021 Vice News online documentary depicted the reality of illegal mercury trade in South America, or as the film title called it, "The Most Dangerous Black Market You've Never Heard Of" (Vice News 2021). Undercover journalist follow the trace of illegal mercury trade in across Georgetown, Mahdia, and other parts of Guyana. The team follows a groups of quicksilver smugglers crossing the Guyana-Surinam river border in a small motorboat. Following the trail of mercury and gold, the journalists visit Brumswick and Paramaribo where the gold is sent to Switzerland and the Middle East. See also InterPress Service (2014, Apr 7), "El mercurio sigue suelto en América Latina";

out the Bolivian government in a country visit and report in 2021 for not acting on the illegal trade of mercury (Orellana 2021). In addition to Bolivia, Colombia has continued to receive significant amounts of mercury in the last few years (García *et al.*, 2017: 41) (see Image 4 below).

A visualization done by Davis (2018) from UNEP, comparing the most significant flows of international mercury trade, illustrates the declining flows of mercury exports from Europe and the massive increase of exports coming out of Mexico in the decade before 2015:

Image 3. Five largest mercury imports in 2008 (image centering the largest)



In 2008, UK, Poland, Kyrghistan, and Peru were the largest exporters of mercury.

Image 4. Five largest mercury imports in 2015 (image centering the largest)



In 2015, mercury flows from and to Europe decreased notably, and Mexico, Indonesia, and Japan emerged as the new largest producers and exporters.

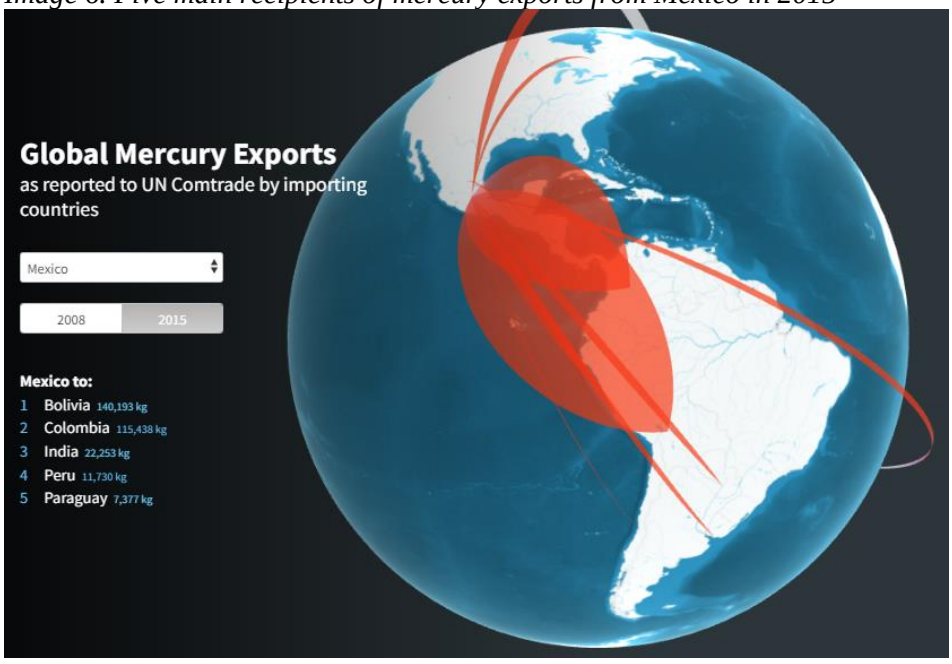
In turn, Bolivia and Colombia became the two leading importers of mercury.

Image 5. Five main recipients of mercury exports from Mexico in 2008



In 2008, Mexico had a modest share of mercury exports, which went primarily to Peru, Colombia, Argentina, and Brazil.

Image 6. Five main recipients of mercury exports from Mexico in 2015



In 2015, Mexico consolidated its role as a regional provider of mercury by spectacularly increasing its exports to South America.

Images by Davis (2018).

These two framings of the mercury problem in South American ASGM sites, as toxic landscapes that need interventions and as critical nodes in international mercury circulation in legal and illegal markets, have gained traction in the last few years (Clifford, 2014; Garcia, 2017). Nevertheless, as I pointed out in Chapter 1, the bundle of relations in which mercury has been involved traces back to long before the last two decades and extends beyond transnational

networks of smugglers or corrupt customs personnel. Mercury, as all residues, cannot escape its history and is a clue for reconstructing chemosocial pasts (Boudia et al. 2018, 168).

In this chapter, I demonstrate how framing the problem of mercury pollution as exclusively or predominantly associated with "illegal" gold mining or illegal mercury trade belies how such a problem has been part of a larger and centuries-long infrastructure of extraction with irreversible legacies that have not been sufficiently acknowledged or discussed. The leadership of Global South mercury producers and the ASGM sector's rising demand for mercury are quite recent phenomena and did not occur in a vacuum. Before ASGM became the largest buyer and user of mercury in the region, the substance had already been used in mining for more than three centuries and reportedly continued to be imported and authorized by South American states interested in integrating to international markets through mineral exports.

I. Amalgamating empire: material and irreversible mercury use in silver colonial mining

The "origin story" of the problem of mercury as a global pollutant is usually traced back to the disaster at the Minamata Bay in Japan in the 1950s or the findings of mercury's presence in the Arctic (see Chapter 4). In both cases, the narrative of mercury as an unruly, “out-of-place” molecule is at the heart of the understanding of its impacts. However, mercury's chemosocial life dates further back, has had a profound impact beyond these two sites, and is also profoundly entrenched in other histories of extraction. One that I highlight here is the history of mercury as a toxic produced by and entrenched in colonialism and capitalism. As a critical component of the extractive circuits of colonial extraction (c.f Arboleda, 2020), mercury helped produce *and* circulate value from silver extraction. In doing so, it sustained the empires’ political and economic power while leaving a global environmental impact that both environmental chemists and environmental historians agree has been under-examined (Guerrero, 2017a; N. A. Robins, 2011). In this section, I illustrate mercury's irreversibility, slipperiness, and unruliness through an analysis of the substance's itineraries across the Atlantic, connecting situated histories of mercury and silver mining and trade in Spain and the Americas.

1. A one way trip? Material and irreversible burdens

For approximately three centuries, the Spanish Empire used mercury to process silver in the Viceroyalties of Peru and New Spain (present-day Peru, Bolivia, and Mexico). Between the mid-sixteenth century and the second quarter of the nineteenth centuries, silver and gold mining were foundations of these Viceroyalties’ economies and one of the main sources of income for the Spanish Crown (Brown, 2012b). Central to this enterprise was Spain's mercury mine, Almadén (meaning "the metal" in Arabic), first brought into production during the Roman Empire. Spanish ships would sail more than 9000 km to the Americas carrying mercury from Almadén and return to Spain loaded with processed silver and gold (Johnston 2013). Not all shipments would make it across the ocean, however. Until very recently, some flasks containing mercury from Almaden were still appearing in Spanish shipwrecks such as the *Galeón Nuestra Señora de Guadalupe* found in Dominican waters in 1973 (Petersen, 1979: 851). After the

finding, a collaboration between Dominican and Spanish scientists recovered over 20,000 flasks lying on the Caribbean seabed (Villa, 2014).



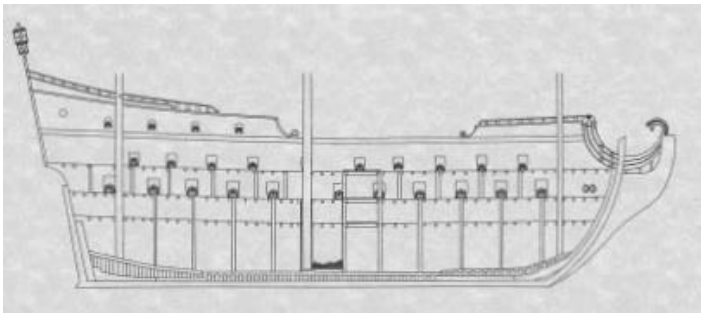


Photo 5 (left). Mercury flasks from Almadén recovered in 1975 from the Galeón Nuestra Señora de Guadalupe shipwreck in Punta Jayan, Dominican Republic waters. Source: Petersen (1979).
Image 3 (right). Reconstruction of the Galeón Nuestra Señora de Guadalupe ship profile carrying mercury flasks. Source: Villa (2014).

It is estimated that between 1499 and 1937, the Spanish crown exploited over 5,985,495 flasks of mercury (about 206,396 metric tons) from the Almaden mine (Almadén Mercury Museum 1937/2019). The chart at Almaden's Mercury Museum shown below (Photo 3) eloquently expresses the uninterrupted and massive production of quicksilver during that time. This cargo shipped to colonial America's mining centers (such as Zacatecas and Potosi) and helped produce at least 136,000 tons of silver, or ~eighty per cent of global silver production in the Americas between 1550 and 1800.[19] The discovery of a cinnabar deposit called Huancavelica in the Peruvian Andes in 1571 expanded the sources of mercury supply. Between 1571 and 1820, Huancavelica produced an estimated 68,000 metric tons of mercury (Robins & Hagan, 2012), about a third of Almaden's output between 1499 and 1937. Until the 1840s, Huancavelica's mercury helped sustain the extraction of silver and gold in Potosí and other mining sites in the Americas (Contreras 1999). Together, Almaden and Huancavelica supplied the extractive enterprise during the colonial period and later.

[19]In 1927, Almadén also became the site for the unique commercial measurement for quicksilver: the "flask" (Meyers, 1951). "The flask itself is made of welded steel, has a screw cap, and is about the size of a 2-L container. When filled, the flask weighs 34.5 kg, and 29 flasks of mercury are contained in a metric ton" (Brooks 2012).



Photo 6. Mercury production in Almadén mines in tons per year (1499-1937). S. Rubiano (2019)

Despite mercury production decreasing substantially in the past century, the question of how much mercury was emitted by the colonial and corporate extractive infrastructures during the past three centuries helps nuance de-historicized and de-politicized framings of the mercury problem and situate it in a larger historical perspective attentive to its materiality. Although sometimes mercury appears as immaterial or invisible, it is a *material object* the residues of which pile up over time in landscapes, bodies, and animals, distributing harm and fortune unevenly among them. Between 1580 and 1820, during the Spanish rule, the calculated consumption and loss of mercury varied from 292 to 1085 tons/year, with the average being 527 tons/year. Plus, for 330 years, from 1570 to 1900, when the early version of the amalgamation method was in everyday use, the discharge of mercury from silver mining in South and Central America averaged 612 tons/year, and it totaled 196,000 tons (Nriagu 1994). Other sources estimate mercury emissions of 220 tons/year for the 1821-1900 period (Strode, Jaeglé, & Selin, 2009).

Also, given that until the nineteenth century, the general assumption in mining and metallurgic practice was that larger mercury quantities equated to more gold production, comparing historical and current measurements could be misleading (N. Robins & Hagan, 2020). Despite this, partial records, estimates, and models exist, and some researchers claim that the contribution of the massive output of silver to global mercury pollution during colonial times is "impressive" and "unprecedented" (Nriagu, 1994). Based on figures for annual silver and gold production, as well as on records of mercury production from the Almadén, Idrija, Huancavelica, New Almadén, and Zacatecas mercury mines, it is estimated that between 1580 and 1900, the cumulative atmospheric emissions of mercury vapors and releases to land and water due to the extraction of precious metals in the Americas totaled 257,400 tons, with 196,000 tons dispersed in South and Central America and 61,380 tons in the US. Approximately sixty per cent of the mercury used in colonial extraction was released into the atmosphere, demonstrating that historical mines were sources of much of today's mercury pollution, because mercury in any of its forms cannot be permanently destroyed (Nriagu, 1994).

Before the colonial powers arrived in the Americas, various indigenous peoples between Alta California and the Inca Empire used cinnabar for ritual and economic purposes, and some of

them in the Andes had smelted non-ferrous ores for centuries (Falchetti 2013). While geochemical studies of lake sediments and archeological evidence show that precolonial smelting of Andean silver ores generated mercury emissions as early as the twelfth century (Cooke, Abbott, & Wolfe, 2008), the magnitude of such emissions seems to be much less than that of colonial silver and gold extraction - though there is still discussion among atmospheric chemists as to how much less. While it is difficult to accurately tell if the toxic legacies of colonial mercury use were more significant than contemporary ASGM's contribution since the late twentieth century, they were vast and were sustained over longer times than any other mining rush in history leaving an irreversible residual mark. As a point of reference, the emissions coming out of the Brazilian Amazon associated with the gold rush in that country in the 1990s were reported to be 90-120 tons/year for about four or five years (Lacerda and Salomons, 1991; Nriagu et al., 1992). Colombia and Bolivia were reported to have emitted between 50 and 180 tons/year a few years ago (UNIDO 2013), and the ASGM sector in all the world is believed to discharge and emit around 1300 tons/year (UNEP 2018).

Global flows of mercury shifted radically in the nineteenth century, shortly before the decline of silver mining and the rise of gold mining. The mining rushes in California, Australia, and South Africa in the 1850s marked the beginning of "(…) a Pacific, and even a global era in mining history" (Lane 2011), as well as a transition to gold as the precious primary metal in the global economy. In the late nineteenth century, the world was transitioning from the silver standard to the gold standard due to changes in silver availability, financial speculation, and the progressive dismissal of bi-metallism in favor of mono-metallism (Polanyi 1944: 31).[20] Since the most accessible placer gold deposits were quickly depleted, the global expansion of gold mining during the mid-nineteenth century required accessing vein deposits, which required that the ores be processed with mercury, as silver had been in the previous centuries. Therefore, a convenient, affordable supply of mercury was needed in the Americas' mining centers. The discovery of a cinnabar deposit in the Santa Clara Valley in Alta California (today's Santa Clara county) in 1820 contributed to that purpose in North America (NPS, 2011). Although native Ohlones had used cinnabar to produce vermillion paint for spiritual uses and trade, it was not until 1846 that settlers, and later an English firm called Barron, Forbes & Co., named the site *New Almaden* and started to extract the cinnabar commercially to produce mercury. This quicksilver supply sustained the California and Nevada gold and silver mining industries for 75 years (Rickard, 1995).[21]

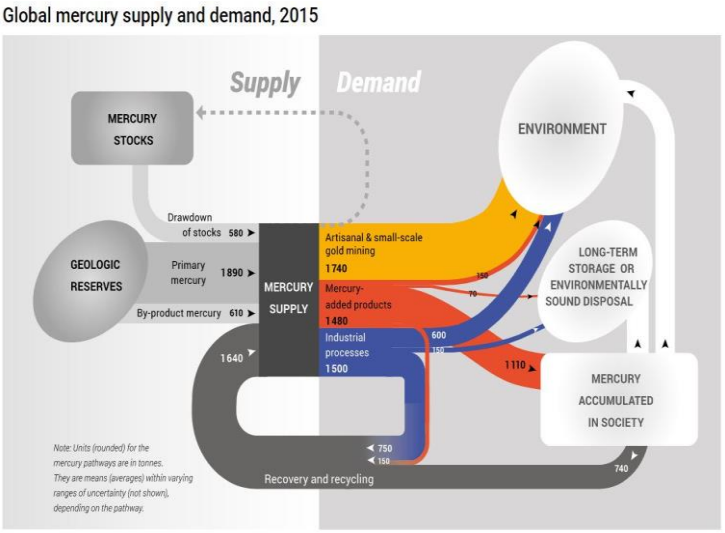
The diverse origins of the mining workforce reflected the global reach of the gold rushes: Cornish, Mexican, Chilean, and Chinese laborers worked in the New Almaden mine between the 1840s and the 1940s and produced over 76 million pounds of quicksilver (NPS, 2013). For around a decade and almost until the mid-1850s, California mercury production surpassed the supplies from Almaden and Huancavelica (López-Morell & O'kean, 2014). During that decade, an unknown quantity of quicksilver was shipped from California to Central and South America[22],

[20] The British West Indies first adopted the gold standard in the eighteenth century, followed by Canada (1854), the US and Germany (1873), and the rest of the world. The last country to abandon the silver standard was China (1935).
[21] After various transfers of share and ownership disputes, a company called the Quicksilver Mining Company assumed control of the mine in 1863 until its bankruptcy in 1912
[22] Personal communication with the New Almadén Museum Archive archivist, Santa Clara County, CA. September 24th, 2021.

an endeavor that motivated some wealthy US mining engineers to promote gold mining investment in places such as Venezuela and Colombia (Rickard, 1995). The rising importance and price of Californian mercury aggravated the crisis of the Huancavelica mine in Peru at the end of the nineteenth century, which was incapable of competing with the lower price of New Almaden's mercury (Robins 2021). At the beginning of the twentieth century, mercury production in Almaden, Huancavelica, and New Almaden began a slow recession, marking the beginning of its drastic decrease as a source for mining.[23]

During the first half of the twentieth century, mercury did not have the prominence it acquired in the following decades (Egan, 2019). It was not until the seventies and the eighties, that the substance gained public notoriety in countries such as the US, where mercury-emitting coal-fired power plants were becoming part of discussions on the EPA's authority and the Clean Air Act. In 2017, in response to the surge in the illegal mercury trade, UNEP published a report on the shifting flows of mercury supply, trade, and use. The report was based mainly on the UN COMTRADE database. It included a thorough description of how mercury trade trends had changed in the last decade and how the decline of historic cinnabar mining sites such as Almaden, New Almaden, Idrija, and Huancavelica had been replaced by new cinnabar mining in countries such as China, Indonesia, and Mexico (UNEP, 2017a). The report synthesized the flows of mercury supply and demand, illustrated in the diagram shown below, as of 2015. While this diagram effectively conveys the current state of mercury supply and demand, it fails to illustrate the changes in amounts and contexts. Most of the mercury stocks, as well as the mercury supplied to sustain silver and gold mining in the previous four centuries, had been a material basis of colonial domination in the Americas and a catalyzer of the global economy in times when silver, the then-global currency, depended entirely on the availability of mercury to process it (Saul Guerrero, 2017b).

Image 8. Flow chart of global mercury supply and demand, 2015



[23] In 1976, Santa Clara County purchased the historic New Almaden quicksilver mine and crated a county park on the site, after a thorough examination of the property and some restoration efforts. Similarly to Almaden's Mercury Museum in Spain, the New Almaden Museum in San Jose includes an exhibit on the history of cinnabar mining, but unlike their counterparts in

Source: UNEP (2017)

After sustaining the world economy for two centuries and enabling the emergence of Spain as a global power in the sixteenth century (Robins, 2011, p. 8), the human and environmental tolls of mercury and silver mining remain today, both locally and globally (Robins, 2011). Mercury cannot be eliminated, biodegraded, or metabolized due to its persistent nature and global reach (Fino et al., 2013). Due to mercury's persistent nature (i.e., it cannot be destroyed or eliminated), historical mercury emissions from pre-industrial times, including Spanish colonial-era mining, have been and will perpetually keep circulating through bodies and landscapes around the globe (H. Selin & Selin, 2020), although the historical period is not explicitly recognized as a source of contemporary mercury pollution. According to Nriagu, "it is really surprising that little has been done to study the persistence of mercury in these chemical time bombs, the environmental impacts, and long-term dispersal of the huge mercury reservoirs in some of the old mining centers" (1994: 12). Only about one-third of the current global mercury stocks consist of new emissions, whereas two-thirds consist of re-emissions (Song et al., 2015). While a lot of the mercury emitted extracted and used during Spanish colonial mining remains in the Caribbean seabed and South American soils and waterways, most has been deposited in the oceans (N. Robins & Hagan, 2020).

The geological, atmospheric, and oceanic life of elemental mercury is perpetual and irreversible. When one considers some of the most acute health effects of methylmercury exposure in humans (such as the incurable Minamata disease), such irreversibility becomes even more explicit.[24] Mercury is irreversible not only because of its indestructible molecular nature but also because of the politics of production and regulation that limit and delay dealing with cleaning up the leftovers. The Minamata Convention does not address historical mercury legacies. This is not an issue that the negotiating parties were willing to discuss at the international level Although the Convention adopts a "life cycle approach," consisting of regulating mercury production, trade, use, managing, and storing, the treaty is focused on goals and timelines in the future for all mercury-emitting or mercury-using industries and sectors and ignores mercury's history—even though its past is still a part of the present. Moreover, as seen in Table 1, mercury mining is still allowed in existing mines under certain conditions, and the world will not see a full stop of production before 2032.

Table 1. UN Minamata Convention main goals and timelines

UN Environment Governing Council agrees to begin negotiations on a legally binding agreement on mercury	2009
Minamata Convention adopted and opened for signature	2013
Entry into force of the Minamata Convention	2017
COP1 - First Conference of Parties (Geneva)	2017
Prohibition of new mercury mining	Upon entry into force for a Party
Phase-out of mercury use in acetaldehyde production	2018 (extension up to 10 years possible in some cases)

[24] Methylmercury is the organic form of mercury that reaches humans through fish consumption and the substance's bioaccumulation in trophic chains. I don't address in depth the well-known impacts of mercury on health. See, among many others, (Steckling et al., 2017).

COP2 - Second Conference of Parties (Geneva)	2018
COP3 - Third Conference of Parties (Geneva)	2019
Deadline to reduce mercury use in VCM production by fifty per cent (2010 baseline)	2020
Phase-out of mercury use in mercury-added products listed in Annex A	2020 (extension up to 10 years
Deadline for submitting ASGM National Action Plans to the Secretariat	**3 years after entry into force for Party (e.g. earliest 2020), or 3 years after notifying the Secretariat that ASGM activity is more than insignificant, whichever is later**
COP 4 - Fourth Conference of Parties (Bali)	2021-2022
Deadline for Parties to require use of Best Available Techniques and Best Environmental Practices for new sources from emissions categories listed in Annex D	5 years after entry into force for a Party (e.g. earliest 2022)
Start date for the COP to begin first effectiveness evaluations	No later than 2023
Phase-out of mercury use in chlor-alkali production	2025 (extension up to 10 years possible in some cases)
Deadline for Parties to require use of ELV, BAT, BEP or alternative measures for existing sources from emissions categories listed in Annex D	10 years after entry into force for a Party (e.g. earliest 2027)
Phase-out of existing primary mercury mining	15 years after entry into force for a party (e.g. earliest 2032)

Source: ICMGP 2017 (modified by author for this dissertation)

The resistance of various economic sectors to agree on sudden transitions and the need to find affordable substitutes for mercury in various products and processes is, of course, at the heart of setting this set of goals and timelines in a progressive manner (H. Selin, 2014a). But from the perspective of mercury's materialities and residues, it can also be read as an acknowledgment of the substance's profound entrenchment in multiple infrastructures of production beyond the mining sector in which "making mercury history" (UNEP 2017) is a long and costly process that confronts society with the question of how to do a just transition but also what landscapes and bodies will carry the burden of dealing with the toxic remnants of mercury and pay for the costs of doing so. Anthropogenic sources of mercury have surpassed natural emissions (from volcanoes, for instance) by a factor of three, and even if we cut all new mercury emissions tomorrow, the already emitted quantities will continue to circulate in global ecologies for centuries more (Noelle E. Selin, 2009).

2. The slippery and unruly webs of toxicity

Toxic chemicals that circulate through ecologies and bodies are textbook examples of environmental problems that trigger regional or global responses, given that they cannot be controlled by states individually, as with other chemosocial problems such as acid rain pollution in industrial Europe (Chasek & Downie, 2021). Such global problems speak to the slippery and unruly nature of mercury and other persistent chemicals as colonial and capitalist residues (Boudia et al. 2018). They cannot be contained within borders, landscapes, industrial sites, or bodies. They are the indelible mark of the permanently polluted world in which exposure to toxicity is irresistible (Liboiron et al., 2018).

Mercury's capacity to move back and forth between landscapes and bodies through atmospheric and oceanic currents and trophic chains (in the latter case, methylmercury) illustrates its slippery and unpredictable nature. Diaz's (2021) study of mercury bioaccumulation and biomagnification in the Peruvian Amazon illustrates this point.[25] Her study of mercury concentrations in mining pits in Madre de Dios found that mercury does not just remain inside a mining pit, it moves from body to body within the pits as predators consume prey. Mining pits export mercury in the bodies of insects and arachnids. Spiders that colonize the vegetation on the riparian edges of mining pits consume adult insects emerging from the ponds, thus transferring mercury from aquatic to terrestrial ecosystems (Diaz et al., 2021). She found that mercury carried in the bodies of these insects can then accumulate and concentrate up the food web into larger predators such as birds and bats whose movements across larger areas further extend the footprint of mercury pollution. In the same line, other studies have documented the far reach of migratory fish species in the Amazon, which can travel greater than 5000 km in their lifetimes to spawn in the major tributaries of the Amazon (Salinas, Cubillos, Gómez, Trujillo, & Caballero, 2014), thus expanding the availability of mercury toxicity in their bodies to landscapes and communities in a greater area. These food web interactions are one way that mercury is mobilized, carried and magnified in concentration in wildlife as they move through Amazonian ecosystems, irrespective of the territorial boundaries of protected areas or titled mining concessions (Diaz 2021).

A final point to highlight about mercury's materialities and residual character is the political and economic work the substance does in specific historical moments and through specific narratives and imaginaries. One example mentioned in Chapter 1 is the declaration of the Almaden mine in Spain as a UNESCO world heritage site, which instantiates what Kryder-Reid and May (2021) call toxic heritage. As I described in the opening vignette in Chapter 1, the declaration of this as a world heritage site celebrates cinnabar mining, mercury processing and its associated knowledges as knowledge and technologies with universal value that fostered exchanges between Europe and the Americas. Nowhere in UNESCO's document about the site's recognition (UNESCO 2013) or the process that led to it (Rojas Avalos 2011) are mentions of mercury's work in sustaining Spanish colonialism, nor of the ecological and human harms caused by its extraction, transport, and use, much less the economic exploitation of the lands in the colonial peripheries or the perpetual and inter-generational legacies of having emitted more than 200,000 tons of mercury to the atmosphere.

Therefore, the declaration of the Almaden mine in Spain declared by UNESCO as a world heritage site has done political work that glorifies it, despite the site's toxic heritage (Kryder-Reid and May 2020). As stated in Chapter 1, the concept of toxic heritage puts a positive spin on the ways toxic sites are remembered by communities and in official heritage narratives such as museums, historic markers, or sites under the UNESCO Convention

[25] Bioaccumulation is the progressive accumulation of a contaminant in an organism by ingesting food or absorption through cell membranes. Biomagnification happens with the concentration of contaminants increases in food webs, from lower to high trophic levels (Scarlat, 2013). After mercury has been dumped directly into a water source, it can adhere to sediment particles in the water and be transported dozens and even hundreds of kilometres down river. Vegetation and soils causes the methylation of inorganic mercury and converts it into methylmercury, the organic and most toxic form of the element. Once it has methylated, mercury bioaccumulates in living organisms and then biomagnifies over time as it circulates through greater levels of the trophic chain, causing its toxicity to increase up to ten times more (Pouilly *et al*., 2013; EPA 2007).

Concerning the Protection of the World Cultural and Natural Heritage (Kryder-Reid and May 2020). At the same time, the same practices and activities associated with cinnabar mining in the present are decried, demonized, and criminalized.

II. Corporate toxic residues and state-sanctioned toxicity

Mercury's chemosocial life has been part of large private and state-owned concessions in Northeastern Antioquia since the early nineteenth century. This section reconstructs the situated history of how the Colombian state granted a perpetual mining concession to American and British capitalists in 1853, who imported mercury for their gold operations with the state's acquiescence for more than 120 years. A century later, in the 1950s, the Colombian state provided mercury to gold mining operations as part of rural technical assistance programs, before shifting completely towards a neoliberal mining policy in which corporate concessions supersede any other claims and the toxic legacies of the past cede before a presentist, ahistoriziced alarmism about mercury use and small-scale mining.

If silver was the pillar of colonial extraction in New Spain and Peru, gold was the primary resource extracted by the Spanish empire in the former viceroyalty of New Granada (today, Colombia) (Orche & Puche, 2000). The Northern Andes in Colombia, along with northern Peru and northern Chile, have historically been some of the major gold producing regions in South America. Various Pre-Columbian cultures like the Tayrona, Quimbaya, Muisca, and Tierradentro developed extraction and metallurgic techniques to work with gold and copper alloys.[26] From the sixteenth century onwards, the Europeans' rush for gold quickly depleted the most accessible alluvial deposits and river terraces and subjugated the native populations through forced labor and disease. The Spanish's response to the declining labor was the Trans-Atlantic slave trade, which ran until slavery's abolition in 1851. Colonial extraction focused in the Pacific lowlands of Choco and Antioquia, where enslaved Africans and freed cimarron (maroon) turned into a rainforest peasantry that independently mined gold (Leal, 2004, 2018).

Unlike New Spain and Peru, mercury was not used in silver or gold mining in New Granada (modern Colombia since 1810) until the late nineteenth century. Until the early nineteenth century, gold mining in the then-Viceroyalty of New Granada had been mostly alluvial, manual, or artisanal, and mainly done initially by indigenous people (since centuries before Spanish colonization), and then by *mestizos*, enslaved black people brought from Africa by the Spanish when native labor decreased, and freed slaves that continued mining gold independently from the companies' operations (called *mazamorreros* or *barequeros*) (Poveda 1981; Leal 2018). In 1805, eighty-five per cent of the gold was produced by *mazamorreros* exploiting alluvial gold (Poveda 1985). But this workforce could not access vein deposits; several European scientific authorities of the time –including Alexander von Humboldt, Jose Celestino Mutis, Jéan-Francois Boussingault and Ángel Díaz– wrote that mining technology was urgently needed and complained about the "backwardness" of mining extraction in New Granada (Hernandez & Espinosa, 1991).

[26] The Spanish plundered most of the metalwork pieces, but some of them remains exhibited in Bogota's *Museo del Oro*. For an analysis of how the ambiguity of the Museum's collections as constitutive of Colombian cultural patrimony and national identity vis-à-vis indigenous peoples histories of dispossession, see (Gonzalez-Galvis, 2009).

After sustaining the empire for two centuries, vein and alluvial gold deposits in New Granada eventually became the basis to thwart colonial domain, but not wholly - the end of Spanish colonialism eroded but did not break with colonial structures in Colombia and elsewhere in the Americas. During the nineteenth century and after the independence wars, there were two waves of changes that illustrate it (Brown, 2012). The first wave occurred in the 1820s with British and French companies who invested in Colombia, Peru, Chile, Brazil, Mexico, and other recently independent South American countries—some of those investments were mining concessions granted in exchange for these empires' support against the Spanish in the independence wars (Brown, 2012b).[27] These investors were forced to deal with the lack of infrastructure, fuel sources, and skilled labor, which slowed mining mechanization, but then expanded and increased production and managed to (re)connect Latin American mining to global markets (Botero, 2002). The other wave took place during the second half of the century and entailed four fundamental sociotechnical changes: the transition from the production of precious metals to industrial minerals; the gradual replacement of animal power with steam; the construction of the railroad, which allowed the entry of new producers; and the replacement of the old refining process based on mercury (mainly Medina's and Barba's variations) by separation using floating and cyanide.

The mining companies that got the colonial titles dominated mining extraction in Colombia between 1850 and 1972, and during that period, they also catalyzed the circulation of mining knowledge, technology, and capital (Brew, 1977). One of the epicenters of gold extraction and mining knowledge and technology has been the region of Antioquia, which has produced half of the country's gold since the 1800s (Poveda, 2005). At the beginning of the nineteenth century, in Antioquia, most gold extraction was not done by enslaved workers, as in Cauca in the Southern Colombian Andes (Leal 2019), but by families or small mining companies that accumulated enough capital to create economic and business entities or to acquire and expand smaller ventures (Botero, 2002). Following the dominance of independent mining during colonial rule, in the mid-nineteenth century, larger companies began to increase the scale and productivity through the incorporation of organizational models and systems and more efficient exploitation (L. F. Molina, 2002). Some of the most prominent national companies in the country in the nineteenth century emerged from that process. In 1848, José Maria Uribe Restrepo (1790-1854), a wealthy merchant, miner, and conservative politician formed the *Sociedad de Zancudo,* a company to work gold vein and alluvial mining operations in Titiribi close to Medellin. The two most essential mines were El Zancudo and Los Chorros, exploited since the eighteenth century. In a short time, a corporation that had been losing money for many years made profits after Uribe and his partners took control of the extraction process and increased the number of rammer and drag mills to crush ore. A few years later, in 1855, the Compañía Minera de Antioquia, was established with Colombian capital (L. F. Molina, 2002).

Although national companies were emerging in the decades after the independence (1820-1860), foreign companies dominated the mining industry in Antioquia for more than a century. In the nineteenth century, Colombia entered the international capitalist system mainly through mineral, agricultural, and manufacturing exports, an articulation made possible by the ties with

[27] Humboldt played a role in this, as he promoted European and American investment in the extractive sector in South America, which he considered as "backwards and inefficient" (Humboldt 1802).

the industrializing nations of the North Atlantic. In the process, mineral exports exploited by mining foreign companies and investors in Antioquia were critical (Ocampo 1978). A critical role these companies had was catalyzing the circulation of mining technical expertise from North America and Europe where the profession of mining engineering was booming (Murray 1997). The growth of the mining education centers in the US during the nineteenth century provided a workforce of mining engineers to send around the globe (including Colombia, Venezuela, and Chile) (Spence, 1993). The discovery of gold deposits in the US, Australia, New Zealand, South Africa, and South America in the mid-nineteenth century increased the migration of European and US miners and mining engineers to these areas, many of which hired by mining companies like the ones operating in Antioquia, namely, British company *Frontino Gold Mines* and French company *Compania Francesa de Segovia* (Herrera 2015).

The role of companies of British, French, and American capital in Colombia and other South American countries (Brown, 2012b)is a point widely discussed in the country's and the region's mining historiography (Brown, 2012b; Poveda Ramos, 1987; Vargas Pimiento, 2012a).[28] In Colombia, studies have also documented how the goal to attract foreign capital and mining technology were also driven by the local elites' interest in propelling the local economies by using mining rents to recuperate after very costly independence wars (Safford, 1976), a task that entailed exploiting low-grade deposits that were previously unknown or inaccessible. However, the sources and archives I consulted on the issue were silent on a crucial question: how did mercury keep flowing into the Americas once the Spanish Dominion was toppled? Various works have addressed the question for New Spain (Saul Guerrero, 2015, 2017c; Saúl Guerrero, 2016) and Peru (N. Robins, 2011; N. Robins & Hagan, 2012), but the issue remains understudied in mining historiography and environmental chemistry in Colombia.

In an attempt to reconstruct the situated history of continued mercury use in Colombia between the turn of the nineteenth century and onwards, I found that the archival information does not offer a conclusive answer, suggesting that more research is needed. I searched the literature on mining history in Colombia and Latin America, investigating this question, and visited the archives of the New Almaden Mercury Museum in San Jose and the Universidad Nacional de Colombia in Medellin. The results were limited. Aside from abundant stories of heroic engineers who invented or imported various kinds of mining technologies, including mills, hammers, explosives, monitors, and manual instruments, among many others (Poveda Ramos, 1993; Vargas Pimiento, 2012b), or very technically oriented and detailed discussions of the technologies themselves (Eafit 2007), I did not succeed in finding studies or records on how mercury imports continued during the second part of the nineteenth century and the first half of the twentieth century.

In the absence of academic sources, I consulted official import records. Colombia's official import statistics reveal that between 1870 and 1905, the country's mercury imports averaged 2.75 tonnes per year, with a peak of 10 tonnes in 1875. It came *exclusively* from the US, France, and Great Britain, as detailed in the imports records from the Ministry of Trade

[28] In Chapter 3, I discuss how the American, British, and French mining engineers and chemists brought by these companies during the second half of the nineteenth century were instrumental in transforming mining extraction in the mountains of Antioquia, as well as in other areas of the countries, by spreading the mercury amalgamation technique and other mining and metallurgic technologies that had not been used in the country until then.

(Anuario Estadistico 1875-1931). As mentioned above, these were the same home countries of the mining corporations with mining concessions in Antioquia. Most mercury is reported to have entered the country through the Caribbean ports of Barranquilla and Cartagena. At the same time, a lesser quantity was registered in the ports of Tumaco and Buenaventura on the Southern Pacific Coast, most likely coming from the New Almaden mines in Northern California. In 1905, two-thirds of the exports came from Great Britain. Given that Nathan Mayer Rothschild & Sons of London had the monopoly over the Almaden mines until 1921 (López-Morell & O'kean, 2014; UCL, 2013), it is safe to assume that the mercury coming from Great Britain was extracted in Almaden, Spain.[29]

Foreign mining companies played a prominent role in stimulating mining extraction and in promoting the introduction of techniques such as mercury amalgamation between the 1820s and the 1890s; these became symbols of the long-needed modernization of the mining sector (Espinosa, 1984; Rivero & Boussingault, 1823). It is safe to assume that much, if not all, the mercury imported to Colombia between the mid-nineteenth century and the first decades of the twentieth century was imported by foreign mining companies. Therefore, on top of the toxic legacies left by the Spanish empire mining in Mexico, Peru, and Bolivia, foreign mining companies who exploited gold in Colombia between 1953 and 1973 added another layer of toxicity. Their impact extended to the rest of the region, given the wide spatial reach of both mercury vapors and methylmercury in river ecosystems. Even if there is uncertainty about the quantities, the foreign companies' role in importing and demanding mercury connects the chemosocial life of the substance in the Americas with the infrastructures of extraction that emerged in the early nineteenth century.

The Ministry of Trade's official archival information on imports shows is no record of mercury imports between 1905 and 1936 (Anuario Estadistico 1905-1936). One reason may be that in 1916 and until 1931, official import records conflated mercury with other imported metals, which makes it impossible to discern the exact quantities of specific metals and chemicals. Mercury imports reappear as a separate category in official records only in 1931. Between 1931 and 1947, 6.6 tons of mercury were imported to Colombia annually, with peaks of 10 tons in 1938 and 20.1 in 1941. Another proxy to estimate mercury imports during this time would be an estimate of the ratio of mercury used to extract such gold. In the same period (1931 to 1947), Colombia produced 12.8 tons of gold annually.[30] Assuming a conservative ratio of 2 to 1 is possible that in those 15 years, Colombia imported between 25 and 30 tons of mercury, although it is impossible to determine it without more.[31] Another aspect that would support this hypothesis is the fact that cyanidation was invented in the 1890s and was introduced in Colombia

[29] In the 1830s, the Spanish monarchy gave the Rothschild family operating control of cinnabar extraction in Almaden as part of the payment of a debt. The Rothschild's companies were mostly based in London, which was one of the world financial centres of the time. For an analysis of the wave of British investment in Latin American mining and agriculture, see (Brown, 2012b).

[30] Between 1948 and 1975, the country produced 9.4 tons of gold annually; between 1919 and 1975, the country produced 9.8 tons of gold annually.

[31] In Chapter 5, I discuss in depth various metrics for estimating mercury use in gold mining. Estimating historical mercury exports based on patchy data and estimating mercury use in thousands of disperse, informal mining sites across a country or the whole world are in the same category of bold metrics inherently characterised by uncertainty. For a further discussion of the numerical work and quantification devices used in estimating mercury pollution, see Chapter 5 of this dissertation.

in 1905. However, it was an expensive process that was not within reach of most miners of the time and only started gaining particular prominence in Colombian mining decades later (Carre, 2005). Therefore, most, if not all, gold mining operations in Colombia must have considerably relied on mercury.

Although this archival exploration left many open questions, it helped trace the incoming flows of mercury at the turn of the century and the upcoming decades – in times when cyanidation was becoming popular in South African and North American mines, Colombia and other South American countries kept importing mercury to be used in gold mining. Moreover, the archival work helped situate some anecdotal evidence I collected in my experience in various gold mining areas of Colombia between 2012-2014 and 2017-2019. In the summer of 2017, I did some exploratory interviews with small-scale gold miners in the province of Nariño in Southwestern Colombia near the Ecuadorian border. Nariño is another prominent region of the country and trails Antioquia as one of the primary gold producers. Some of the interviewees in the towns of Iquira and La Llanada (two of the towns where the Alliance for Responsible Mining is promoting fair gold certifications for operations that process gold with no mercury) were elder. In our interviews, we were discussing the national mining strike that small-scale miners in different parts of the country were preparing a protest against harsh gold trade regulations and legal uncertainty. One of the points the miners were protesting was the near end of the 5-year deadline for the banning of mercury use in ASGM established in 2013 and scheduled to enter into force in 2018. Pedro and Eduardo, 87 and 79, coincided in a recount of a critical memory – in the 1950s, the Colombian government would provide mercury as part of technical assistance offered to small-scale miners.[32] Then, certain aspects of small-scale mining, such as finance and technical assistance, were covered by the Agrarian Bank of Colombia, an institution created by the 1936 Agrarian Reform law to provide finance to rural producers.

I have yet to find official government documentation to corroborate the miners' claim that the government handed out mercury in the 1950s. However, research finds similar practices in nearby Peru, today condemned for being the most polluted and polluting sites of Earth and the nodes of illegal mercury trade. Miners in Madre de Dios, Peru, reported to Diaz (2021) that beginning in the 1970s, the state-run mining bank (Banco Minero), sold tools to miners, allegedly including mercury, and bought their gold at strategic outposts proximate to mining camps. For gold miners who worked in Madre de Dios during the 1970s and early 1980s, the mining Bank was both a symbolic and material representation of state support for gold mining and mining livelihoods. The Banco Minero, which operated from 1942 to 1991 under the jurisdiction of the Ministry of Energy and Mines, played an essential role in the development of the small-scale gold mining economy in Madre de Dios and Peru more broadly (Diaz 2021). Regardless of how extended the state-sanctioned provision of mercury was in the previous decades, under neoliberal mining policies enacted in Colombia and Peru from the 1990s and on, most state support shifted away from small-scale gold mining and went towards large-scale industrialized gold mining (Bebbington & Bury, 2010; Duarte-Abadía, Boelens, & Buitrago, 2021).

In Antioquia's goldfields, this shift from small to industrial mining is also manifest in mercury reduction policies to further marginalize ASGM. In August 2017, a few months after

[32] Interviews 59 and 60.

my interviews with Pedro and Eduardo in Nariño, I traveled to Antioquia, where the miners' strike we had been discussing months ago had just erupted. That month, more than 30,000 small-scale miners in various municipalities of Antioquia (most prominently Segovia and Remedios in the Northeastern region) stopped working for 42 days. They were protesting the protracted uncertainty about the end of the formalization program deadline later that year, the coming deadline for the mercury ban in gold mining to enter into force in the upcoming months, and the increase in military crackdowns to artisanal miners who are just trying to make a living and are not criminals as the government and companies such as Gran Colombia Gold depicted them. Given that smallscale gold miners in Antioquia produce about sixty per cent of the gold in the country (the smallscale or informal sector produces eighty-six per cent of the total national output (Ministerio de Minas y Energia 2019)), the strike disrupted the entire regional economy, processing plants stopped working. No gold was sold in the region for five weeks. Road blockages and clashes between the police and the protestors occupied the media's attention for weeks. In Segovia and Remedios, the police killed three protestors and wounded another 30.

The towns of Caucasia and El Bagre are in the Lower Cauca River Basin region, another prominent gold mining area in Antioquia. A miners' organization in Caucasia allowed me to accompany them to one of the marches they organized during the strike., Juan and Elena, two miners, were discussing the intervention of Eliober Castañeda, the president of the National Confederation of Miners (Conalminercol) in a hearing before the Senate plenary that same week. Invited by the leftist coalition in the Senate, Castañeda reiterated the protestors' reasons to strike and reiterated how the 2013 Mercury Law gave the ASGM sector five years to abandon mercury use. However, so far, the government had not provided the required finance, technical assistance, and support to implement it. Instead, it scaled up the military crackdowns in Antioquia and other mining regions and has refused to discuss reforming the harsh formalization requirements that most miners in the country cannot meet. In response to Castaneda's intervention to the small crowd in front of Caucasia's city hall, Juan and Elena expressed pessimism about the possibilities of resolving the mercury ban. "We have no affordable way to replace the mercury. In the meantime, the government keeps subsidizing and giving companies leeway to do anything, as they have always done".[33]









[33] Interviews

Photos 7, 8, 9, 10. About 1,200 small-scale gold miners' strike in Caucasia, Antioquia, July 2017. Photos: S Rubiano (2017)

The reference to Southern governments' preferential policies to corporations does not commonly feature in global debates on mercury. In Segovia and Remedios, the miners' protests were intimately connected to sedimented layers of violence and toxicity produced by corporate power and state acquiescence to that power. Frontino Gold Mines, the company that extracted gold from Northeastern Antioquia between 1853 and 1975 (first owned by British investors and then sold to American owners in 1911) went into bankruptcy in 1973. In 1975, the NY-based company signed an agreement in which they committed to transfer the company's assets to the workers, given that many of them were owed salaries and pensions. The Colombian government shelved the agreement for various decades despite the workers' requests to implement it. In 2003, the pro-corporate mining and right-wing government of Alvaro Uribe (2002-2010) advanced a rigged interpretation of the agreement not to return the company's assets to the workers as stipulated in 1975, including the ownership of the concession, which for the first time since 1853 would return to Colombian nationals. Instead, the Ministry of Mines granted the 300-hectare concession to Zandor Capital, a Canadian mining company later acquired by a larger pool of Canadian investors and renamed Gran Colombia Gold Co. Since then, Gran Colombia Gold has held the mining concession, which covers sixty per cent of Segovia's land, including the four mines that have been producing gold since the 1800s (Quiroga 2015). Most miners in town have continued to work in this mine illegally. As part of the attempts to regularize the miner's informal status within the concession, some miners have signed operation contracts with the company, that is, two-year renewable agreements to extract gold within the company's concession area, but without ownership.[34]

The government's decision not to return the company's assets to the former mine workers as originally promised turned the workers into invaders and illegal miners in the eyes of the Colombian state and Gran Colombia Gold Company. A few months after the 2017 strike ended, the CEO of Gran Colombia Gold (GCG) sent a public letter to the Ministry of Defense explicitly asking for a firmer military response to the massive illegal mining in some areas of the company's concession. In Segovia and Remedios, there are more than 200 mines considered illegal that produce more than 100,000 ounces of gold per year and employ around 30,000 people. For one of the leaders of Conalminercol (the small-scale miners' association), the mercury ban and the company's stigmatization strategy (of which the latter was the most recent and one of the most high-profile manifestations) are part of the same logic of criminalization against small-scale mining in Segovia and Remedios. The company that unlawfully inherited the mining concessions that the Colombian government had given to British investors in the mid-nineteenth century –who played an active role in the production of the Northeastern Antioquia

[34] Interviews 48, 49, 50, 21 and 56.

region as a toxic landscape–, was now actively asking the government to prosecute and crackdown the miners that had already been denied their lawful rights.

Seeing miners protesting in Antioquia is rare and therefore politically significant given the control that armed groups have exerted in the region – the bloody Segovia massacre in 1988, when paramilitary groups killed 30 people accused of being guerrilla members (some of them current and past unionized miners working for Frontino Gold Mines), is imprinted in the local and national memory as one of the grimmest episodes of the armed conflict (Centro Nacional de Memoria Historica 2013). Those right-wing paramilitary squads operated in Northeastern Antioquia from 1986 until 2003 when the Uribe government approved an amnesty-like law that demobilized over 35,000 paramilitary combatants. The heads of the organizations brokered plea bargains or were extradited to the US. In response, smaller groups have taken over the drug trafficking routes, the territorial control, and some segments of the gold supply chain.[35] In Antioquia, the demobilization of the Bloque Mineros, the largest paramilitary group in the region until 2003, was only partial – in the next decade, at least 13,000 combatants have regrouped into various atomized neo-paramilitary groups (like the Autodefensas Gaitanistas, los Urabeños, los Libertadores del Nordeste, Nueva Generación, los Zetas, la Mano que Limpia, las Águilas Negras). Those groups and some remnants of the former FARC guerrilla dispute control of the Northeastern Antioquia region and routinely extort both large-scale and small-scale miners, demand a cut on gold purchases, and according to some reports, play a role in mercury trade, too (Bedoya-Builes, 2011; Ureta, 2021).

In sum, the logic of exploitation and violence is the backdrop against which ASGM takes place in Segovia and Remedios. Said logics have been intimately connected to mercury's residual and irreversible materialities and temporalities and entangled in colonial, corporate, and state power, and the armed violence in the region. Some large-scale companies claim that they either stopped using mercury decades ago or use it in close circuits in which they recycle the mercury vapors with retorts and reuse them. For instance, Mineros S.A., a Colombian-owned company that exploits alluvial gold in the Nechi River not too far from Segovia, claimed to have stopped using mercury as late as 2012, a year before the Mercury Law was enacted. Mineros S.A. started their exploitation in 1908 with British and American capital, as it was the norm in the mining sector back then. In 1974, the owners sold their investment to Colombian owners, which continued to operate the mines of the Nechi River and became one of the largest gold extraction operations in the country. The fact that the second largest gold mining operation in Antioquia and the country publicly acknowledged having mercury to process gold between 1908 and 2012 demonstrates. While I could not find records on when exactly Frontino Gold Mines Co. (and its corporate heir Gran Colombia Gold Co.) stopped its mercury use, the corporate extraction of gold with mercury during the twentieth century precedes recent use of mercury in small-scale mining in the last few decades and possibly supersedes it in magnitude.

[35] The times of high profile, Escobar-like *narcos* or spectacular combats have been left behind - since the years of the law-and-order and US-backed military Uribe administration (2002-2010), the Colombian armed conflict turned into a mid-level intensity confrontation and characterized by varied sub-national dynamics. For an analysis of the recent subnational dynamics of the war and varied resource conflicts in Colombia (emeralds, coca, coal, gold, oil), see Rettberg, Prieto, and Nasi (2019).

III. Conclusion

The narratives of Latin American countries as enablers of mercury contraband sales or as hosts of toxic landscapes requiring urgent intervention due to the havoc created by small-scale gold mining conceal critical dimensions of mercury's chemosocial life and regional histories: specifically, the ways in which colonial, corporate, and state power have created the conditions for mercury to be a problem today. The maintenance of colonial, corporate, and state power in Colombia and Latin America more broadly has enabled and sustained the current "disorder" that mercury-using small-scale miners in sites such as Northeastern Antioquia, as I discuss in Chapter 5, represent.

The chapter has shown the colonial, corporate, and independent state history of mercury's use and legacy in Colombia and other parts of Latin America. What my analysis revealed – thinking with (Boudia et al., 2018), (Murphy, 2017), and others– is that residues, like mercury, cannot be made history or left behind not even through coordinated multilateral action. On the contrary, as material manifestations of empire, colonialism, and industrial capitalism, residues such as mercury continuously *make* history through their embeddedness in larger and always shifting political ecologies of knowledge, technology, power, and intergenerational toxicity. As the derivatives of toxic heritage sites, mercury legacies stemming from Spanish colonialism in the Americas embody colonial relations that do not feature in the representations of mercury and its associated knowledge and technologies as heritage or as undesired guests in a detoxified future. This suggests that the reframing of mining legacies as heritage is another form through which residues remain while still accomplishing important political work that enables some historical memories and hides others.

Although in the environmental health sciences there is broad consensus about mercury's toxicity (National Research Council, 2000; Steckling et al., 2017), examining situated histories of places affected by or involved in the slippery and unruly webs of toxicity's reach such as those of Antioqueño gold miners, helps highlight how toxicity is not a universal or homogenous experience but instead indexes various forms of power and injustice. Some scholars have argued that we are living in a "permanently polluted world" (Liboiron et al., 2018) where it is impossible to escape so-called "Anthropocenic exposure," brought on by the uncontrolled expansion of capitalism and industrial chemistry (Roberts 2017). However, as I demonstrated in this chapter, mercury pollution is uneven and mediated by various ecological dynamics and power relations among states, miners, and exposed vulnerable populations. Most importantly, the situated histories of colonial, corporate, and state legacies associated with mercury extraction, import, and use in silver and gold mining reiterate said uneven distributions of harm, exposure, and blame.

Unless critically acute, toxic legacies are often invisible to the human eye and incommensurable (Boudia et al., 2018), whether because they are unknown, actively hidden, or manifest in slow or imperceptible ways (cf. Nixon 2011). The case of mercury's chemosocial life in the Americas, and particularly in the mining sector, reaffirms that the persistent nature of pollution and its residues are not just side effects of colonialism but rather enactments of ongoing colonial relations to land and people; those relations, through which a socio-environmental order at one scale is sacrificed in the name of another, embody colonial and state-sanctioned toxic

violence rather than being mere symptoms or side effects of them (Liboiron, 2021). In the Americas, mercury use in silver and gold mining helped sustain colonial, corporate, and state power but left enormous environmental harm. In Chapter 4, I will go back to how environmental science came to document those harms on a global scale.

CHAPTER 3. Mercury's toxic heritage and itineraries of metallurgic expertise in the Americas



Photo 11. *Mercury's molecule installation at Almaden's Mercury Museum. Photo: S. Rubiano (Almaden, Spain 2019)*

Introduction

In some accounts of mercury use in ASGM as a global problem, the technique they use to process gold with mercury –called mercury amalgamation– is often described as being "the same one rediscovered in the sixteenth century" (Chasek and Dowie 2021, 141). Others depict it as a backward, 'non-technical' way of processing gold - a report by Pure Earth and Green Cross (2016) claims that mercury amalgamation is an "exceedingly primitive" and "rudimentary method". Commenting on the efforts of a GEF-funded project implemented by Conservation International in a series of gold processing centers in Guyana, the organization's CEO declared in an event in 2019:

> "Mercury is not necessary to mine and process gold. In the developed world, mercury has not been widely used in gold production for a century. By improving small-scale gold mining in the developing world, we can improve the health of people and preserve nature that provides us so much. That means mining in the right places and in the right ways. It means professionalizing practices to not only protect human health and the environment but to create better returns for mining communities".
> *Dr. M. Sanjayan, CEO, Conservation International (2019).*

This views reflect a common idea in international development circles – that mercury amalgamation, the worse practice that the UN Minamata Convention seeks to "reduce and, when possible, eliminate" in countries with ASGM sectors (UNEP 2017), is a remnant from a distant past that the "developed world" already left behind, unlike mercury-emitting miners in the developed world who still use it and therefore need "improvement" and professional expert assistance from their developed counterparts to know where and how to mine and process ores. While the environmental health effects of mercury amalgamation are undeniable and very well-documented, the depiction of the technique as a static knowledge frozen in the past hides its

politicized history and some of the reasons why it has been so difficult to phase it out in countries and regions with intensive mercury-use (Boris Verbrugge et al., 2021).

In Colombia, the country signaled today as the largest contributor to global mercury pollution, the historiography of mining also tends to simplify the trajectory of the amalgamation technique by framing it as a European invention introduced in the nineteenth century. In most accounts, the first use of the technique in the country is traced back to the 1820s, when American, French, and British mining corporations started investing in mining ventures in Colombia, Peru, and other countries in the region (Poveda Ramos, 1987). Economic and business historians underpin amalgamation as one of the various technological improvements that European mining engineers invented and injected into the nascent republics' attempt to reinvigorate mining extraction between the 1820s and the end of the nineteenth century, alongside stamping mills, monitors, and explosives (Deustua, 2017; Poveda Ramos, 1987). Such depiction is not a mere instance of historiographic parochialism that sees technology as 'imported magic' (Medina, Marques, & Holmes, 2014). Until recently, high-profile academic venues such as the Nature journal considered Ignaz von Born, an Austrian metallurgist that developed important adjustments to the amalgamation method in the 1780s, the inventor of the technique (Nature 1942). However, such a depiction overlooks that the amalgamation method was not invented in Europe in the nineteenth century – it was first developed in the sixteenth century and has been adapted and modified in various ways until its widespread use in ASGM in present times (Saúl Guerrero, 2016).

This chapter interrogates these two framings of the mercury amalgamation technique –as a backward practice and as an imported innovation– and presents a more nuanced account of the social relations and trajectory of the technique. Such an account centers metallurgists, miners, and indigenous peoples in the Americas as active co-contributors to the technique's development and not just recipients of it. In this chapter, I argue that the history of mercury amalgamation in gold and silver mining is not a linear one but rather a more fluid and asymmetrical ecology of power and knowledge, which is concealed and de-politicized by UNESCO's declaration of such technology and knowledge exchanges as "horizontal" and universally beneficial, as discussed in Chapter 1. I argue that knowledge about mercury amalgamation traveled through colonial, corporate, and state circuits of power and knowledge in unequal ways that challenge the former Spanish colonies' status in the history of the technology as subordinate suppliers of raw minerals and passive recipients of foreign expertise.

I use two specific situated histories to develop this argument. The first is the history of how expertise and technology underwriting mercury use was deployed under colonial rule. I reconstruct the co-production between colonial rule and practices of translation, adaptation, dismissal, and reuse of mining technology and knowledges on both sides of the Atlantic. Second, I nuance the idea that runs across Colombian mining historiography and other venues: that Europeans first invented and introduced mercury amalgamation in Colombia. On the contrary, I dissect the broader process through which the amalgamation method was re-introduced in elsewhere in South America (specifically, Peru and Mexico) in the early nineteenth century and redefined as a European innovation that epitomized the promise of a mining revolution based on technology, foreign expertise, and dreams of modernization, and situate Colombia in such

dynamics while discussing the specificities of the process there and its connections to current debates on the mercury problem in ASGM.

I. Trans-Atlantic itineraries of metallurgic technologies and expertise: from the *patio method* to cyanidation

In this section, I reconstruct various practices of translation, adaptation, and dismissal of knowledge about the amalgamation technique on both sides of the Atlantic, preceded by a brief explanation of the early version of the method.

1. (Re) inventions and 'invisible technicians': the patio method

In 1553, Sevillian merchant and metallurgist Bartolome de Medina built a refining complex (*hacienda de minas*) around the mine of Purisima Grande in Pachuca, New Spain. There, he developed a method that allowed for the expansion of colonial silver mining and, subsequently, became the financial basis of the Spanish empire for the next hundred years (Bargallo 1955). While Medina developed the amalgamation method in the Mexican highlands (Bleichmar, De Vos, Huffine and Sheehan 2008: 2), its use in Spanish America was, in a way, a rediscovery and an adaptation. The Egyptians and the Romans had produced quicksilver from cinnabar and attempted to use it for sorting other minerals—so technically they were the first to discover its amalgamating properties. However, during the Middle Ages, knowledge of the process in the Old World did not lead to profitable exploitation and was not actively promoted (Teich, 1975). It was then rediscovered by German metallurgists in the fifteenth century who successfully attempted to amalgamate silver using mercury, but could not develop a simple and accessible technique (Hernandez & Espinosa, 1991). It was not until mercury was sent to New Spain (Mexico) to process silver that Medina began experimenting with mercury amalgamation with some success (Waskis 2014: 78). Until that time, the smelting method to process mineral ores (applying heat to ore to extract a base metal from a mixture) was effective enough to process vein material with very high-grade minerals. Still, when the grade was low, a lot of ore was wasted and the process consumed large quantities of vegetable oil, which caused deforestation around the mills (Paez Courreau, 2003).

Medina's patio method was a 10-step process that combined smelting and refining. After crushing the minerals, the ground-up ores were arranged in a courtyard or patio—hence the name for the method. Then, reagents such as salt, copper, or *magistral* (roasted copper-iron sulfite or chalcopyrite) were added to the piles of ores, which would harden the mixture. At this point, mercury was added to the mixture, which was then stomped by mineworkers in shallow circular pits, sometimes with the help of mules dragging large blocks of stone over the mixture. Chemical reactions that could take up to 30 days freed the silver from other compounds and bound it to mercury. Next, the solution (now in fine mud) would be washed with water in tubs to flush away the lighter particles, leaving the partially formed amalgam of silver and mercury that were approximately 20 percent silver and 80 percent mercury. To separate the silver from the amalgam, refiners would burn the amalgams in pineapple-shaped molds, which would produce cone-shaped bars of silver, as well as mercury vapors. The silver cones were later sent to mints

and tax houses for processing. In the Andes, refiners roasted the amalgam again to compensate for the lower temperatures (Bargalló 1955; Bigelow 2021: 241).



Figure 1. The patio process. Source: Brown (2012, 104)

The patio process was slow, but the wait allowed the exploitation of medium and lower-grade ores. These could not be refined with the traditional smelting processes. Medina´s method also allowed the profitable exploitation of silver ores that were more difficult to process due to their complex combinations of chemical elements, especially sulfur and copper (Bigelow 2021, 218). Another draw of this method was its potential to reduce the dependency on fuelwood. By the mid-sixteenth century, deforestation was a concern for the refiners in the mining centers of Spanish America (Studnicki-Gizbert & Schecter, 2010). Several adjustments were introduced in different locations, such as varying ore grinding sizes and techniques and varying the quantities of *magistral* used. However, the basic process spread rapidly through crown-appointed merchants or the military. By the 1570s, less than 20 years after Medina's essays, the patio method had been adopted in the Andean silver mines of Potosi and was eventually re-adopted in Europe (N. Robins & Hagan, 2012; Teich, 1975).

While Medina is credited with the patio method invention in some accounts, (Bargalló 1955), they downplay the fact that he did not develop it by himself. Instead, he relied on both colonial and native labor, infrastructures, and knowledges. Other metallurgists of the time claim that he took the idea from *De la pirotechnia* (1540) by Vannoccio Biringuccio, the first printed book on metallurgy ever published in Europe (Ortega 1956); or from *De Re Metallica* by the famous Georg Agricola (1556) who wrote about gold processing using salt, copper, and yeast (Waskis 2014: 31). However, Medina always acknowledged he had rediscovered a process that an unknown metallurgist in the Habsburg empire had helped him understand (Almansa, Monters, Iraizoz, & Fuentes, 2011). At that time, Habsburg[36] imperial structures in European empires and their colonies allowed prominent German banking families' control of Spanish assets once mined by the Roman empire (including the Almaden mines, which the Spanish crown ceded to the

[36] The Habsburg was a German dynasty and one of the most prominent royal houses in Europe in the second millennium. The Spanish Empire under the Habsburg monarchs (primarily Charles I and Philip II) rose to the pinnacle of their power and influence between 1516 and 1700, until they were succeeded by the Bourbons.

Frugger family[37] in various moments, way before ceding them to the Rothschilds). These investments help explain the prominence that German mining and metallurgic expertise would acquire in the following centuries in the Americas (Bigelow 2021: 43).

Medina's reliance on labor, infrastructures, knowledges, and, in general, the material basis of its invention process reflects that this was far from the work of a single acting genius but rather the outcome of overlapping networks of power, knowledge (including a divine one, according to himself), and resources. Most importantly, the most reliable silver networks in the Viceroyalty of New Spain were controlled by the native Mexica, whose networks of silver miners, refiners, and trade routes were critical for Medina to carry out his experiments and eventually perfect the method: the combined role of tribute laborers, knowledgeable artisans, war materials, and finished goods was essential for running the refining complexes (*haciendas de minas*) (Bigelow 2021: 42). In that sense, the technological success of colonial amalgamation thus

> "*reflects the contributions of German financial networks that organized Spanish mines; a Spanish merchant in Mexico; and Mexica imperial systems that organized natural resources and specialized knowledges into efficient networks for the production and distribution of metals, minerals, and stones"* (Bigelow 2021: 43).

Therefore, mining and metallurgy already had a history in the New World and the Mexica were not only laborers stomping on the mercurial ores for Medina's experiments and refining work.

2. Adaptation and scientization

Metallurgists in New Spain and Potosí developed adjustments to the patio method, partly in response to differences in access to labor and inputs. One of those adjustments was made in the mountains of Potosí in the Viceroyalty of Peru (modern Peru and parts of Bolivia) in the early seventeenth century. Besides dealing with labor problems, silver refiners in Potosí often had to tackle the shortage of mercury and sometimes devised new technological remedies. At Cerro Rico, local refiners (the Ortiz brothers) designed an amalgamation machine to stir the crushed ore and mercury, eliminating the labor costs of mixing the materials with their naked feet. Elsewhere in the province, where mercury costs were even higher than at Cerro Rico but where fuel was more readily available, refiners developed a refining method of mixing ore, mercury, and boiling water in copper cauldrons. With this process, amalgamation took hours rather than the days or weeks required by the "cold process" traditionally used at Cerro Rico and had the additional benefit of expending less quicksilver (Brown 2012, 105).

Another variation of the patio method, *metodo de cajones*, was developed by a medical doctor and metallurgist Alonso de Barba in Peru in the 1590s (Paez Courreau, 2003). Barba dedicated his life to studying and developing mining techniques. He synthesized his knowledge and experience in his very famous treaty "*The art of metals in which is declared the manner of their generation and the concomitants of them" (Arte de los metales: en que se enseña el*

[37] The Fuggers of Augsburg were a German family devoted to banking and trade that dominated European business during the fifteenth and seventeenth centuries. They held various investments in Central Europe, Portugal, and Spain, which contributed to the capital structure of the global mining economy of the sixteenth century (Graulau, 2008a).

verdadero beneficio de los de oro, y plata por açogue, el modo de fundirlos todos). In 1633, Barba improved the furnaces used to distill mercury from cinnabar –called the *jabeca*–, making gold and silver processing much more accessible and boosting productivity by increasing the availability of quicksilver. This method would last for the rest of the colonial era and beyond it and, just like Medina's method decades before, would be adopted in European mercury mines from then on (Robins 2011: 58). Barba also developed the *metodo de los cazos* (bucket method), consisting of extracting silver from a metal ore using common salt and copper sulfate in addition to mercury. The Barba technique was used widely from 1609 to the nineteenth century, although European metallurgists would ignore it for most of this time. The reason was that until the 1780s, silver smelting was the preferred method for processing this mineral in Europe. Most European metallurgists believed that the American way was inferior, inefficient, and not suitable for treating the low-grade silver ores mined in Europe (Teich, 1975).

However, at that time, the dire finances of the Austrian Habsburgs pressured them to support various efforts to raise gold and silver production in territories under their rule - one of those was led by Austrian metallurgist Ignaz von Born who experimented with the mercury amalgamation technique and advocated for its adoption in European mining. Born was one of the first alumni of the Slovakian Mining Academy founded in Banská Štiavnica in 1735 (Teich, 1975). This mining academy was one of the first of a group of mining schools created in nineteenth -century Europe to support the imperial attempts to reinvigorate mining extraction in Europe and its colonies (Deustua, 2017). In the seventeenth century, Newton, Boyle, Locke, and other European alchemists had exchanged extensive correspondence on the question of transmuting metals and exchanged formulae for the transmutation of ore into gold (Grossmann, 2009). Still, it was not until the eve of the Industrial Revolution that imperial needs for revenue were coupled with Enlightenment ideas and translated into formal education programs in scientific mining and metallurgy.

After two years of experimentation, Born developed a version of the mercury amalgamation method using closed barrels instead of Medina's open-air patio method, an adjustment that made the process faster. In Born's version, the ore was mixed with salt, roasted, pulverized, and slurried with mercury and water in heated copper kettles, stirring by windmill-driven paddles. The heat applied to the closed barrels (called *heated amalgamation*, in contrast to the patio method's *cold amalgamation*) enabled the processing of silver in less than a day, while the patio method required at least ten days (Caswell & Stone-Daley, 1999). Born's method also adjusted Alonso Barba's buckets method (*metodo de cajones)*, a variation of Medina's patio method, and made it less expensive. However, the Born method consumed more mercury and produced less silver than the patio method (López de Azcona 1992: 113).

Given that Hispanic-American metallurgists' contributions were not valued in the same way that their European/German counterparts (Contreras 1999), it's not surprising that some sources document Born's criticisms of the American amalgamation method as "retrograde" (Teich, 1975, p. 311). In other sources, Born is said to have acknowledged the American origin of amalgamation in more amicable terms (Caswell & Stone-Daley, 1999). At any rate, the contributions of Medina, Barba, and the indigenous metallurgists, traders, and workers whose knowledge, exchange networks, and labor were instrumental in the development of the amalgamation method and its adoption in the Americas, were devalued during the scientization

of the method in Europe and the Industrial Revolution's push to "apply scientific knowledge" to mining (Graulau, 2008b).

The Austrian Habsburgs' support of Born's experiments was paralleled by a similar effort by the Bourbon monarchy in Spain. At the end of the eighteenth century, increasing costs, declining yields, and social revolts left gold and silver mining in the Americas in decline after fluctuating production for more than 250 years. The massive extraction had depleted the most accessible deposits in the past centuries, and silver and gold production stagnated. In response, the Neo-Bourbon reforms of the late eighteenth century, which aimed to modernize the Spanish empire's finances, expanded the networks of mining knowledge and technology by drawing on the developments of emerging mining education centers in Europe such as Freiburg or Paris and sending missions of chemists and mining engineers, a recently emerging profession at the time, to the three viceroyalties in the Spanish Americas (New Spain, Peru, and New Granada). These missions had the instruction of transmitting "new knowledge and technology" to reinvigorate mining production in the colonies (Pelayo, 1990), but had mixed results.

Fausto D'Elhuyar was sent to New Spain (Mexico), his brother Juan Jose D'Elhuyar to New Granada (Colombia), and Thaddeus Nordenflycht to Peru. The D'Elhuyar brothers had been educated in Paris and Freiburg mining schools and were prolific writers about the minerals of Northern Spain. Juan Jose D'Elhuyar had worked with Born and had been an active interlocutor in his attempts to make amalgamation profitable for low-grade silver ores (Teich, 1975). Given that by the late nineteenth century, the transport of mercury from Almaden became too costly, initially, the missions were supposed to promote smelting to process extracted minerals from the colonies—the work included, among other tasks, drawing topographic and mining maps showing the location of mines and mineral deposits in the colonies (Díaz Ángel, 2016; H. V. Scott, 2015). However, after the D'Elhuyar brothers attended the 1786 conference in Skleno (modern Slovakia) in which Born publicly shared the results of his experiments on mercury amalgamation, the Spanish crown shifted the goals of their "technical assistance" missions: instead of diffusing smelting (then prevalent in European mining), the missions were redirected to introduce the Born's version of the amalgamation method (Caswell & Stone-Daley, 1999)

Although the Bourbons had high hopes of bringing the newest developments in mining and metallurgic knowledge to the Americas, the Nordenflycht and D'Elhuyar missions were thwarted and ended early due to various financial, technical, and political hurdles. Nordenflycht's innovations were not suitable for the Andean mountains of Peru and Bolivia; the version of the amalgamation method he brought turned out to be more expensive, required more mercury than the one used in Peru, and used a lot of wood, which was scarce in the Andean mountains' mining areas (Pelayo López & Rebok, 2002). While Fausto D'Elhuyar and his colleagues were unsuccessful in applying the Born amalgamation method to the refining of silver ores in Mexico, they did contribute to the reform of the Mexican mining industry. They established the first mining technical college in the New World in Mexico City. The elder brother, Juan José, failed to improve and reorganize the mining industry of New Granada but succeeded in having it applied using Born's method because there was enough fuel available there. By the time the Born amalgamation process was introduced in New Granada, it had already been abandoned in Europe in favor of smelting (Caswell & Stone-Daley, 1999). By

1812, at the dawn of the Spanish-American wars of independence, the three missions had ended with few results and great animosity from locals (Escamilla, 2009).

Further hindering attempts to introduce the Born method in the Americas, the quantity of ores extracted in New Spain was six times higher than the ones extracted in Freiberg, where the Born method was invented. The higher quantities of ore strained the capacity of mills and the extended processing times deterred the adoption of this method. These factors revealed how the variation of local mineralogical conditions would complicate attempts to develop a general theory of amalgamation, that is, a universally applicable steps to amalgamate silver anywhere, as Humboldt and others reported (Humboldt 1818, cited in López de Azcona 1992: 114). Despite the material impossibility to develop such theory and much less to spread it successfully in the colonies and in Europe, a specific variation of it became the most widely used from the mid-nineteenth century onwards: Born's hot amalgamation. Born's theories of amalgamation were printed in German, French, and English and had a wide reach in practically all of Europe's mining areas. For historian Allison Bigellow, that may be the reason why some historians to believe that Born first invented the method and to map the eighteenth-century exchange of European knowledge and American practice back onto their readings of the colonial archive "supposing that European metallurgical technologies had been more advanced than Spanish American mineralogical science in the seventeenth century, as well" (A. Bigelow, 2012, p. 89).

3. Translation, Erasure, and Dismissal

According to Bigelow (2012, p. 93), the origins of amalgamation cannot correctly be situated in either an American or a European context because the history of the method "does not adhere to national or linguistic borders that did not exist in the colonial era. Instead, the technique indexes a story of the transcultural, multilingual transmission of the knowledge and exchange of methods from willing and unwilling agents of science". Even though bodies, knowledge, and materials from the New World were interwoven into the colonial extractive enterprise, this was not enough for non-European knowledges to secure a place in the pantheon of mining science and technology celebrated today by UNESCO in Almaden and Idrija.

While the combination of knowledge produced in both the New World and Old World allowed for the development of colonial amalgamation technologies in the sixteenth and seventeenth centuries, several works in the historiography of mining technology depict nineteenth -century European mining engineers as the inventors and introducers of mercury amalgamation, milling, and other science-based mining technologies and techniques in countries such as Colombia, Peru, and the Americas more broadly (Cubillos, Poveda, & Villaveces, 1980; Poveda Ramos, 1986, 1987). The main reason is that eighteenth-century mining writers reframed the definition of scientific mining to argue that amalgamation was a European invention. One of the consequences of such redefinition was that it further erased the Andean knowledge and mineral naming and classification systems when they were translated into different European languages (A. Bigelow, 2021). Classification systems were key because knowing the features of deposits and the methods to extract them or its uses was essential for the extractive enterprise. Thus, a key mechanism through which the knowledge and techniques for amalgamation traveled–leaving some of its marks behind– was the translation of mining treaties (A. M. Bigelow, 2021).

The Eurocentric translations of mining treaties are better understood in the context of the rise of scientific chemistry and mining engineering in Europe in the nineteenth century (Cooke, Environment, Abbott, & Wolfe, 2008; Sánchez-Gómez & Delli-Zotti, 1994). Through this practice, a rich tradition of mining and metallurgic knowledge was erased. The Mexica were not the only pre-Hispanic cultures who worked metals. Central and South America is one of three geographic areas where metallurgy independently emerged (the others being China and Sub-Saharan Africa), and Andean metallurgy constitutes one of the world's most significant historical metallurgical traditions in terms of material outputs at their time (Hosler 2013). Before Spanish colonialism, ancient Andean metalworkers smelted ores from various deposits to produce a wide array of practical and ritual objects from alloys of copper-gold, copper-tin, copper-arsenic, and copper-silver. Also, in diverse metalworking communities of the Caribbean, refiners added herbs to molten mixtures of alluvial gold and copper, which enhanced the different textures and colors of gold and copper with scent, thus facilitating its sorting and collection (West 1952). The then-new method to amalgamate silver with mercury, using the techniques developed by Medina in the 1550s, allowed refiners to extract ores from a wider variety of silver-like metals, ranging from unmixed metals to various combinations of ferrous, cupric, and sulfuric elements (Muro, 1964).

While the translation of mining treaties did not ignore native knowledge of minerals, it misrepresented it and changed its meaning. Bigelow's (2021) work charts a critical genealogy of said erasure through the writing, translation, and circulation of mining treaties in Europe. Her analysis of mining treaties written in the Americas and their translations to five languages in Europe demonstrates how translations done by Enlightenment-era writers in Europe used the language of colonial treatises to argue in word and image for the European origins of the technology (Bigellow, 2021: 295). In the shift from smelting to amalgamation in the sixteenth-century Andes, mineral classification, sorting, and naming became more complicated, intricate, and essential. Miners and refiners in the Andes developed extensive color vocabularies that they recorded in new ways, incorporating terms derived from Spanish (with Latin and Arabic roots), Quechua, and Aimara. Indigenous terms for silver minerals highlighted similarity ("friendship," "sympathy," "likeness," "love") and difference ("enmity," "antipathy," "unlike-ness," "hatred").

In contrast, the colonial *cronistas* (writers) and translators of mining treaties in Europe reinterpreted metallic classifications in Quechuañol, including "pacos, mulatos y negrillos" (roughly translating as clear, brown, and black metals) and they chose terms that communicated their own, culturally specific ideas about color and racial categories. Analyses of these color terms and the distorted forms in which they were written and published in European circles show how the silver industry drew from and gave greater authority to existing discourses of race, color, and *casta* (Bigelow 2021). As she argues,

> "*scientific concepts of similarity, difference, and the causative spark of change circulated widely throughout early modern Europe, but writers working in different regions and language communities created their own expressive metaphors and analogies. Even when refiners in Germany, Italy, Spain, and Latin America used similar vocabularies and worked with technologies that were transferred throughout the*

Habsburg, Holy Roman, and Hispanic empires, the words that they used did not mean the same things" (295).

In that sense, nineteenth -century mining treaties operated as subordinating objects in a sense described by Rodriguez-Medina (2013), that is, as epistemic objects that structure and reinforce epistemic centers and peripheries by their transnational circulation (Rodriguez-Medina, 2013).

During and after the rise of modern science and engineering in Europe and the Americas, the technique of using mercury to process silver and gold was not only adjusted and reframed as scientific as opposed to alchemical but also mercury itself was rendered devoid of its alchemical and mystical meanings (S. W. Miller & Miller, 2015). Although cinnabar and mercury were first used in Antiquity and early modern times by various civilizations, the early reformulation of chemistry during the chemical revolution of the late eighteenth century and the early nineteenth century allowed the redefinition of mercury as a substance known and controlled by technoscientific expertise and governed by the law of conservation of mass and the oxygen theory of combustion (Crawford, 2009). Thus, mercury was no longer the mystical substance used by alchemists, emperors, and native peoples in allegedly arcane and magical rituals but rather an input for science-based industrial processes (which included mineral processing) critical for sustaining empires and nations.

II. You say you want a (mining) revolution: E*l Dorado Technicum* and mercury in South American gold mining

The second history displaces the focus from the regional level to the case of Colombia, although with similarities across countries in the region too. To replace the myth of El Dorado, nineteenth-century elites and classical political economists produced a new myth, which today underlies the economic mentality about mining: a myth that Jeannette Graulau calls *El Dorado Technicum*, "embodying faith in technology to modernize mining of valuable metals for economic revenue" (Graulau 2008b: 154). The promise of a science-based technological revolution in mining was the backdrop against which mercury amalgamation remained relevant in the Americas during the nineteenth century, now also in gold extraction and processing. Despite the poor results of the missions sent by the Bourbon monarchy to reinvigorate colonial mining in the 1780s, after the independence wars of the early nineteenth century, the young Latin American republics kept importing foreign mining professionals to survey and exploit the new nations' minerals. The opening of internal frontiers boosted an unprecedented migratory wave of foreign mining experts, no longer seen as alchemists or practical metallurgists as in the previous centuries, but as the representatives of the most advanced mining knowledges and techniques of the time, which by then were considered to be held in Paris, Freiburg, Slovakia, Sweden, and Spain.

In the 1800s, this revamped and technology-centered version of El Dorado ran across the developments of the mining industry in Europe, the Americas, and elsewhere (including, for instance, the Mineral Revolution in 1860s South Africa) (Graulau, 2008b). *El Dorado Technicum* accurately captures the kind of power and knowledge infrastructures of the time, with

gold mining rapidly rising in light of the decline of silver extraction and the increasing attempts to incorporate Taylorist ideas to develop more efficient and scientific production and processing methods (F. Molina, 2011). In that context, the expansion of mercury amalgamation in the New World, even after the invention of cyanidation (the method that substituted mercury use in seventy per cent of the world's operations (Li 2015)) must be seen as part of a larger ecology of power in which the young South American nations were attempting to build their authority and connect with global markets through foreign investment and technology. Such a larger picture also encompassed the European Enlightenment, and its reverberations into multiple fields of knowledge and practice, including the exclusionary implications for indigenous and non-European traditions of mining and metallurgy explained in the previous section (A. Bigelow, 2015).

In this section, I discuss how mercury amalgamation was introduced in the 1820s in Colombia, one of the few sites of the former Spanish empire where it had not been used before. I will examine the continuity of the mercury amalgamation technique in South American gold mining in the nineteenth and early twentieth centuries, specifically in Colombia, today's largest mercury emitter in Latin America and the third largest in the world (Cordy, Veiga, Bernaudat, & Garcia, 2015). As one of the places where UNEP and the Minamata Convention parties have focused their efforts to eliminate even "the last drop" of mercury in ASGM, understanding the historical and cultural politics of mercury amalgamation in Colombia is worthwhile. I show how the expansion of mercury amalgamation techniques in Colombia comprised efforts to form technical elites by creating mining schools, bringing European engineers to educate local students, and attracting foreign capital to invest in mining operations. These efforts took place amidst the residues of colonial rule during the post-independence: ruined economies, impoverished populations, and tense political disputes about the political organization of the new nation (Safford, 1976).

1. A story of two revolutions

Aside from bridging the *Longue dureé* history of the technique with the more recent efforts to eradicate it, the continuity of the mercury amalgamation technique throughout the nineteenth and early twentieth centuries serves as a lens to see not only the toxic residues of colonial domination but also colonial domination as a residue in itself. Although substitute techniques like leaching and activated carbon became widely available in the 1890s and up to the 1950s in Europe and the US (Boris Verbrugge et al., 2021), Mercury amalgamation was not entirely abandoned in all the Americas; on the contrary, metallurgists, engineers, and investors kept the technique alive, but now it was being used to mine mostly gold instead of the then declining silver. One key difference was that it was no longer German metallurgists or Spanish chemists who spread the mercury amalgamation technique and encouraged its use, but rather mining engineers working for the US and British companies that invested in the region, as well as locally trained mining engineers.

In that context, two ideas about mining took shape in Colombia, as well as in other South American nations: that foreign investment and imported technology would spark a mining revolution (Graulau, 2008b). The persistence of these expectations not only gave rise to an unprecedented wave of mining speculation in various mining areas in Colombia (Leal 2009: 155) but also facilitated the diffusion of mining technologies such as mercury amalgamation into a

country eager to reinvigorate and modernize its mining sector. These calls resonated with local elites whose desire for modernization in the early and mid-nineteenth century translated into the welcoming of foreign capital, technology, and expertise for mining (Murray 1997). Between the 1820s and the 1850s, dozens of European mining engineers and metallurgists (mostly Swedish and German) migrated to different parts of Central and South America, eager to work for the companies that were starting to claim the underground of the young nations (West 1952; Poveda 1985; Ramos et al. 2007). In response to the increased investments described in chapter 2, several waves of foreign experts traveled to Latin America to introduce technologies to "modernize" the extractive industry (Murray 1997).[38] One of those *modern* techniques was the European version of the amalgamation method to process silver and gold (the so-called Born method) (Poveda 1985; Ramos et al. 2007).

2. Amalgamating the nation: mining technology and expertise in Colombia

With the interest of the newly independent countries' local elites to grow based on mineral extraction, the need for modern mining technologies became a priority. After the gold rushes of the second half of the century in the US, Australia, New Zealand, South Africa, and to a lesser extent South America (Venezuela, Brazil, and Argentina), the most superficial gold deposits were depleted and vein mining became attractive. However, unlike alluvial or placer deposits, vein deposits are embedded in rocks, and since sometimes they have a low grade (measured in grams of gold per ton, according to the World Gold Council standard), physical methods for separating ores (such as manual gravimetric concentration) became insufficient for profitable exploitations. The fact that low-grade deposits became more profitable incentivized the exploitation of smaller deposits in countries such as Colombia and Peru and propelled the expansion of mercury to process vein-origin gold (Brew, 1977; Lenis Ballesteros, 2010).

The mercury amalgamation process was first attempted in Colombia by French chemist Jéan-Francois Boussingault in Marmato in 1824 and then by Swedish engineer Pedro Nisser in some mines in Anorí and Santa Rosa de Osos in 1827 (Nisser, 1834).[39] Then-President Simon Bolivar had brought Boussingault and Nisser there. However, their work was unsuccessful due to a lack of financial support and the political heat of the late 1820s that led to the dissolution of *Gran Colombia* into five different countries.[40]

Tyrell Moore, a British mining engineer, arrived in Colombia in 1829 and worked in the mines of Marmato for 25 years, where the archives indicate he introduced amalgamation and other mining technologies (Augusto & Ballesteros, 2010; Lenis Ballesteros, 2015). A few

[38] "Crucial sectors, such as mining, were very active in attracting German experts, whose knowledge was productively absorbed (Sánchez Gómez 1989). But mining is even more meaningful in relation to these transnational and global connections if we consider that the Welser and the Fugger obtained the monopoly concession to exploit the mines of Almaden, thus promoting the migration of technicians from Central Europe to Spain (Kellenbenz 1999)." Cited in (Yun-Casalilla, 2018).

[39] For an analysis of Pedro Nisser and its embeddedness in British networks of investment and technical innovation in the 1850s, see (Campuzano-Duque, 2018)

[40] The Gran Colombia (1819-1831) was a state that roughly encompassed the area of present-time Panama, Colombia, Ecuador, Peru, Venezuela, and north-western Brazil. The dispute between centralists and federalists, which would lead to various civil wars throughout the nineeenth century, was the main cause of the dissolution in 1831.

decades later, in the 1860s, a Swedish-German mining engineer –Carl Sigismund De Greiff– working for a US mining company in Antioquia, attempted to introduce mercury amalgamation in the gold mines of Segovia and Remedios in Northwestern Antioquia (Ramos et al. 2007). De Greiff, along with a group of German and Swedish mining engineers, worked with local miners, engineers, and investors to modernize mining techniques in Colombia, mainly in Antioquia, where gold mining between the pre-Columbian times and the mid-nineteenth century had been almost exclusively alluvial. Aside from mercury amalgamation, De Greiff promoted other technical changes such as the use of stamp mills and rammers to crush and grind ores more efficiently. Between 1863 and his death in 1870, De Greiff was the head of the British company Frontino & Bolivia Ltda. Mining Co., which had been exploiting the gold of the Northeastern Region of Antioquia since 1852 (Ramos et al. 2007: 550).

Geographer Robert West documents how metalworking communities of the Pacific Coast have added herbs to molten mixtures of alluvial gold and copper, which enhanced the different textures and colors of gold and copper with a new scent, thus facilitating its sorting and collection (Craig & West, 1994). However, historiographical accounts on the history of amalgamation and mining engineering in Colombia do not discuss how European mining engineers engaged or not with other forms of mineral processing (Lenis Ballesteros, 2015; Lenis Ballesteros, Augusto, & Ballesteros, 2010; Poveda Ramos, 1986, 1987, 1993). Therefore, the same downplaying of native knowledge that characterizes UNESCO's declaration of metallurgic knowledge from Almaden as heritage is also reproduced in the local accounts of the technique and its trajectory.

3. The toxic legacies of an unfinished technical revolution

The nineteenth-century demands for industrialization and the scarce local expertise on mining also brought about certain dependence on foreign specialists for geological-mining prospecting tasks throughout the second half of the nineteenth century (Poveda Ramos, 1986, 1987). In response, the government and members of the elite started to send their sons to study mining engineering in Europe and the US, mainly to the school of mines of Cornell, Rensselaer, Colorado, Berkeley, and Paris (Murray 1997). This migration triggered the creation of the first school of mines in Colombia, almost a century after Mutis and the D'Elhuyar brothers sent by the Bourbon kings had failed to do so. In 1887, siblings Tulio and Pedro Nel Ospina[41], two sons of Antioquia's conservative and Catholic elite who had studied mining engineering at UC Berkeley's then-recently established College of Mining, returned to Colombia after completing their studies and founded the Escuela Nacional de Minas in Medellin, Antioquia, which became the first institution of mining education in Colombia (Murray 1997).

In the context of this increasing available expertise and technology, another key indicator of the companies' prominent role in stimulating mining is that since the diffusion of mercury amalgamation in the 1860s, and at least until the 1970s, there are reasons to believe that mining companies brought or imported practically all the mercury imported to Colombia. As discussed at the end of Chapter 2, my archival research of Colombia's official import statistics suggests that it is plausible that between 1870 and 1905, the country's mercury imports all came from the

[41] Pedro Nel Ospina eventually became president of Colombia between 1922 and 1926. His father had been President between 1851 and 1857.

US, France, and Great Britain (Anuario Estadistico 1875-1931). Moreover, another important factor that helps explain the persistence of mercury use in mining well into the twentieth century is that while cyanidation was introduced in Colombia precisely in 1905, it was an expensive process that was not at the reach of most independent, non-corporate miners of the time. Cyanidation only gained prominence in Colombian mining in the 1980s and it was not until the 1990s that the Ministry of Environment endorsed it as a "clean production" practice.[42] Nonetheless, as discussed in Chapter 2, the Colombian's state active provision of mercury as part of government technical assistance projects in the 1950s (which deserves a further inquiry in a future project) was also part of the conditions that enabled mercury amalgamation to persist in Colombia and elsewhere in South America.

In sum, the diffusion of mercury amalgamation (and, in general, the efforts to promote mining education and modernize mining) in the nineteenth and twentieth-century in the young Latin American nations went hand in hand with elite efforts to modernize and build the states, their militaries, and financial autonomy (Brown 2013).[43] In this context, mercury amalgamation was a critical technology that epitomized modernity, independence, and technical advancement. Due to the investment and expertise catalyzed by these companies, gold and silver mining in Colombia between 1852 and 1912 was carried out and controlled primarily by foreign companies (Castillo and Rubiano-Galvis 2019). Their investments facilitated the massive introduction of mercury amalgamation for extracting gold (Born's version), as well as other mining technologies such as the variations of stomping mills (called Chilean, Californian, or the *Antioqueño* which had wooden stomps (Ramos et al. 2007) which were also critical in the revival and expansion of vein deposit mining.

III. Conclusion

This chapter traces the use of mercury as part of the amalgamation process in different periods. Today, artisanal gold miners in Latin America, Africa, and Southeast Asia who use mercury to amalgamate gold are blamed as the culprits of a toxic global economy (Goldstein, 2021). But before being considered a "bad practice" to be eliminated in the name of global environmental health (UNEP, 2019a), for more than three centuries, the amalgamation technique catalyzed Spanish colonialism and global capitalism (J. Moore, 2010) and was a symbol of modernity and financial power. During that time, the expertise for extracting and processing silver and gold spanned alchemy, metallurgy (both Indigenous and European), geology, and the emerging field of mining engineering. With the rise of gold mining and the decline of silver mining in the mid-nineteenth century, metallurgists on both sides of the Atlantic kept enacting the alchemists' dream (obtaining gold using mercury) but now with a professionalized mining

[42] Interview 27.

[43] But the adoption of amalgamation for processing vein gold in South American mining was not homogeneous across the region. Contreras (1999) argues that before the waves of German engineers' migration to South America in the second half of the nineteenth century, Peruvian metallurgists were already amalgamating gold. It is important to note that by the mid-nineteenth century, the patio method was abandoned in Mexico's silver mining, and by 1885 it was no longer used by any large silver producing nation in the Americas or elsewhere (Contreras 1999: 393). The invention and diffusion of leaching in the 1890s significantly decreased mercury use in silver mining worldwide (Contreras 1999). In turn, the Born method started to become widespread in gold mining in a context that favored foreign investment and technical expertise.

expertise inspired by ideas of modernization and efficiency. Cyanidation became widely popular in large gold operations worldwide in the 1900s, but many middle- and small-scale mining sites have continued using it.

To understand how mercury took center stage in international politics, as well as the prominent role of ASGM in such process, one must be attentive to the history of the amalgamation technique, its emergence, diffusion, uses, and adaptations in specific locales, particularly in those where the international community now seeks to eradicate this technique. The history of mercury use and mining has been heavily obscured in the contemporary focus on artisanal mining as a primitive, outdated, and damaging production model; and in the blame being put on smaller miners worldwide. Consequently, the idea that the international community needs to 'clean up' ASGM has become widespread -- no matter that this will not solve the 400 years of adverse effects from colonial mining or address the historical responsibility for these. Also, this narrative downplays that silver and gold mining was practiced for centuries and is still being practiced in parts of what became the US, Europe, and Europe's Latin American colonies. Far from Europe providing the science and knowledge to Latin America, the flows of knowledge and science were much more complex, interactive, and multi-directional, with essential developments happening within Latin America both prior to and during colonialism.

Mercury was a symbol of industrial modernity from the rise of the Spanish empire through the twentieth century. Despite changing forms of the colonial government, entrepreneurial identities, and the rise of professional, scientific metallurgy, amalgamation and mercury use remained 'modern', and Latin Americans were erased or made 'backward', despite their knowledge, expertise, and experimentations with amalgamation processes that built on what they learned from early European interlocutors. The discussion of the flows of knowledge and technology associated with mercury use in silver and gold mining that I presented here counters and complicates contemporary mainstream, policy-oriented accounts of the amalgamation technique as a symptom of cultural and technological backwardness of the developing world—when in fact, it was the symbol of modernity. Today, the international community promotes the phasing out of mercury with the promise of detoxifying the future (whose?) but with little attention to the histories of dispossession and toxic colonialism that mercury amalgamation has long been a part of.

The imaginaries of a mercury-free world and the declaration of Almaden as a world heritage site discussed in chapter 1 seem contradictory, but they are in fact, complementary; not only do they share an enthusiasm for the universal value and power of science and technology, but they also downplay and omit a key part of mercury's history that came before the attempts to discourage it: the history of attempts to promote it in the name of empire and modernity. Aside from not accounting the material (residual) legacies, the imaginaries of a mercury-free world that center the amalgamation technique as the target of intervention risk losing sight of situated histories in which said technology has been embedded.

Two situated histories that complicate said imaginaries are the exploitation of indigenous labor during colonial mining and the uneven exchanges between European and American metallurgists of mercury-related expertise, artifacts, and methods. Against dehistoricized depictions of mercury amalgamation as a backward technique in backward underdeveloped

countries, this chapter highlighted how mercury use in colonial silver and gold extraction in the Americas relied on both native and imperial networks of knowledge and technology involving Amerindian peoples, Mexican, Spanish, and Peruvian metallurgists, and European and South American mining engineers and characterized by various power asymmetries.

CHAPTER 4. Global toxics and epistemic justice: the politics of knowing mercury as a global pollutant

Introduction

When an environmental problem is constructed and makes it onto the global stage, various knowledge production and circulation processes come into being or become more visible. The increased attention and visibility stimulate new research and collaborations, donor agencies may expand or adjust the scope of their funding, and national science policies shift to reflect and foster the local relevance of the new global problems (Tyfield, Lave, Randalls, & Thorpe, 2020). In turn, collaborative efforts to characterize the global dimensions of the problem emerge, constituting communities of practice or making visible already existing ones. When international organizations such as the UN, WHO, or the World Bank become involved in producing knowledge about a problem, for example, by instituting science-policy platforms, scientific assessments, advisory panels, or data dashboards updated almost in real-time, the global scope of their work endows them with particular visibility and authority (Beck, Forsyth, Kohler, Lahsen, & Mahony, 2017). However, as many STS and environmental politics scholars studying knowledge production have demonstrated, credibility and authority are not a given. The claim that those institutions speak for a global audience does not prevent them from concealing or ignoring inequalities in current and past practice and reporting, as well as power asymmetries nor does it necessarily shape how the problem in question is understood and acted upon (Corson, Gruby, Witter, Hagerman, & Suarez, 2017; Kohler, 2019). As we saw in Chapter 3, knowledge is produced in various locales and travels in multiple directions configuring epistemic geographies which are not only highly politicized but which can also reproduce patterns of inequality and injustice (Beck & Mahony, 2018).

One important aspect of mercury's recent social and political lives has been its framing, first, by national states as a sort of appropriate technology with a part of "identity" related to national patrimony, and second, a very recent reframing as a "global pollutant" across the board. I have shown in earlier chapters that, since the first half of the twentieth century mercury's use in silver and gold mining has increased. In contrast, its use in other industries, such as chlor-alkali production and the manufacturing of various products such as pesticides, explosives, and medical measurement devices, has decreased (UNEP, 2002b). This diversification of mercury uses expanded the reach of its toxicity to a wider range of landscapes and led to its recognition as productive of environmental health issues (Egan, 2019). Since the 1970s, governments, scientists, and activists have produced much knowledge about mercury toxicity across scales and sectors (Basu et al., 2018). That body of knowledge includes biomonitoring studies measuring mercury's unwelcome presence in humans and landscapes, models estimating atmospheric fate and transport of mercury emissions, as well as remote sensing and satellite imagery used to monitor land change activities associated with mercury emissions or releases (D. Jensen & Petersen, 2018; Lacroix et al., 2019; Selin, 2009; UNEP, 2018). This body of knowledge has also been instrumental in the element taking center stage in international politics and has co-produced

specific instruments and regulations such as the Clean Air Act in the US, the CLRTAP Convention in Europe, and the Minamata Convention.[44]

A critical process in producing mercury as a global pollutant has been the conduct of the Global Mercury Assessment (or GMA), a scientific process established and commissioned by UNEP in 2001. Some 130 scientists over two decades and four assessment reports have been enrolled in this process. UNEP's Governing Council requested UNEP to conduct a scientific assessment including existing knowledge about mercury in four areas: the chemistry of the substance, particularly methylation in various forms and environments and its transformations, creating inventories of sources of atmospheric mercury emissions and releases to land and water, estimating the scope of long-range environmental transport; and documenting the dynamics of mercury as a global commodity.[45] There was no directive to participating scientists as to how to interpret or follow this mandate. For instance, mercury's *history as a colonial commodity* could have been considered in the fourth area, but it was not. Exposed populations could have been invited to contribute their voices and experiences as coauthors of the assessment. However, they were not; their knowledge was never part of the compilation in any of the four areas. Moreover, insufficient financial contributions from the states who were part of UNEP's Governing Council also shaped the scope of the first GMA report. Contrary to the group's original intentions, the lack of funding limited the discussions to English-speaking experts from Northern countries. Moreover, UNEP adopted a somewhat narrow interpretation of the mandate according to which atmospheric chemistry and ecotoxicology were the only two fields of knowledge deemed relevant, and almost no expertise on the social or political dimensions of mercury's global reach or the unevenly experienced effects of toxicity were considered.

The call to carry out a global mercury assessment echoed the common practice by UNEP and other international institutions of commissioning assessments or reports to science-policy platforms, ad hoc working groups, or other forms of institutionalized expertise on urgent global environmental problems. The IPCC and IBPES are some of the largest international science-policy platforms and, therefore, the ones that have received the most scholarly attention (Mahony & Hulme, 2018; Patterson, 2021), and there is copious literature about these and other cases (Cash & Clark, 2005; Clark, Mitchell, & Cash, 2006; Mitchell, Clark, Cash, & Dickson, 2006). However, the Global Mercury Assessment is not as large as other assessments, and the mercury regime does not have a research organization resembling the IPCC – at least not for now. For reference, the Global Biodiversity Assessment started with 1,500 scientists from 80 countries in 1995 (Cash & Clark, 2005), and the pool of IPCC authors in 2022 has already surpassed 6,000 names. The Global Mercury Assessment, in its four iterations, has only summoned 127 authors

[44] At the global level, the regulation of mercury as a pollutant began in 1972 when the UN Stockholm Declaration included mercury as part of a broader concern about the toxicity of harmful chemicals, and eventually crystallized in the 2000s and the 2010s with the UN Minamata Convention and other regulatory instruments such as certifications and voluntary guidelines for mineral supply chain transparency (H. Selin, 2014a; Sippl, 2015).

[45] The assessment should: "(a) *Summarize* existing information including recent authoritative reviews of the chemistry, including transformation and methylation processes, toxicology, and impacts of mercury on human health and the environment; (b) *Compile* and *summarize* existing information concerning the global natural and anthropogenic sources of mercury; (c) *Consolidate* and *analyze* information regarding relevant environmental long-range transport and the origin, pathways, deposition and transformation of these substances on a global scale; (d) *Examine* and *describe* the sources of release of mercury to the environment, and the current production and use patterns of mercury as a global commodity" (UNEP GC 2001).

from 25 countries. The first GMA in 2002 was drafted by only four people who even hesitated to call their own report "global."[46]

Even though UNEP's GMA effort is smaller than, say, IBPES, IPCC, or FAO's Global Forests Assessment, the stakes of defining how mercury matters globally have profound implications for all industries and economic sectors that use or emit mercury, especially those under particular political scrutiny such as gold extractors/miners and coal-fired power plants. Decisions and processes globally associated with what to know about mercury, how to know it, and from what standpoint have implications over what dimensions of the problem are more important, urgent, and actionable at the global level and which ones are left to nation-states alone. Given the politicized history of mercury as a chemosocial substance entangled in histories of extraction, exploitation, and domination, when such a substance is redefined as globally relevant, it matters to know who participates in defining it, with what knowledge, and with what engagements with the regulatory apparatus wanting to "make mercury history" at the global level. As has been the case in climate science (O'Neill et al., 2010), epistemological hierarchies risk marginalizing specific framings of the problem and excluding fruitful political and social responses.

This chapter examines the politics of scientific practice on global mercury pollution in the last three decades and argues that at the global level, mercury has been known through a knowledge production apparatus characterized by acute disciplinary, geographic, and gender inequalities. I make the case that such inequalities are co-produced with how mercury is governed and imagined globally, a process that also privileges certain dimensions of the substance's chemosocial life as more urgent than others and leaves some of them to be addressed locally, such as mercury releases to land and water, or in other forums such as human rights and indigenous rights treaties. Eschewing the dominant narrative that mercury science and subsequent governing laws and policies are apolitical, I demonstrate that knowledge production around mercury as a global pollutant is highly politicized and intimately entangled with the politics of scientific practice and its representation.

The chapter is divided into three sections. First, I revisit the process through which mercury was globalized as a pollutant. Second, I empirically analyze some of the most authoritative nodes of knowledge production about mercury globally and discuss how they are characterized by geographic, disciplinary, and gender inequalities that shape how we collectively think of and act on mercury as a global problem. In particular, I present an analysis of the International Conference on Mercury as Global Pollutant (ICMGP) founded in 1990; UNEP's Global Mercury Assessment reports written between 2002 and 2018 commissioned by UNEP's

[46] Interviewee 40. Also, see UNEP 2002: *"Because of the large volume of reports, articles, abstracts, etc. relating to mercury that were submitted/collected, it was not possible to review all the information in detail in the time available. The information was screened and a prioritization was made. Focus was given to country-specific information that might add to the global understanding of the use and regulation of mercury, especially from non-OECD countries, and information that might add to the general knowledge of the various issues linked to mercury, based on the recently published authoritative reviews on such issues. As this report should provide a global overview, summarizing the issues related to mercury, there are substantial amounts of detailed information dealing with various aspects that have not been included, such as detailed national mercury consumption and use data. This information might, however, be a basis for further, detailed review and analysis later should a decision on further work be taken."* (UNEP 2002).

Governing Council; and the emerging networks of knowledge production about mercury in South America in the last thirty years. In the third and final section, I provide evidence of why a range of voices, climactic zones, and national and local perspectives need to be included in the GMA assessments and decision-making forums on mercury. I speculate how the framing of mercury as a global problem would look if such knowledge inequalities in global political and knowledge forums were to be corrected and if other voices such as those of indigenous people, women, and social scientists other than economists were included.

I. Producing a global pollutant

Although the toxic effects of mercury have been observed for centuries, the visibility of the substance in international development and global environmental politics is relatively recent. The origin story of mercury's social life as a global pollutant is often traced back to the well-known Minamata Bay disaster in Japan in the 1950s.[47] The Minamata Bay disaster, as well as emerging scientific studies done in Scandinavian countries and the US, triggered a myriad of local and regional efforts in the 1970s –especially in Europe and the US– to curb the circulation and adverse effects of anthropogenic liberations of mercury (Selin 2013). The interest in its high toxicity and hazard to human health and the environment took hold in the last century, as communities and scientists began finding mercury *out of place* (see Douglas 1967) in regions where it was not being used locally such as the Arctic, Scandinavia, or the Great Lakes. In parallel, states and international agencies began developing acceptable pollution and exposure standards to make mercury's health and ecological transgressions legible.

In the 1980s and 1990s, a more widespread environmental concern about mercury arose chiefly from three aspects of mercury pollution also seen in other chemicals, such as persistent organic pollutants (POPs) that were then being documented: persistence in the environment; global transport; and bioaccumulation (Selin 2010). Scientists found that mercury travels through atmospheric and oceanic flows and confirmed that once it deposits, bacteria degrade it and turn it into its organic form called methylmercury. Methylmercury is readily taken up in tissues and is not excreted by the body as easily as inorganic mercury. Bioaccumulation of methylmercury in the food chain is a primary contributor to human exposure through the consumption of contaminated fish (Yang, 2014). Today, it is known that mercury toxicity for humans and other organisms varies widely depending on the chemical form, the pathway of exposure, the amount, and the vulnerability of the person exposed (UNEP 2002). The human populations who suffer the most significant health effects from exposure to mercury emissions and releases are pregnant women, neonates, children, and adolescents (UNEP, 2013).[48]

[47] Due to a chemicals company's dumping of mercuric chloride as waste in the Bay, mercury concentrations in silt near the factory exceeded two million parts per billion (mercury concentrations at sea are typically lower than two parts per billion). A rash of mercury poisonings around Minamata came to be known as Minamata disease and caused profound health impacts in surrounding populations (Yang, 2014). These extreme cases showed that mercury poisoning could result in fetus deformities, mental illness, paralysis, and coma (Gibb and O'Leary 2014), and stimulated an extensive body of knowledge about the risks of mercury to environmental health (United Nations Environmental Programme, 2013).

[48] Mercury poisoning causes different manifestations based on age, for example, in fetuses, children, or adults. Symptoms are varied and can include skin irritation, fever, headaches, nausea, diarrhoea, fatigue, insomnia, irritability, diminished sensorial acuity, blindness, renal problems, memory loss, tremors, brain damage, and other neurological

Like Minamata Bay in Japan, the Artic has a prominent place in the history of mercury and our scientific knowledge about it. Since the 1970s and 1980s, there was already concern about exposure to persistent organic pollutants (POPs) that had been discovered in the Arctic. This motivated scientists to investigate the presence, pathways, and effects of mercury and other pollutants there, as well (Herrmann 2017; Selin 2010). The fact that elemental mercury can travel long distances through atmospheric and aquatic transport, explains its unwelcome presence in regions with no sources of mercury emissions such as the Arctic. It is estimated that about 200 tons of mercury are deposited in the Arctic each year (UNEP, 2013b, p. 22). Once there, mercury bio-accumulates and biomagnifies in animals used for subsistence food sources such as fish, seals, whales, and polar bears. Studies have shown that Inuit men, women and children in the Arctic have high levels of mercury in their blood, higher than the global average and above health guidelines (Herrmann 2017; cf. AMAP 2013). External pollution has piled up in the Arctic for centuries. However, the steady rise started with the coal dependency created by the first Industrial Revolution - recent studies estimate that the Arctic permafrost holds 32 million gallons of mercury and other toxins, which is twice as much as is present in soils in the rest of the world (Schuster et al., 2018).

The centrality of the Arctic in global debates about mercury toxicity is also owed to the work of the Arctic Council (AC), primarily its scientific working group, the Arctic Monitoring and Assessment Program (AMAP), established under the Arctic Council in 1997. In their analysis of the science-policy interface between 1989 and 2013, leading to the adoption of the UN Minamata Convention on Mercury in 2013, Platjouw, Steindal, & Borch, (2018b) highlight the role of AMAP as a "science broker" whose work was critical for the signing of the Minamata Convention and, more broadly, for raising the alarm about mercury being “out of place” (Douglas 1967). AMAP acted as a "provider, broker, and communicator" of science related to the environmental problem of mercury, first at the regional level in the Arctic and then globally (Platjouw, Steindal, & Borch, 2018b). The pool of experts linked to AMAP did assessments of mercury in the Arctic in 1997, 2002, and 2011, compiling the existing evidence about mercury's presence in Arctic landscapes, wildlife, and communities, with whom they collaborated. AMAP's work had regional significance by catalyzing the negotiation and adoption of the two Protocols of the Convention for Long-Range Transport of Atmospheric Pollutants in Europe, one on heavy metals and one on POPs (H. Selin, 2014b).

AMAP's work eventually became relevant beyond the Arctic and Europe. In the 2000s, AMAP started cooperating closely with UNEP to inform ongoing debates about global pollutants, including the negotiation that led to the Stockholm Convention on POPs in 2001. Other authors deem AMAP a critical contributor to the body of knowledge that justified global action against mercury pollution, in what some see as an example of how Arctic voices have shaped global politics (Young, 2012). Findings of atmospheric mercury deposition and subsequent exposure and bioaccumulation in wildlife and humans confirmed that "the atmosphere is the major transport pathway for the distribution of Hg globally" (Gustin et al., 2016). Alongside the evidence that human influences have dramatically altered the global

disorders such as Minamata disease (Methylmercury Toxicology Effects Committee et al., 2000). There is sound evidence that mercury –in both its elemental and organic forms– has adverse neurological effects and is particularly toxic during fetal development and childhood (WHO 2016, 29).

biogeochemical cycle of mercury relative to a [modeled] pre-industrial baseline, such a conclusion became a critical scientific input for negotiating a global-scale mercury treaty (Noelle E. Selin, 2009, 2014). This cooperation between AMAP and UNEP has been said to be "enhanced the strength of scientific evidence, whereby the severity of the environmental issue and the urgency of drafting a global legal instrument [on mercury] were clearly reinforced" (Platjouw, Steindal, & Borch 2018).

That global legal instrument was the 2013 Minamata Convention. A few years before the treaty was negotiated and the US, China, and India refused a legally binding response to global mercury pollution, part of the compromise was to create the Global Mercury Partnership (hereafter "GMP"), a voluntary alliance of stakeholders convened by UNEP interested in supporting and "catalyzing global action on mercury and offering information, capacity-building, and awareness-raising." The Partnership's work, which included scientists, NGOs, and private firms, contributed to the body of knowledge that kept mercury on the global agenda. The GMP has been characterized as an example of how private-public partnerships can, at least in some cases, "generate new knowledge that advances the formation of intergovernmental regimes, and even influences the content of regimes by enhancing their cooperation and socialization with members of epistemic communities" (Sun, 2017).

From the influence question to epistemic justice

While the accounts above reveal important insights and milestones in the history of how mercury came to be considered a global pollutant, they do not fully account for how authoritative knowledge about mercury was produced, and how it has circulated and reordered a world where until not too long ago, mercury was a positive symbol to the highest levels of empire and industrial modernity (see Chapters 2-3). The account presented above relies on what scholars have called the "speak truth to power" model, particularly the epistemic communities concept – a network of scientists insulated from politics but influencing it through shared causal and principled beliefs (Haas, 2004). This approach depicts the impact of mercury science in policy as fairly linear and with the Minamata Convention as a point of arrival and understands knowledge as a single sort (scientific) and as a variable that can explain international cooperation. For instance, Sun's analysis of the GMP focuses on the "pathways of influence" through which the UNEP-led voluntary Partnership mentioned above managed to propel the intergovernmental negotiations that led to the Minamata Convention in 2013 (Sun, 2017). Overall, accounts of AMAP's role follow the same linear narrative in which Arctic Science "leads to" an international mercury treaty (Platjouw et al., 2018b). Such approaches dismiss the role of the material dimensions of knowledge production and the hierarchies and inequalities embedded in the process (Lahsen, 2004; Martello & Jasanoff, 2004; Rocheleau, 2011).

Given the increase in the demand for scientific knowledge to address many global environmental problems, STS and environmental politics scholars have shown that while the content and rigor of global scientific assessments and science-policy reports matters, its influence is often shaped more by the process of generating them and by external factors affecting the receptiveness of different audiences. That can include the context and nature of the problem, how politically contested it is, how it is linked with other issues, and the degree of

consensus (Mitchell et al. 2006: 6; Kohler 2019). [49] Thus, reports are social processes in which the questions asked about a given problem and the information collected and analyzed are addressed not only at the outset but through ongoing and iterative processes between policymakers, scientists, and stakeholders (Kohler, 2019; Kohler, Conliffe, Jungcurt, Gutierrez, & Yamineva, 2012).

Another concept is Jasanoff's (2014) *three-body model* for studying scientific advice and expertise, which proposes to observe what bodies sit at the table, what bodies of knowledge or techniques they mobilize or rely on (including metrics, measurements, and classification devices, a theme I return to in Chapter 5), and through what institutional arrangement is their work organized (*see also* Kohler 2019). Each of those decisions and those affected by them exemplify what STS scholars have called boundary work: the discursive and material means of policing that thrives by distinguishing experts from non-experts, science from knowledge, and science from politics, thereby augmenting and reinforcing the intellectual and social power of those deemed experts (Beck & Mahony, 2018; Gieryn, 1995). Attentiveness to the politics of knowledge is also a matter of representational justice, particularly for scientists and experts from the Global South, who need to go to great lengths to have their voices heard internationally and domestically (Biermann 2006; Lahsen 2004). Indeed, aspects such as the disciplinary diversity, gender, and geographical origin of the experts shape the type of chosen metrics and their implications for defining the problem to be 'assessed' (Biermann 2006; Lahsen 2004).

Widely cited and referred to in scholarly and policy spaces, UNEP's Global Mercury Assessment has become the most authoritative source of science for mercury policy (Selin et al. 2018). A token of this is that all three COPs of the Minamata Convention have always secured a special side event for the GMA authors to showcase the latest 2018 report, despite the GMA preceding the Convention and being largely independent of it although closely connected. Also, while country delegates, NGOs, and observers have different views on the GMA, they tend to regard it as an authoritative and inescapable source of knowledge. UNEP's Global Mercury Assessment (GMA) has not been critically studied in the assessments literature, nor are there studies about the politics of knowledge of which the process is part. Yet, the making of the GMA sheds light on the politics of environmental knowledge and the global toxic injustices in which mercury is embedded, including the increasing flows of mercury coming in and from the Global South. Rather than a focus on the "influence" or "effectiveness" of scientific advice –defined as instrumental for international negotiators to reach consensus decisions (Eckley, 2002)–, I characterize the GMA process as part of a larger circuit of knowledge and power, and I examine it using criteria such as institutional, disciplinary, and gender diversity. Before the in-depth analysis of the reports, I present a brief background of the GMA process and an overview of each report.

II. Whose voices counted? Knowledge production about mercury as a global pollutant

[49] Generations of IR scholars have dealt with the role of scientific knowledge for international politics (Haas 1983; Mayer, Carpes, and Knobilich 2014: 19), but some of the most salient contributions have come from global environmental politics scholars (Haas 1990; Kohler 2019).

In this section, I present an empirical analysis of knowledge production about mercury as a global pollutant. Specifically, I examine the International Conference on Mercury as a Global Pollutant (ICMGP) meetings and its members' policy-making involvement, the UNEP's Global Mercury Assessment process, and the emerging research networks on mercury in South America. Since international conferences, authoritative reports, and networks of exchange are typical sites and objects through which knowledge circulates unequally across various worlds and instances (Rodriguez-Medina, 2013), they are ideal vantage points for the analysis.

The analysis advances two ideas. First, the centers of calculation (Latour 1987) of scientific research on global mercury pollution and training on how to assess it have been primarily located in Europe and North America. Despite various efforts to diversify the scientific workforce in some countries and the ICMGP network in general, the networks of knowledge production and exchange have mainly been dominated by researchers from those places and characterized by the marginal place of researchers from Southern countries, the social sciences, and indigenous peoples. Second, the UN's effort to render mercury a problem of global relevance through UNEP's Global Mercury Assessment reports (considered the most authoritative scientific source on mercury) has also been characterized by marginal participation of Southern and female researchers and by a disciplinary hierarchy of experts coming from the atmospheric sciences and ecotoxicology.

1. The ICMGP Conferences: towards disciplinary and geographic diversity

The awareness of the global nature of mercury pollution led to the formation of an International Conference on Mercury as a Global Pollutant (ICMGP) in 1990. Every two years, since the first meeting in Gävle, Sweden, in 1990, the ICMGP convenes researchers, policymakers, and industry to discuss advances in mercury research and facilitate international collaborations. In terms of expertise and disciplines, atmospheric chemists, biogeochemists, and environmental chemists have been the most prominent in the conferences and their outputs. ICMGP scientists' perspectives on mercury policy have appeared in numerous peer-reviewed journals such as *Environmental Science and Technology, Science of the Total Environment, Ambio,* and Royal Society of Chemistry publications. Consensus-making and a strong impetus for influencing policy agendas have been critical traits of the ICMGP crowd.[50] In preparation for the 8th ICMGP in Madison in 2006, the ICMGP network put together five expert panels that synthesized the state of mercury science in the ‘Madison Declaration on Mercury Pollution’, a document containing consensus conclusions on key policy-relevant questions concerning atmospheric sources of mercury, methylmercury exposure and its effects on humans and wildlife, socioeconomic consequences of mercury pollution, and recovery of mercury-contaminated fisheries (Lindberg et al., 2007). OK tell us here how many participants were from Northern countries and how many were white men. As a start.

Since the early 2000s, ICMGP-affiliated scientists have been actively involved with the efforts that led to the negotiation and implementation of the UN Minamata Convention. After the 10th meeting in Halifax in 2011, ICMGP participants published a set of papers updating some points from the Madison Declaration, particularly about mercury sources and human and wildlife

[50] Interview 3.

effects (Celia Y. Chen et al., 2016). ICMGP members provided these materials to delegates at the negotiations that led to the Minamata Convention signing in 2013, as well as at the first Conference of Parties (COP) of the Minamata Convention in September 2017, where Chinese, Russian, Arabic, Spanish, and French translations of the documents were available (Chen & Driscoll, 2018).

Table 2. Year and location of annual ICMGP conferences 1990-2022

1st ICMGP 1990 Gavle, Sweden	9th ICMGP 2009 Guiyang, China
2nd ICMGP 1992 Monterey, CA, USA	10th ICMGP 2011 Halifax, Nova Scotia, Canada
3rd ICMGP 1994 Whistler, BC, Canada	11th ICMGP 2013 Edinburgh, Scotland
4th ICMGP 1996 Hamburg, Germany	12th ICMGP 2015 Jeju, South Korea
5th ICMGP 1999 Rio de Janeiro, Brazil	13th ICMGP 2017 Providence, RI, USA
6th ICMGP 2001 Minamata, Japan	14th ICMGP 2019 Krakow, Poland
7th ICMGP 2004 Ljubljana, Slovenia	fifteenth ICMGP 2022 online
8th ICMGP 2006 Madison, WI, USA	

Source: own elaboration based on ICMGP conferences websites

Despite their active role in making or underwriting mercury policy at the global level, most ICMGP meetings have been held in Europe and North America and dominated by researchers from those places. The fifteenth meeting scheduled for 2022 was going to be the third out of fifteen meetings in three decades convened outside the global North (it was going to be in Cape Town, South Africa), but it was moved online due to the pandemic (ICMGP 2022). In interviews with me, the conference leadership stated that they are aware of the sub-representation of the Global South not only in terms of meeting locations but also regarding the attendance of researchers from Southern nations and the research topics that they deem important for policy making.[51] Such a problem was also highlighted at a UNEP Governing Council meeting in 2002, when a delegate from Slovenia, where the then-next ICMGP was going to take place, noted that "there had unfortunately been few participants from African developing countries" in international mercury conferences and encouraged UNEP Governing Council members to "publicize the [ICMGP] conference in their regions" (UNEP 2002).[52] The organizers of the 7th ICMGP in Ljubljana in 2004 acknowledged the problem and even signaled ASGM as one of the topics that might motivate more researchers from "developing countries of Latin America, Africa, and Asia" to join.[53]

[51] Interviews 3, 4, 7.

[52] "The representative of Slovenia informed the meeting that a series of technical and scientific conferences on mercury had been held in the past for which assistance had been granted to ensure the participation of delegates from developing countries and thereby encourage the wide dissemination of knowledge on health and environmental problems related to mercury. She announced that the Seventh International Conference on Mercury as a Global Pollutant would be organized in Ljubljana, Slovenia, from 27 June to 2 July 2004. She noted that in the past there had unfortunately been few participants from African developing countries and encouraged members to publicize the conference in their regions" UNEP/GC.22/INF/2 15 November 2002, par. 49.

[53] "*The global nature of mercury issues is also shown by increasing international participation, from a few nations at [the first meeting in 1990 in] Gavle, mostly from the Northern hemisphere, to more than 64 in Minamata in 2001, where almost half of the participants were from developing countries. One of the reasons is related to a revival of gold exploration in the developing countries of Latin America, Africa, and Asia, for which mercury is used to extract gold; this caused an increase in mercury research because of the need to set environmental quality criteria in these areas*." (emphasis added). Taken from: http://www.speciation.net/Events/7th-International-Conference-on-Mercury-as-a-Global-Pollutant-;~/2003/12/17/791.html

At Minamata COP1 in Geneva in 2017, I interviewed 12 mercury researchers who were assiduous participants of ICMGP. Milena Horvat is one of the most senior mercury scientists and coordinator of two of UNEP's Global Mercury Assessment reports. She acknowledged that during the first decade of ICMGP, there was little geographic and disciplinary diversity at the conferences. Dr. Horvat recounted that modelers' presentations on atmospheric chemistry and lake chemistry dominated the first ICGMP– they occupied at least seventy-five per cent of the conference program.[54] Dr. Horvat also highlighted how, unlike today's international focus on marine fish or ASGM, back in the 1990s, mercury was very high on the agenda in the US because of concerns over mercury-contaminated fish in lakes and reservoirs, but it did not have the international significance it acquired fifteen years later. Back then, there was much mercury from coal burning, and many plants did not have the best technology. Therefore, the US Department of Energy invested significant resources in funding mercury research, but at the domestic level only. In addition, mercury was part of the public concern for acid rain, which was on the headlines for many years. Moreover, as in Scandinavia, there were concerns about significant pollutants emitted from large stationary sources that cause acid rain, one of them being mercury. With slight variations, such thematic emphasis –almost exclusively focused on mercury's chemosocial life in the Global North– characterized the following conferences.[55]

After three conferences in North America, ICMGP moved to Europe in 1996, but the thematic and disciplinary emphasis did not shift substantially. The fourth meeting in Hamburg was also mostly about atmospheric transport modeling. According to Dr. Horvat, it was not until the ICMGP moved to Brazil for the fifth meeting in 1999 and then to Minamata in 2001 that the network started to attract people from other disciplines, different regions of the world, and researchers who used other methods to study mercury's global impacts and relevance. In those meetings, there were presentations about human exposure to mercury in the Brazilian Amazon for the first time. The Minamata meeting (2001) also gathered researchers who had been following the legacies of the disaster in Minamata Bay in the 1950s and were doing biomonitoring work.[56] The 2006 meeting in Madison gave place to the network's involvement in mercury governance globally, bringing about the Madison Declaration mentioned above and then a meeting explicitly organized around the issue of "science informing global policy" (Edinburgh in 2013). While most of the space and power at ICMGP is still dominated by atmospheric chemists today, an unprecedented number of presentations related to ASGM and mercury in Southern nations characterized the 14th ICMGP meeting in Krakow in 2019, significantly more than in the Rio meeting, almost two decades earlier.[57]

Despite the increasing expansion of ICMGP's network, it is still primarily dominated by European and North American scientists. A prominent American mercury scientist and an active member of ICMGP defined the low participation of Southern researchers at ICMGP (and the Minamata COPs) as a symptom of a larger problem in science: "we [at the network] don't know any mercury scientists in many countries because in many places there are not any mercury

[54] Interviewee 8.
[55] Interviewee 8.
[56] Interviewee 8.
[57] Scientists, consultants, and mining engineers who attended the meeting coincided in having observed a larger disciplinary diversity in the conference program and venue halls. Interviewee 12, Interviewee 1, Interviewee 36.

scientists at all".[58] Indeed, the massive disproportion of the scientific workforce across the developed and the developing world has been a more extensive historical problem widely discussed by science studies scholars (De la Vega & Vessuri, 2008), agencies such as UNESCO, and other observers of the uneven international dynamics of knowledge production and circulation.

2. UNEP's Global Mercury Assessment (GMA) reports

a. Background and context

In February 2001, UNEP's Governing Council[59] called upon UNEP to initiate a global assessment of mercury "that could form the basis for appropriate international action" (UNEP 2001), a decision representing a political agreement by countries to make mercury an issue that required global cooperation (Chasek and Dowie 2021, 162). One of the main foundations of the call was the evidence of mercury's presence in the Arctic that AMAP had been documenting in the previous decade, as explained in section 1 above. In response, the Governing Council exhorted UNEP to initiate an "expeditious, open, transparent and inclusive process" that includes contributions from "governments, intergovernmental and non-governmental organizations and the private sector" to undertake a global assessment of mercury and its compounds (UNEP 2001).

While UNEP's mandate language asked the contributors to compile already existing information merely, the instruction to *summarize, compile, consolidate, describe,* and *outline* existing knowledge also entailed a particular way of assembling the information – one which would accentuate the already existing asymmetries in the ICMGP network. The mandate to compile "*existing information*," including "*recent authoritative reviews*," came with the implicit and very tangible power to carry out a *boundary work* to determine what counts as "existing" and authoritative knowledge at the global level (Mahony, 2021). To a large extent, the "already existing information" and the authoritative reviews were referring to the work of scientists affiliated with the ICMGP network. In addition, the mandate left some room for the assessment contributors to also "describe" and "outline" "ongoing actions" and "plans" for policy goals such as reducing mercury emissions and releases, improving international cooperation, and enhancing risk communication.[60] The possibility of referring to policy-oriented goals illustrates that the

[58] Interviewee 3.

[59] In 1972, the UN created UNEP to serve as a node for global environmental cooperation UNEP's Governing Council (GC) was then formed as a platform for the international community to discuss important and emergent environmental policy concerns (Ivanova, 2020).

[60] "(e) *Compile* and *summarize* information about prevention and control technologies and practices, and their associated costs and effectiveness, that could reduce and/or eliminate releases of mercury, including the use of suitable substitutes, where applicable; (f) *Describe* ongoing actions and *compile* information about future plans at the national, subregional or regional levels for controlling releases [to land and water], and limiting use and exposures, including waste management practices; (g) *Outline* options for consideration at the twenty-second session of the Governing Council/Global Ministerial Environment Forum addressing any significant global adverse impacts of mercury, inter alia, by reducing and or eliminating the use, emissions, discharges and losses of mercury and its compounds; improving international cooperation; and ways to enhance risk communication" (UNEP GC 2001).

GMA did not simply provide neutral knowledge nor limited its work to merely "describing" the mercury problem.

Given the long-standing relevance of the problem of heavy metals in the Arctic, Arctic States had an active role in UNEP's GMA. Out of eight Arctic Council members, four (Canada, Finland, Russia, and the US) were part of the GC in 2001 that commissioned the first GMA report - in a way, this helped globalize what already was an Arctic and a European concern (Chasek and Downie 2021, 163). The leadership of Arctic countries and their scientific bodies in putting mercury in the global agenda contrasts with the fact that only a third of the world's countries –those who were part of UNEP's GC then– had a voice in the decision 21/5, which commissioned the GMA and defined the terms for how mercury was going to enter international policy and what kind of knowledge was going to be relevant. Since 1972 and until 2012, UNEP's Governing Council was composed of 54 members elected by the UN General Assembly (UNGA) for 3-year terms. Only until the 2012 Rio + 20 Summit, UNGA finally established universal membership to UNEP's Governing Council (Perrez, 2020), which was then replaced by the United Nations Environment Assembly (UNEA), a periodic special session of the UNGA focused on environmental matters.[61] In 2001, only 54 countries had a seat in UNEP's GC: 16 countries from Africa, 12 from Asia, 13 from Europe, 9 from Latin America and the Caribbean, 2 from Oceania, and Canada and the US.

Such uneven and limited participation had tangible consequences on the fate of the GMA and the framing of mercury as a global problem. As part of the implementation of Governing Council decision 21/5, UNEP convened a Global Mercury Assessment Working Group whose main task was to determine whether the assessment report delivered to UNEP by the pool of appointed experts *"provided sufficient evidence of any significant global adverse impacts of mercury that might be addressed by international action (par 30)* (UNEP Governing Council, 2002). As we know, eventually, the response was positive and that approval set in motion a process to negotiate a legally binding treaty. However, an important detail in this process is that due to a lack of financial support, the meetings of the Working Group established by UNEP to evaluate the assessment process was limited to English and had to be shortened in duration and scope due to a lack of resources. The original idea was to hold the Working Group meetings in English, French, and Spanish and to cover the cost of participation of *"one Working Group member per country that was not a member of the OECD would be covered by UNEP"*.[62] However, in the end, governments only contributed half of what had been promised – therefore, the Working Group meetings had to be reduced to only one, the meeting documents were available in English only, and participation of Working Group members from non-OECD countries was funded "*on a "first come, first served" basis until the available resources were exhausted*" (UNEP Governing Council, 2002).

[61] UNEA now works as UNEP's governing body and is the world's highest-level decision-making body on the environment.

[62] UNEP reports that "*the cost of organizing the meeting and supporting participation of members from non-OECD countries was estimated at $410,000, and the extra budgetary resources needed to implement the project totaled $634,000. UNEP was hoping that the full cost of the project would be covered by extra budgetary contributions from governments to a Global Mercury Assessment (GMA) trust fund. However, in early 2002, UNEP had received pledges or receipts of approximately $230,000, meaning that there was a serious shortfall in the funds needed to cover the cost of the Working Group meeting as originally planned"* (UNEP Governing Council, 2002).

Despite these constraints, the Working Group, while composed mostly of experts from OECD countries, managed to meet and "*confirm the need for a global approach to address the issue of global adverse impacts of mercury, as there was evidence that mercury impacts on the environment have considerably increased globally due to human activities and that mercury was being transported globally to regions far from the source of release"* (UNEP 2002). The Group concluded that despite various data gaps in many countries and topics, *"there was sufficient evidence of significant global adverse impacts of mercury and mercury compounds to warrant international action".* The Group also stressed that it was not necessary to have total consensus or complete evidence in order to take action, and therefore potentially significant global adverse impacts should also be addressed. They also recognized the greater vulnerability of certain populations such as children, pregnant women, lactating people, indigenous people and communities dependent on fish as a food source, and workers occupationally exposed to mercury *(*UNEP 2002). It was also noted that mercury could affect agricultural production and other productive activities depending on land and water.

b. Brief overview of the four GMA reports: 2002, 2008, 2012, and 2018

The 2002 GMA report (GMA-02) examined the reasons for concern about mercury, its toxicology for humans and the environment, sources and levels of mercury in the environment, and the prospects for policy actions. The report relied on the best available information at that time, which were primarily from 1995 and before.[63] The authors report that because of the large volume of sources relating to mercury that were submitted and collected, they prioritized certain sources and focused on *"country-specific information that might add to the global understanding of the use and regulation of mercury, especially from non-OECD countries, and information that might add to the general knowledge of the various issues linked to mercury"* (UNEP, 2002a). The report drew heavily on "*recently published authoritative reviews on the various topics relevant to mercury"*, most of which focus on OECD-countries where much of the mercury research was and is still ongoing.[64] In response to the data gaps, the authors attempted to identify and include relevant information from non-OECD countries, with the caveat that it was impossible to construct a global overview of the issues related to mercury *"on a limited number of pages with all the information submitted by each individual country or organization"* (UNEP, 2002a).

The 2008 GMA report (GMA-02) was done at the request of the UNEP GC meeting in 2005. This request came at a conjunctural moment for international mercury action after various years of political blockade that cut across the North-South divide. GMA-02 highlighted the global dimension of mercury and the need to address it through international cooperation. However, between 2001 and 2009, a group of veto states led by the US and joined by China and India blocked twice the initiative to negotiate a legally binding instrument on mercury or heavy metals more broadly. Those countries feared that mercury regulations would hamper their

[63] It was originally drafted by two consulting companies, COWI Consulting Engineers and Planners AS from Denmark and Concorde East/West from Belgium. Then, it was reviewed by members of UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD as part of the Inter organizational Programme for the Sound Management of Chemicals (IMOC), and later approved by the GMA Working Group and the Governing Council.

[64] The most well-document sources of mercury pollution referred to stationary combustion, non-ferrous metal production, pig iron and steel production, cement production, waste disposal, and mercury use in ASGM in 24 countries.

domestic coal industries. In response, in 2005, UNEP and all other states supporting international action compromised on a voluntary body (the Global Mercury Partnership), which would include members from governments, industry, and civil society stakeholders, to address the mercury problem in other key sectors on a global scale. At the same meeting, the GC commissioned an update to the GMA-02, mainly focused on making a global inventory of anthropogenic emissions of mercury to the atmosphere (Platjouw et al., 2018a).

The GMA-08 provided a more solid knowledge base on the global distribution and contribution of emissions sources. GMA-08 estimated that mercury levels in the Arctic air could be five to fifty times higher than levels measured in Europe and North America. The report estimated that forty-five per cent of global mercury atmospheric emissions came from coal burning, whereas fifteen per cent came from cement production. Given the request to focus on atmospheric emissions, UNEP prepared the report cooperating with the AMAP Secretariat (UNEP, 2008). AMAP had recently published two reports updating their estimates on atmospheric mercury deposition in Arctic landscapes. AMAP's involvement cemented the Arctic Council's leadership in global mercury policy not only as a broker of Arctic data but now even contributing to global efforts to document the scale and character of the mercury problem (Platjouw et al., 2018a). [65]

In 2009 the UNEP GC requested UNEP to update GMA-08. [66] The fact that virtually all states validated the GMA ‘02' and ‘08 reports' findings despite only 54 of them having a voice in commissioning them, demonstrates that the GMA reports have been widely influential – even to the point, as we saw above, of propelling the negotiations that led to the Minamata Convention (Platjouw et al., 2018b). In 2007, only the US, alongside Canada, India, and China, were opposed to a more stringent and decidedly global anti-mercury strategy than the voluntary Partnership created in 2005. However, the landscape would radically change in 2009 with the election of Barack Obama in the US. Obama reversed the Bush administration's opposition to regulating mercury globally, a shift that motivated China and India to come on board (Chasek & Downie, 2021, p. 163). The breaking of the veto created momentum, and 120 countries expressed support for a legally binding agreement on mercury during the UNEP Governing Council (GC) meeting in Nairobi in February 2009.

Between 2010 and 2013, three large-scale reports on mercury as a global threat were published: the UNEP "Paragraph 29 study" which recalculated atmospheric emissions estimates from GMA-02 and GMA-08 but accounted for the offsets obtained by emission control technologies such as scrubbers in coal-fired plants; an AMAP report "Mercury in the Arctic" following up a previous report published in 1997, and the 2013 UNEP Global Mercury Assessment. During the same period, five negotiation meetings toward a mercury treaty took place. The GMA-13 report was published in January 2013, five months after states agreed on a convention text. Platjouw et al. argue that because of the timing, the report probably had a

[65] Considerable efforts were made to engage a wide participation of national experts from regions around the globe. That was partially achieved thanks to funding provided by Canada, Denmark, Norway, Japan, Sweden, the Nordic Council of Ministers, and the EU. Experts from Australia, Argentina, Brazil, Mexico, China, India, Japan, Republic of Korea, South Africa and the USA actively participated in Chapter 2 of GMA-08. The sections concerning artisanal and small-scale gold mining were developed through cooperation with experts from the UNEP Partnership on Reducing Mercury in Artisanal and Small-scale Gold Mining and from the Artisanal Gold Council (AGC).
[66] UNEP Decision 25/5 par. 36 "update the 2008 report on atmospheric emissions and transport".

limited impact on the negotiation. However, "it may have provided motivation for some of the delegates to complete negotiations" and was indeed used during the intersessional period when guidance documents, thresholds, and other supporting material were to be developed anyway (Platjouw et al., 2018b). Despite this, most observers attribute the progress of the treaty negotiations to the political turnaround made by the US rather than the substantial and growing knowledge base (Platjouw et al., 2018b).

The GMA-13 estimated that ASGM and coal burning were the most significant contributors to anthropogenic emissions (responsible for thirty-five per cent and twenty-four per cent of global emissions), followed by ferrous and non-ferrous metals and cement production. Anthropogenic sources were responsible for about thirty per cent of annual mercury emissions to air; another ten per cent came from natural geological sources, and the remaining sixty per cent from 're-emissions' of previously released mercury (both natural and anthropogenic) that has built up over decades and centuries in surface soils and oceans. Unlike previous reports, the GMA-13 report was the first attempt to compile a global inventory of mercury releases to water and land, an understudied issue compared to the mercury dynamics and pathways in the atmosphere (UNEP, 2013a). The report emphasized that in the past century, deposition of anthropogenic emissions has caused the amount of mercury in the top 100 meters of the world's oceans to double and concentrations in deeper waters to increase by up to twenty-five percent. The report highlights that anthropogenic mercury releases into waters are likely to reach at least 1000 tons per year. Significant environmental releases are linked to contaminated sites and deforestation, with an estimated 260 tons of mercury previously held in soils being released into rivers and lakes (UNEP 2013).[67]

Whereas earlier studies and assessments concentrated on identifying and comprehending the scope of the mercury problem in the 1990s and early 2000s, later research and assessments have increasingly focused on quantifying emissions and releases (Platjouw et al., 2018a). GMA-18 draws on improved information for estimating emissions and releases and an improved understanding of the mercury cycle. GMA-18 estimated that mercury amalgam combustion during ASGM was responsible for thirty-eight per cent of the total anthropogenic mercury emissions, followed by coal combustion (in thermoelectric plants, although not exclusively) with twenty-one per cent of emissions. Other emissions come from the production of non-ferrous metals (fifteen per cent), cement production (eleven per cent), waste with added mercury (seven per cent), biomass combustion (three per cent), ferrous metal production (two per cent), and other lesser sources (two per cent) (UNEP, 2018). At the same time, the first three GMA reports were dominated by environmental expertise; in GMA-18, WHO collaborated with UNEP to include a chapter on human health and exposure, an addition that signaled WHO's involvement in the Minamata Convention negotiation (at INC6 in 2012) and highlighted the health dimensions of global mercury pollution. In addition, GMA-18 also expanded the scope to include data on biota.

GMA-2018 was launched at COP2 of the Minamata Convention in Geneva in 2018. A slide from a Side Event at the COP on the then-soon-to-be-launched report said, "*The advancement of the GMA work is the result of mercury research and monitoring around the*

[67] https://news.un.org/en/story/2013/01/429592-new-un-environment-studies-show-rising-mercury-threat-people-developing

world. This provides a strong base of knowledge to support actions to reduce mercury emissions and releases to reduce ecosystem and human exposure." The slide signaled that GMA-18 was done with contributions from the Nordic Council of Ministers, the European Commission, the governments of Sweden, Canada, Denmark, and Norway, and "in-kind contributions from many participating countries and institutions." Being the latest report in a process in which topics, priorities, and methodologies shifted, GMA-18 notes that caution is needed when comparing inventories for different years. The following table presents an overview of the topics covered by the GMAs.

Table 3. Evolution of topic coverage in GMA reports 2002-2018

Topic mandated or covered	UNEP GC 2001 Mandate	2002	2008	2013	2018
Chemistry of Hg (methylation, transformation, toxicology)	■	■			■
Current production and uses of mercury	■	■			
Current mercury exposure and risk evaluations for humans		■			■
Impacts on biota					■
Sources and cycling of mercury to the global environment	■	■	■	■	■
Atmospheric Pathways, Transport and Fate			■	■	■
Releases to terrestrial and aquatic environments				■	■
Prevention and control technologies, initiatives for controlling releases and limiting exposure, options for addressing any significant global adverse impacts, and data and information gaps	■	■		■	

Source: UNEP (2001, 2002, 2008, 2013, 2018)

Various things stand out. First, the question of atmospheric pathways and dynamics of mercury has been consistently considered the most crucial topic due to its centrality in UNEP's original mandate and the power of Arctic states and researchers–it has been covered in all four reports. Second, the topical reach of the GMA has expanded beyond the original mandate to include and give more attention to topics such as mercury releases into water and impacts on biota, which until 2018 had been considered more local issues – echoing the emphasis on atmospheric mercury emissions as global and aquatic and terrestrial releases as local that characterized the negotiation of the Minamata Convention between 2009 and 2013.[68] Third, two of the reports went on to propose and "outline" control technologies and even policy recommendations, which included formalizing ASGM or banning mercury use in all industries (UNEP, 2002, 2008). While the latter was part of the original UNEP GC mandate, the report and the pool of authors were unexpectedly specific with the policies they promoted. Nonetheless, they did not provide enough justification or discussion of why those were the most appropriate solutions, especially in countries where ASGM is entangled in more complex politics of informality, inequality, and violence. Perhaps acknowledging this, as well as the increase in social science research on mercury, toxics, and regulation, the most recent GMA dropped the chapter on outlining policy options.

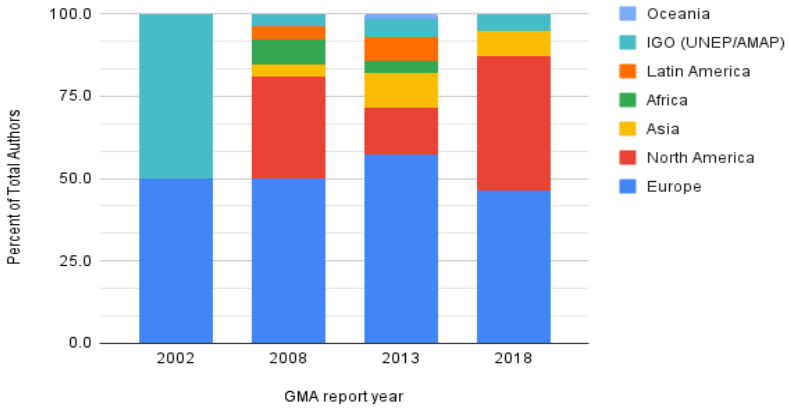
[68] Interviewee 5, Interviewee 6.

c. Analysis of GMA reports' authorship

Geography of institutional affiliation

Since participation in a global environmental assessment speaks to a global audience, various forms of geographical or national representation are considered when nominating authors. One way to examine who structures the structure and the content of the GMA assessments is by looking at the geography of institutional affiliations. Graph 1 illustrates the variation of GMA authors' geography of institutional affiliation across the four reports. Authors affiliated with European and North American institutions overwhelmingly dominate the pool of experts in the four reports.

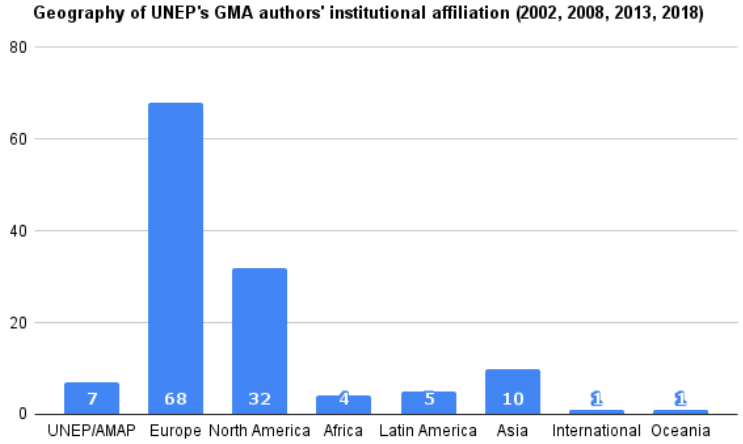
Graph 1. Geography of GMA institutional affiliation in each report



Source: UNEP (2002, 2008, 2012, 2018)

The GMA 2008 report mentions that thanks to funding provided by Canada, Denmark, Japan, Sweden, Norway, the Nordic Council of Ministers, and the EU, it was possible to engage experts from Argentina, Australia, Brazil, China, India, Japan, Mexico, Republic of Korea, South Africa, and the USA in the assessment that year (UNEP 2008). While the participation of authors from Asia and South America increases in GMA-13, it decreases altogether in GMA-18. When the distribution is seen aggregately for the whole GMA process (by accumulating the net total of authors across the four reports between 2002- and 2018), the Euro- and North America-centric character of the body of experts is even more revealing. In turn, both graphs reveal that the participation from Latin American, African, and South-East Asian experts not only has been low throughout the four assessments but even decreased in the GMA 2018 report, where no author from Latin American or African institutions participated. It is important to note, though, that experts affiliated to a European or North American institution can be from the South, and their views might coincide or not with that of the institutions they work for. In that sense, this analysis must be interpreted with those caveats and limitations in mind.

Graph 2. Geography of GMA institutional affiliation in each report



Source: UNEP (2002, 2008, 2012, 2018)

According to Argentinian environmental lawyer Leila Devia, one of the three Latin American authors in the GMA's reports and an IPCC author,

> "(…) in the chemicals and waste arena, Southern countries hold an ambiguous status. There is limited capacity to do research, and often the data quality is poor or preliminary, but that does not mean there are not people researching these topics. We have much work here [in Latin America] but, unfortunately, it does not always get recognized or cited enough at UN bodies due to language barriers and limited resources." [69]

As Devia and other GMA authors told me in our interviews, specific disciplines and experts from the natural sciences have dominated the GMA process, as I also illustrated above with the analysis of the reports' thematic scope variation over time. Two interviewees attribute the authority of atmospheric chemists who can mobilize resources from sponsors from industry and government, but I could not independently confirm this claim.[70]

Various mercury scientists from Latin America, Asia, and Eastern Europe I interviewed during Minamata COPs 1, 2, and 3 mentioned that elevated costs of attendance, lack of English language proficiency, lack of support from their institutions, and doubts about the perceived returns of attending international meetings where most of the researchers do not care about their work, as some of the reasons why few mercury scientists from developing nations do not attend ICMGP meetings or meetings under the UN Minamata Convention.[71] Others perceived that they can have more influence locally and decided to put their efforts into working with specific communities. As one mining engineering professor at a public university in Colombia said: "everybody loves international conferences and panels, and the benefit for one's career is

[69] Interviewee 16
[70] Interviewee 17
[71] Interviewee 2, Interviewee 11, Interviewee 18, Interviewee 37.

undeniable, but under these [working] conditions [with limited resources], one needs to prioritize the local work."[72]

Discipline and contents

Disciplines are "simultaneously indispensable for training and job markets and useless for defining issues and new fields" (Kuhn, 1970; Latour, 2016, p. 12). However, when disciplinary affiliation is a source of authority, especially in science-policy platforms of global assessments, epistemic hierarchies may be created and reinforced. As (O'Neill, Hulme, Turnpenny, & Screen, 2010) discuss with the case of the IPCC Assessment Report and a massive climate science conference in Copenhagen in 2009, there have been profound knowledge biases toward the physical and economic sciences, and a geographical divide in climate science research produced in Northern and Southern institutions. These epistemological hierarchies risk marginalizing specific framings of climate change and excluding fruitful political and social responses (O'Neill et al., 2010). In this subsection, I discuss to what extent we see a similar dynamic in the case of knowledge about global mercury pollution.

Table 4. Distribution of GMA authors by expertise in each of the GMA reports expressed as the number of experts in each field)

Expertise	GMA 02	GMA 08	GMA 13	GMA 18	4-Report Average
Atmospheric chemistry and mercury's biogeochemical fate and transport	3	16	41	40	24
Environmental chemistry/Ecotoxicology	3	7	3	0	3
Trade, policy, socio-economic aspects	1	4	8	0	3
Waste and industrial sources	0	0	5	0	1

Source: author data.

Although the GMA reports are entitled "Global Mercury Assessments", the 2002 report authors clarified that the document *"does not assess mercury in the true meaning of the word"* (sic), which implies a compartmentalization of the substance into what science has said about it (its "true meaning") and what states and international organizations consider to be its globally relevant characteristics. Instead, *"it attempts, for each element identified by the Governing Council, to compile and provide, as far as possible, a global overview of evaluations and assessments already made and conclusions already drawn by the scientific community, national Governments, organizations, etc. on the various issues related to mercury."* While the GMA-02 report was not peer-reviewed, the Global Mercury Assessment Working Group is considered to be an authoritative summary of current science and other topics relevant to mercury:

[72] Interviewee 2

> *"The report draws mainly on recently published authoritative reviews on the various topics relevant to mercury, supplemented by national information. As a large part of the previously published reviews focus on OECD-countries, where much of the current research is ongoing and some reduction measures implemented, an attempt has been made to identify and include relevant information from non-OECD countries. As this report attempts to provide a global overview of the issues related to mercury on a limited number of pages, all the information submitted by each individual country or organization cannot be reflected. However, certain compilations have been developed that contain comprehensive national data"* (UNEP 2002, 175).

As shown in Table 4, to address the question of disciplinary diversity more systematically, I categorized GMA authors' expertise in the broadest possible way. Drawing on various methods from the literature on epistemic geographies, I constructed five broad categories of expertise to classify the backgrounds of the GMA authors.[73] Based on this categorization, the most dominant disciplines in the GMA have been atmospheric chemistry and ecotoxicology, which altogether account for two-thirds of all GMA authors. The former discipline is based firmly in the physical sciences and, for methodological reasons, has a heavy emphasis on modeling rather than experimental or observational studies. In contrast, the latter uses methods from ecology and other bio-physical sciences and seeks to understand the fate and transport of pollutants at a more local level and how they affect wildlife, humans, and ecosystems.

Disciplinary hierarchies by definition come with various forms of boundary work that decides what counts as a scientifically (or field/disciplinary) authorized voice to produce knowledge about a particular matter (Gieryn, 1995), in this case, mercury as a global pollutant. Part of the boundary work described here as disciplinary hierarchy was expected, as it was derived from UNEP's mandate. The mandate chose to prioritize long-range transport [of mercury in the environment] and focused on the demonstrated vulnerability of Arctic landscapes and peoples as topics to be addressed. This epistemic work was commissioned to the Working Group and later to the disciplinarily differentiated pools of authors in each report (see UNEP 2002). As shown above, economists or social scientist assessing the economic and social costs of global mercury pollution and attempted and potential solutions to address it were minority in the pool of authors and the topic was not at the heart of the reports.

In GMA-02, there were only four authors, a deficient number for a global assessment - three out of the four were experts in environmental chemistry and ecotoxicology, whereas the other had expertise in trade, policy, and socioeconomic aspects. But starting in 2008, and due to UNEP's GC and the Arctic Council's push to study long-range atmospheric transport of mercury, atmospheric chemistry has been the dominant expertise in the GMA reports ever since, and

[73] Some studies have used conference abstracts to assess disciplinary diversity (Mahony & Hulme, 2018; S. J. O'Neill et al., 2010). I used three criteria to affiliate each GMA author to a broad disciplinary domain. First, I took into account the author's contribution to the GMA report. For example, if an author contributed to a GMA chapter on water releases, I interpreted that as an indicator of environmental toxicology expertise. Then, I reviewed each author's stated disciplinary affiliation on their publicly available profiles (membership to professional associations, chapters in ICMGP, among others), and the journals and venues where they usually publish.

expertise on trade, policy, socioeconomic has remained very much marginal. This has clearly limited the possibilities to better understand mercury's chemosocial life at the global level.

Nevertheless, in addition to that, the North-South divide in authorship and the *de facto* disciplinary hierarchy translated into other practices of scientific demarcation, which in essence are no different from the standard criteria used to demarcate "central" from "peripheral" science: prestige, financial resources, the dominance of science's *lingua franca*, and privileged roles in the networks of publishing (Kreimer & Vessuri, 2018; Rodriguez-Medina, 2013). Some senior GMA authors I interviewed at the Minamata COPs pointed out that the criteria to determine what to include in the GMA reports was "science published in English, in peer-reviewed *science* journals, by respected authors and research communities."[74] This ended up excluding, for instance, reports on mercury research (mainly biomonitoring) done by NGOs such as IPEN, the Biodiversity Research Institute, or Balifokus.[75]

Gender

Through a thorough search of the GMA authors' publicly available profiles (which included CVs, pictures, and professional bios), I assigned an externally perceived gender to each author in my database. Names and pronouns occasionally found in scholarly bios are typical expressions of one's gender identity. While I acknowledge the limitations of determining a person's gender through an externally assigned classification (such as possible misgendering or the impossibility of directly confirming non-explicitly stated binary or non-conforming gender identities), I confirmed an overall gender imbalance in the mercury science community through interviews with some of the authors who asserted that mercury science is a male-dominated field, as is most engineering and or chemical science; though that is changing albeit slowly. This dimension of the analysis should be interpreted with these caveats in mind.

My analysis of the GMA authorship along gender lines reveals that, on average, only twenty-six per cent of the authors have been women. Although GMA-18 had the most significant female participation across the four reports (12 women out of 40 authors), the GMA authorship has been and still is primarily dominated by male researchers. This minority of women scientists' participation is a constant in international science-policy platforms such as the IPCC and IPBES. A recent study found that the percentage of female core authors on teams writing IPCC assessment reports has grown from eight per cent in 1990 to thirty-three per cent in 2021 (Liverman et al., 2022).

Table 5. Distribution of GMA reports' authors by gender

Gender	GMA 2002	GMA 2008	GMA 2013	GMA 2018	Four-report average
Male researchers	3	20	43	28	73.6 per cent (24)

[74] Interviews 7, 9.
[75] Interviews 5, 6.

Female researchers	1	7	14	12	26.4 per cent (9)

Despite the male-dominated landscape, there has been a rapid rise in the numbers of women in the four reports. The vast majority of authors were experts in atmospheric and environmental chemistry, and female researchers were too few to determine of there was pattern of interest for a particular field. What would mercury science look like if a less male-dominated scientific workforce characterized it? How would that science shape a different mercury policy? As feminists STS scholars have long argued, the gender imbalance in science goes well beyond parity as it has roots in a male-dominated epistemologies (Haraway, 1988; Harding, 2008). Nevertheless, various studies have shown the difference gender makes in knowledge production about the environment. For instance, American ornithologists famously attributed singing behavior to mating male birds only, mainly because they had not bothered to study female birds enough to challenge the assumption, which was proven to be wrong when evidence of female birds started to emerge once people started actually researching it (Haines, Rose, Odom, & Omland, 2020; Odom, Hall, Riebel, Omland, & Langmore, 2014).

Some recent developments indicate that the gendered dimensions of mercury's chemosocial life are starting to become more visible. In 2021, the Minamata Convention Secretariat issued a call for input on the relationship between mercury and gender and published a brief booklet highlighting the importance of mainstreaming gender in implementing the Convention, demonstrating a willingness to advance the conversation on the gendered dimensions of mercury toxicity and the need to attend to the particular vulnerabilities of women, children, fetuses, and breastfeeding people (Minamata Convention Secretariat, 2021).

3. Regional disparities in monitoring and sampling

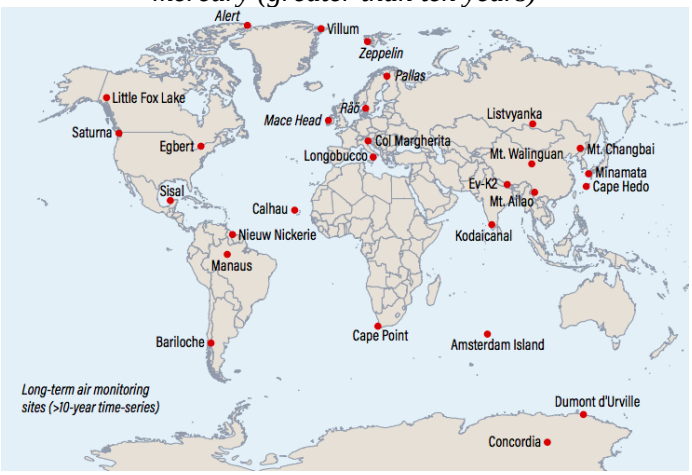
The critical nodes and the bulk of the scientific workforce producing knowledge about mercury as a global pollutant are mainly located in Europe and North America, the regions that also concentrate the material infrastructures for monitoring, sampling, and analyzing mercury and other pollutants. An example that illustrates the disparities is the issue of atmospheric emissions. Despite the vast understanding of mercury's biochemical cycle, the majority of studies on atmospheric vapors have been conducted in temperate or Artic regions (Siegel, 2007, p. 25; Porcella et. al., 1997), whereas the evidence in humid tropical zones is more limited (UNEP, 2013). There are few studies on the regional biochemical dynamics of mercury in zones such as the Andes and the Amazon (Gerson et al., 2022). Many countries in Latin America and the Caribbean that emit high levels of mercury due to ASGM and other industries do not have sufficient regional and national monitoring networks. Only three passive monitoring stations exist in the region (Brazil, Suriname, and Argentina). In turn, there is only one station in the whole African mainland, and one for all South-East Asia (Muller *et al*., 2012) (UNEP, 2016: 42).[7677] In other words, many of the countries that are most contributing to global mercury

[76] https://www.atmos-chem-phys.net/12/7391/2012/acp-12-7391-2012.pdf

[77] http://www.mercuryconvention.org/Portals/11/documents/2016%20call%20for%20submissions/UNEP%20-%20Global%20Review%20of%20Mercury%20Monitoring%20Networks_Final.pdf

emissions are the ones that are being less studied and that have fewer resources to remediate such a gap. This disparity has significant implications for our understandings of mercury's global biochemical cycle, both because of the degree of in-place emissions in Latin America but also because these sites are in the tropics and temperate zones, with different climates and atmospheric components and dynamics.

Image 9. Geographic distribution of fixed monitoring stations for long-term measurements of gaseous mercury (greater than ten years)



Source: UNEP (2019: 21)

Another example is how the issue of human exposure has been first left out of assessments and even today is under-developed. The magnitude of human exposures was only included recently in the scope of UNEP's GMAs. A recent extensive review of all the studies published between 2000 and 2018 confirmed that most of the data on human exposure to mercury used in these "global" reports comes from a handful of countries, all but one of them in the Northern hemisphere. The study analyzed 424,858 mercury biomarker measurements from 335,991 individuals represented in 312 articles from 75 countries.

The review also found that only nine of the world's 194 countries have national biomonitoring programs (US, China, Japan, South Korea, Brazil, Saudi Arabia, Canada, and Russia), and sixty-nine per cent of the data for the review came from those same countries. Therefore, around 119 countries lack human mercury exposure data of the required quality. Reliable data are especially lacking for people in Asia, Africa, and Small Island Developing States, who have been reported to be highly exposed to mercury (Bell et al., 2017). Further, within the 75 countries from which the data came, and focusing strictly on the cross-sectional studies as an example, nearly fifty per cent (forty-eight per cent) of individuals studied lived in four countries: in decreasing order of contribution: South Korea, China, Japan, and the USA. The addition of Brazil, Saudi Arabia, Canada, and Russia, in order, takes this number to nearly seventy per cent (sixty-nine per cent) (Basu et al., 2018; Gibb & O'Leary, 2014). Therefore, there is a stark regional inequality in knowledge production about mercury.

Regional knowledge networks are key windows into larger knowledge ecologies (Lahsen et al., 2013). While scarcer than in Northern countries, mercury research has increased in Latin

America in the past thirty years (Guimaraes, 2020a; Rubiano Galvis, 2020). In his review of three decades of mercury research in Brazil, one of the most active countries in the region, Guimaraes (2020) recounts how a series of factors awoke Brazilian geochemical scientists to the mercury problem. A key event was the massive gold rush in the Brazilian Amazon following the steep rise of gold prices in international markets in the early 1980s. Before this, Guimaraes claims that mercury in the environment had not been treated as "a problem" relevant in Brazil nor other countries in the region – except (as I argued in Chapter 2) as an input for large scale mining operations in Colombia. The early 1990s witnessed a multitude of research projects on mercury in the Amazon. While these early studies assumed that gold mining was the primary contributor to mercury pollution, they also considered and analyzed other sources such as biomass burning and historical mercury emissions during the Spanish colonial silver mining period (Guimaraes, 2020b), a finding that further nuances historical analysis of mercury residues. Although there has been an increase in mercury science in South America in the last decade –a great deal of it has focused on the Madre de Dios region in Peru to the detriment of other regions (see Gaston 2022; Diaz-Leiva 2021). For many reasons, then, profound asymmetries in terms of knowledge production remain.

III. The way forward: epistemic justice and the voices of "Others"



Photo 12: The first Indigenous representatives to participate at a Minamata COP are seated in a section called "Others". At the center, Julio Cusurichi from FENAMAD (Peru) intervenes in the plenary. Geneva 2019.
Photo: R. Goldstein (2019)

Feminist philosopher Miranda Fricker defines epistemic justice as wronging someone in their capacity as knower or as an epistemic subject based on prejudices based on gender, ethnicity, race, or origin – it means receiving an unfair deficit of credibility (Fricker, 2007). Knowledge about mercury as a global pollutant has been used and produced in various institutional, bureaucratic, and scientific settings, which include the UN and international or national aid agencies, universities, research institutions, NGOs, and private consultants. The efforts to know mercury and act on it globally encompass varied forms of knowledge production, compilation, and circulation about the lifecycle of the substance, including biomonitoring initiatives to measure its presence in bodies and landscapes, atmospheric modeling to estimate

the reach of its long-range transport, remote sensing and satellite imagery initiatives, and international trade flows analysis. These practices take place in various institutional, bureaucratic, and scientific settings which include UNEP's Global Mercury Assessment Reports published between 2002 and 2018; workshops and training sessions including thousands of capacity-building and technical assistance programs done by aid and UN agencies aimed at mercury-emitting industries in developing countries; formal and informal networks of collaboration and exchange between NGOs, scholars, and consultants; equipment and samples in public and private universities and laboratories, among others.

Geographic, disciplinary, and gendered and racialized hierarchies in mercury science are not coincidences nor mere data gaps but rather constitutive features of how mercury is known and acted upon in contemporary international politics—that is, based on profound political and epistemic inequities that then shape how the problem is addressed on the ground. Atmospheric chemistry and toxicology experts have played a key role in internationalizing the concern about mercury as a global pollutant. However, such internationalization has shifted over time and has been uneven in various ways, along the lines of discipline, gender, and geographic emphasis. In addition, the material objects through which knowledge about mercury circulates, such as in conference programs, publications, scientific assessments for UN bodies, synthesis papers distributed at side events at treaty COPs, and governmental reports, not only create and distribute a biased sense of urgency about mercury's environmental and health harms in particular places and bodies, but also reinforces existing inequalities along the lines of research capacities, disciplinary hierarchies prioritizing particular methods and research subjects affected by and affecting pollutants and toxins, and gender, regional, and racialized diversity in science more broadly. Therefore, more diversity of disciplines, experts from different parts of the world, and experiences are needed to know in greater detail how mercury acts globally in ways that will do justice to its chemosocial life.

One example is that of indigenous peoples in the Amazon, who have made attempts to expand their participation at the tables where of global mercury science and policy are discussed. While the GMA reports extensively cited studies and assessments done by AMAP in which the exposure of indigenous peoples in the Arctic was mentioned, those in other regions were not and there were no indigenous authors on any of the GMA reports. Indigenous peoples in Latin America and elsewhere used mercury before the mercury amalgamation technique was “invented” (or “discovered,”). They also contributed to the development of the technique with labor, knowledge, and contacts with existing networks of extraction and trade. They have also suffered the differentiated effects of mercury toxicity in their bodies and territories today and in the past. In countries such as Colombia, Peru, and Brazil, many indigenous communities also work periodically in mining extraction, which generates internal political disputes. These are issues that should be taken account of in imposing new policies. Despite this, no indigenous expert, practitioner, or scientist has been part of the collective process of producing and compiling knowledge about mercury as a global pollutant.

This epistemic marginalization is co-produced with the marginal political standing of indigenous peoples under the Minamata Convention. The treaty negotiations saw various indigenous organizations walk away from the process in light of the refusal of states to include a provision referencing indigenous peoples and not just "communities," as it was finally drafted in

the treaty Preamble. The Convention Preamble included a vague mention of the particular vulnerability of "*indigenous communities because of the biomagnification of mercury and contamination of traditional foods"* and a declaration of *"concern"* about indigenous communities more generally with respect to the effects of mercury. Moreover, although Article 19 of the Convention encourages parties to develop and carry out "assessments of the impact of mercury and mercury compounds on human health and the environment, in addition to social, economic and cultural impacts, particularly in respect of vulnerable populations", no dimension of cultural damage has ever been included in any of the GMA reports and there are no guidelines to estimate or determine cultural damages, nor instances to address them. With the notable exception of indigenous peoples from the Artic, by and large, mercury science, toxicology, and atmospheric informing global mercury governance have not included indigenous perspectives, experiences, or bodily harms. Moreover, these are complex and cannot be taken simply or at face value.

Despite these exclusions, indigenous peoples from different parts of the world have continued to insist on having their voices heard. At COP2 in November 2018 in Geneva, Julio Cusurichi, the president of the Peruvian indigenous organization FENAMAD (*Federación Nativa del río Madre de Dios y Afluentes*), intervened in the plenary, calling out the Peruvian state for its lack of response in the mercury crisis in Madre de Dios and calling on the parties to raise the profile of indigenous vulnerability in the implementation of the treaty. As (Goldstein, 2020) describes it, the fact that the first indigenous representatives from the Amazon to participate at a Minamata COP were seated in a section called "Others" is telling of their vague and unarticulated political and epistemic status, not to mention demonstrating exactly why more extensive participation is necessary to illustrate the social and socio-ecological complexities and differences among parts of the world. In the logistical language of international meetings and summits, observers of the treaties (that is, all of those who are not states or international organizations) are grouped into the category of observers. At the COP3 venue in Geneva's Center for International Conferences, the two final rows at the back of the seat map are reserved for "OTHERS." These seats are on the opposite side of the room from the main scenario.

Despite this, FENAMAD and other allies have continued to push for a seat at the table and a more decided response to mercury's harm in their territories. The most recent attempt was a side event at COP4. With the support of the Gaia Amazonas Foundation, the University of Wisconsin, Madison, and UC Berkeley, FENAMAD alongside two indigenous organizations from Colombia and Brasil (the *Consejo Indígena de Yaigojé - Apaporis y Gobiernos Indígenas del Macroterritorio de los Jaguares del Yurupari* from Colombia, and the Coordenação das Organizações Indígenas da Amazônia Brasileira – COIAB from Brasil co-organized the side event at the COP4. The event aimed to raise the international profile of debates on the cultural impacts of mercury in indigenous territories in the Amazon. Representatives of indigenous organizations from the Amazon region of Peru, Colombia, and Peru discussed the problem of exposure to mercury in their territories and the strategies their organizations are carrying out in response to the effects of the problem. The UN Special Rapporteur on Toxics and Human Rights Marcos Orellana participated as a discussant. Unlike all the other side events on the agenda of the COP held in English by default, the event took place in Spanish and Portuguese with simultaneous interpretation in English available.

Earlier in the text, I asked: how would mercury science (and the framing of global mercury pollution, for that matter) be different if it included more women, social scientists, indigenous peoples, and non-English speaking scientists and activists? This chapter is an exploratory response to this question – based on these reflections, I will continue studying how the epistemic marginalization of subordinated and vulnerable actors from knowledge production has shaped the production of mercury as a global pollutant, as well as its regulatory response. In the meantime, I return to ASGM in Chapter 5, guided by a similar premise: how do we know environmental problems such as mercury toxicity are not just mere descriptions of the phenomena "as they are known." The conditions under which knowledge is produced matter and, as I will show in Chapter 5, have impactful consequences on how the problem is addressed.

CHAPTER 5. Inventories, spreadsheets, and the politics of environmental blame: quantifying mercury use in artisanal gold mining

Introduction

At the First Conference of the Parties (COP1) of the UN Minamata Convention on Mercury in September 2017 in Geneva, one of the most anticipated spaces was the Side Event on the 2018 UNEP Global Mercury Assessment (from now on, GMA or "the Assessment"). The report would come out a few months later, but the COP attendants were about to get a sneak peek of it before the broader public on an event branded as "special" in the COP agenda. Several lead authors of the GMA report, also panelists at the event, were present at the COP as observers and, in some cases, advisors of country delegations. Some of them have been long-time colleagues, collaborators, and active participants in producing knowledge about mercury as a global pollutant, as discussed in Chapter 3. Once the morning session of the COP's plenary ended, dozens of country delegates and observers rushed to get a seat at the 'special side event' and listen to some of the world's most reputed mercury scientists present the key takeaways from the long-awaited report. By far, the GMA side event was one of the most attended events of COP1. The room was packed, but I could grab a seat and get a firsthand account of the "take-home messages."

The panelists highlighted that one of the GMA's primary "data needs" was a new globally consistent, independent, transparent, science-based inventory of mercury emissions to the atmosphere. "It is a necessary tool for reducing mercury emissions globally," one said. The panel showcased the recently updated inventory, according to which global emissions reached "2200 (2000-2820) tons" in 2015. A key insight was that the shift documented in the previous 2013 GMA report had taken hold: ASGM had surpassed every other source of mercury emissions – including coal-fired power plants, a historical source of atmospheric mercury pollution– and now emitted between 900 and 1600 tons per year (UNEP 2019). The panel warned the audience about the limits of the current inventory and its interpretations, though - they clarified that such global figures are based on assumptions that include measurement-based and non-measurement-based estimates, highlighted the varying quality of data across nations, and stressed that in many cases the available data was not necessarily recognized as official by governments, but they had included it in the assessment anyway. Finally, they warned that it would be "problematic" to compare the 2015 inventory presented in the 2018 GMA report with the previous reports published in 2002, 2008, and 2013 due to changes in methodology. Moreover, they said it was challenging to compare mercury emissions across sectors due to varying definitions at the national level.

This cautionary note contrasted with the general narrative of COP1, which consistently highlighted the role of ASGM as the main culprit of the global mercury problem and foregrounded mercury-free gold supply chains as a central topic of the meeting. "This looks like a gold buyers' convention," an Indonesian activist muttered while we walked the conference halls. As it happened during the treaty negotiations (Sippl, 2015a), there was a notable presence of gold traders and NGOs promoting fair mined certifications and labels (like the Artisanal Gold Council and the Alliance for Responsible Mining) and other actors interested in connecting

buyers and producers of mercury-free gold. The Swiss government and Geneva-based gold refiners and buyers were a vital part of the conversation about tackling global mercury pollution through market-based mechanisms. There was also a High-Level Segment with ministers of environment and even a head of state discussing the Global Environment Facility's pilot project for implementing the Minamata Convention's ASGM provisions in Guyana. Moreover, as discussed in Chapter 1, the art installations outside the venue, the side events agenda, the Convention logo, and the presence of major gold refiners like Valcambi and Chopard reminded attendees of COP1 that the 836 tons of mercury emitted by ASGM annually to the atmosphere (also presented as thirty-eight per cent of the total emissions) were the main target of global mercury governance – even more so than all other emission sources including stationary combustion of coal (twenty per cent), non-ferrous metals production (fifteen per cent) and cement production (eleven per cent) (UNEP, 2019b).

The absence of artisanal miners in a space where they were depicted as threats to the global atmosphere was inevitable to notice. "There are no miners here, but since this is a UN forum, in a way, they speak through their country representatives," a hopelessly optimistic –or cynic– country delegate told me during an informal conversation. Representatives of organizations like the Artisanal Gold Council and the Alliance for Responsible Mining noted that they spoke not on behalf of miners but of "their rights and interests." "The less mercury ASGM emits, the more gold they can produce and, therefore, the more gold global buyers can purchase – so all this benefits them even if this is mostly a bunch of delegates discussing documents," an experienced NGO representative expressed.[78] In parallel to reinforcing the well-known unequal politics of representation of ASGM in international forums (Hilson, 2007a), this emphasis on shifting gold and mercury quantities caught my attention. A more profound observation made me aware of how the circulation of numbers and data about ASGM and their responsibility for global mercury pollution was a recurrent way miners were being 'brought into' the global stage despite being physically and politically absent. For instance, one of the most recurrent numbers I came across was the percentage of ASGM's contribution to global mercury pollution presented by the UNEP GMA 2018 report pool of authors (the 38 percent mentioned above), which circulated widely and consistently across the COP1 venue and beyond it in reports, booklets, PowerPoint slides, and hall chats, sometimes as a verbally expressed number or as part of a pie chart.

With this attentiveness to numerical work (that is, who produces and mobilizes numbers and for what purposes (Martin & Lynch, 2009)), I attended COPs at the UN but also training on mercury-free mining, public events that congregated experts on the subject, and mining processing plants in Colombia. Among other things, I found that assessments, databases, baselines, atmospheric pollution models, and biomonitoring -all of which were widely displayed and distributed at Minamata COPs- are part of a broader array of worldly practices to produce knowledge about artisanal and small-scale miners who use mercury and estimate where they are, how much mercury they use, how much gold they produce and, ultimately, how much they contaminate the global commons and harm exposed populations (Evers, Keane, Basu, & Buck, 2016). The operation of such administrative and epistemic infrastructure has involved the active work of bureaucrats, toxicologists, atmospheric scientists, mining and metallurgic engineers, and experts in supply chain management in mining sites (e.g., through biomonitoring, technical

[78] Interview 33.

assistance programs, and field trials) or far from mining sites in universities, laboratories, and governmental and intergovernmental offices (through atmospheric modeling, remote sensing, and inventories of mercury emissions).

However, what do these people's work do besides quantifying mercury pollution and measuring expected and achieved mercury use reduction? They do much more than aggregate data and produce figures on global pollution. Their work has become an 'obligatory point of passage' for miners, states, and the broader public to 'translate' mercury pollution and make it intelligible as a matter of fact and a matter of public concern (Latour 1990; Star 1999). Through their work, scientists, engineers, and bureaucrats reiterate their authorized voices to make mercury pollution in ASGM a relevant, legible, and actionable problem at both local and global levels. In doing so, numerical work about mercury use in ASGM has become inseparable from decisions about what dimensions of the problem we want to leave at the local level and which ones at the global level; how much can states be pushed or incentivized to collect data and respond to the problem; how do we address states of uncertainty and lack of data produced by powerful actors with state acquiescence; and how do we respond to vulnerable actor's environmental responsibility when quantitative evidence (for some, 'objective') seems to put the blame and the burden on them.

Drawing on STS and political ecology debates on the role of science and knowledge in producing unequal narratives of environmental blame, I examine and problematize the quantitative metrics, data assemblages, and the accompanying accounts that have rendered ASGM the main culprit of global mercury pollution in the last two decades. Based on participant observation, critical text and data analysis, and interviews with experts, bureaucrats, and miners, I discuss five devices of quantification and visualization that have helped produce ASGM as the main target of intervention in global anti-mercury policy in the last two decades. Specifically, I discuss rates of mercury use per gram of gold produced, pollution emissions inventories, percentages of blame, national pollution rankings, and certified mercury-free gold circulating in global gold markets. I argue that far from mere descriptions of a fixed reality in the ASGM sector, these quantification devices have played an active part in constructing the problem framing and are political processes in themselves. An analysis of the numeral work required to make mercury use in ASGM a global problem sheds light on how the environmental politics of blame is co-produced with the quantification and visualization devices that render environmental problems legible and visible to global audiences. While I ground part of my inquiry in Colombia, I examine how said practices are multiscale and embedded in the global efforts to know and govern mercury use and in the political reconfigurations of global gold markets.

The numerical work about the magnitude of mercury use in ASGM and its increasing contribution to global mercury pollution is a descriptive and performative process that operates through various devices at different sites. Given that the 2013 UN Minamata Convention on Mercury encourages a legal and economic transition of ASGM from illegality to formalize or get a certification to partner with buyers in formal supply chains (i.e., Article 7 and Annex C), knowing ASGM and estimating its contribution to global mercury pollution has become a key goal in countries with ASGM activities that are "more than insignificant". While methods like biomonitoring and atmospheric emissions modeling have been salient in the production of knowledge about the fate and transport of mercury in the environment since the 1970s (Selin et

al., 2018), the growth of ASGM has stimulated knowledge production to estimate how much mercury the sector uses at the national level and how much of it accounts for the global budget of the substance. Such practices are numerical and have helped purposes like justifying crisis narratives of ASGM as a big, unruly polluter that is out of control[79] or, to a lesser extent, as the promising source of mercury-free gold for global supply chains. Broadly, my analysis dissects these practices and narratives and, in doing so, contributes to a better understanding of the signaling of environmental blame and virtue operating in the contemporary extractive sector.

More concretely, my focus on practices of quantification and visualization makes two contributions. On the one hand, focusing on the metrics, measurements, and other inscription devices provides a window into the production of extractive landscapes and the social relations of toxicity that tend to characterize them (Ureta 2021). My analysis denaturalizes the status of ASGM as the "world's largest mercury polluter". It problematizes the role of numbers and quantification in the configuration of the political economy of gold and mercury. Others have written about how toxic ecologies are known, governed, and normalized through toxicity thresholds, risk assessments, and environmental impact assessments (Murphy 2017; Barandiaran 2017; Bond 2022). Here I add to that literature by studying other devices like emission ratios, inventories, per capita emission rates, and more mundane forms of numeral work like percentages and rankings. The case of mercury use in ASGM illustrates how the numerical work of making global mercury emissions legible and actionable is co-produced with normative aspirations to control, formalize, and govern the sector altogether. Studying epistemic and numerical work in a sector typically considered illegible or characterized by 'data gaps' (World Bank 2019) helps denaturalize the politically and epistemically marginal status of the ASGM sector and extends the analytical focus toward silent but politically relevant forms of work like measuring or inventorying tons of toxic chemicals.

The chapter proceeds in three sections. In the first section, I review the broader debates on the relationship between quantification, power, and social order and highlight how my analysis of the numbers of mercury use in ASGM contributes to debates on the production of toxic landscapes, the formation of extractive subjectivities, and technoscientific work in the extractive sector. In the second section, I present the analysis of the specific devices of quantification and visualization mentioned above. In the third section, I conclude reiterating how the collective framing of mercury use in ASGM is mediated by the entanglement of the politics of quantification, temporalities, and scale.

I. Numbers, power, and environmental politics

What role do metrics, measurements, and numbers more broadly play in our understanding of a global environmental problem like mercury use in ASGM? How is the production and circulation of data about mercury use in ASGM intertwined with the political and economic subordination of the ASGM sector and the politics of blame and responsibility in global mercury governance? In other words, how do these numbers describe but also help produce the so-called mercury problem in ASGM?

[79] See, among many others, NY Times (Dec 18, 2018). "Illegal mining is worse than ever before"; UNEP (2018). "Why does ASGM pollute so much?."

Numbers are sociologically important because of the power they unleash but are also as social processes in themselves (Diaz-Bone & Didier, 2017). As Rose (1991) argues, "the domain of numbers is politically composed, and the domain of politics is made up numerically." Numbers are neither alone nor in the 'air' because their credibility depends on local parameters and actions aligned to create an "infrastructure of accountability" (Castillo 2017, 15). Opposing parties can mobilize the same numbers in conflicting ways (Adorjan 2011) and use them to reveal patterns of injustice but also to conceal or obscure inequalities (Merry, 2021). For instance, public health officials can use rhetorics of exaggeration to justify specific policies (Obregon 2002), or corporate actors can tinker with evidence to justify the impacts of large-scale mining projects (Kirsch 2014). Therefore, numerical work (producing, mobilizing, interpreting, and using numbers) is inherently a work of numero-politics, that is, work involving power asymmetries in "generating and resisting the production of numbers" (Martin and Lynch 2008) a work that, of course, has tangible effects for those who count and those who are counted. That is why Verran (2014) –drawing on Austin's (1962) ideas on the performative character of language– invites us to think of numbers and quantification practices more broadly as "speech acts" that present information and accomplish actions.

The impact of numbers is triggered, among other ways, through the production and circulation of reports, texts, studies, and other material objects that enshrine numerical speech acts (Riles, 1999). Pine & Liboiron (2015) have argued that quantitative measurements of social and environmental phenomena "exercise covert political power by bringing certain things into spreadsheets and data infrastructures, and thus into management and policy while leaving other things out." Measurements and the infrastructures in which they are embedded are also performative in that when deciding what counts and what does not, they produce ontologies and *make things* (Bowker and Star 1999). This process also entails moral and aesthetic judgments about the objects being counted. Callon & Law (2005) proposed the term "qualculation" to denote that quantitative calculation always involves qualitative judgment. Qualculation is "the act through which judgment and calculation, and their vested values, are stabilized into standardized things" (cited in Pine & Liboiron, 2015).

Drawing on this concept, Pine & Liboiron (2015) propose that activist and advocate groups have recognized the performative role of measurements and leveraged it for social change in the realm of health. They propose the concept of "charismatic measurements" to suggest that some measurements are more "charismatic" than others, meaning they "inspire action more than other forms of evidence, because of both pre-existing social and cultural values and affective modes of representing crisis" (Pine & Liboiron, 2015). In a similar vein, Murphy's (2017) analysis of the GDP metric proposes the concept of phantasmagram to draw attention to the "affectively charged and extra objective relations that are part of the force of numbers" (Murphy 2017, 25).[80] Therefore, metrics and measurements can become black-box statements in which assumptions, controversies, historical trajectories, potential negative impacts, and alternative

[80] Michelle Murphy uses to notion of phantasmagrams to denominate "quantitative practices that are enriched with affects, propagate imaginaries, lure feeling, and hence have supernatural effects in surplus of their rational precepts" (Murphy 2017, 24). This concept foregrounds the "felt and astral consequences of social science quantitative practices, such as algorithms, equations, measures, forecasts, models, simulations, and cascading correlations" (24).

solutions are hidden (Forsyth 2003). Both open and closed, the black boxes of measurements also embody, shape, and contest narratives of social order.

In the case of ASGM, I turn my attention to the "qualculations" and 'numeric speech acts' of the sector's quota of responsibility for global mercury pollution. Qualculations are, as any knowledge practice, situated. While international agencies and research institutions do a significant part of the work, the prominence of ASGM in Global South countries makes states equally relevant for the work of knowing ASGM. Indeed, states have an interest and an incentive to compile and submit data to build global inventories but also face political pressures that complicate the construction of reliable data and nuanced treatment of mercury use in ASGM. Also, more data often means more visibility and, therefore, more accountability demands. Increasingly, local communities also want to become part of biomonitoring efforts to determine their mercury exposure, and judicial and administrative organs have started to request baselines and data to address harm and exposure. In turn, international gold markets demanding mercury-free gold and investors demanding clean gold to have safe investments have increasingly become interested in knowing (and letting others know, especially their buyers) that the gold they trade contains no mercury. In sum, more and more people want to know how much mercury ASGM emit and how much of it was used to process the gold they buy.

II. Constructing numbers and responsibilities: ASGM as a global mercury polluter

The tabulation of global mercury pollution requires large infrastructures of data collection and multiple practices of measurement, quantification, and estimation that render the phenomena in an accessible, understandable, and actionable way and that help determine –quite literally– what counts as pollution and toxicity and what does not (Fortun, 2004). International organizations like the World Bank, the ILO, and UN agencies have funded, encouraged, and carried out a significant part of the technoscientific work that has contributed to the now-established understanding of mercury as a global problem (Gibb and O'Leary 2014), part of which has taken form or manifested through various forms of quantification. In this section, I present an interpretive analysis of the most important numbers and quantification and visualization practices regarding mercury use in ASGM, as well as its corresponding narratives of responsibility, blame, or virtue. Here, I examine six of them (emissions ratio, inventories, percentages, rankings, per capita emissions, and certification of mercury-free gold) and how they are co-produced with assumptions, normative expectations, and values about specific sectors like ASGM and global mercury pollution more broadly.

While the sequence of the vignettes might give the impression that I am tracing 'the assembly line of knowledge production' (Goldman 2004, 103), I am attentive to various non-sequential forms of numerical work that cut across the global and the local. Because of the multiscale nature of the numeral work required to quantify ASGM's mercury use and mercury pollution in general, UNEP has been the leading data broker of the international mercury bureaucracy and one of the most active promoters of knowledge production and collection

initiatives as well as regulatory responses.[81] Alongside UNEP, other agencies like UNIDO, UNDP, the World Bank, aid agencies, states, and their research institutions constitute an administrative and epistemic infrastructure invested in collecting aggregated data to produce global figures warranting global responses. Two key goals of UNEP –which I discuss here– have been producing global and national pollution inventories in the form of documents and infographics and calculating "emission rates" of tons of Hg used per tons of gold produced in specific sites. However, I also explore how state officers, mining engineers, scientists, and other actors besides UNEP bureaucrats and consultants have engaged in numerical work regarding mercury use in ASGM.

1. The mercury-gold ratio: from the field to the global database

The rate of mercury used vis-à-vis gold produced is one of the metrics that mining engineers and international consultants have proposed to estimate the magnitude of mercury use in ASGM (UNEP 2005, 2013, 2017) and thus make its seemingly invisible damage commensurable. Emission rates are a standard metric in environmental chemistry - finding the emission factor is the gold standard of pollution emissions calculation. Depending on the pollutant and the source, the units to calculate can vary. However, in essence, the operation is very similar: comparing a ratio of two quantities for a specific moment or period. Sometimes, the formula to calculate emissions ratios accounts for technologies to reduce them. For instance, sometimes emission rates account for emission control technologies, like filters, scrubbers, or other reduction measurements, as well as time variations. In others, rates are calculated without field measurements and work more as estimates than as accurate depictions. In this subsection, I discuss how a deeper look into how the mercury ratio was produced reveals how a seemingly technical device characterized by yielding useful but largely uncertain data when applied shapes the standing of ASGM in global mercury governance.

The ratio is a scientific inscription device, but it is also a qualculation that intends to shape decision-making at various levels. A 20 min prime-time special published by Canal Caracol - a major broadcaster in Colombia - in April 2022 illustrates this clearly. The presenters depicted illegal gold mining in Antioquia as a “nightmare,” a “disease,” a “predator,” and the fuel of illegal armed groups also involved in narcotrafficking. They highlighted that in the last five years, the impact of illegal gold mining on deforestation equated to 100 soccer fields, that is, 50.000 hectares of forest (Caracol TV, 2022). One of the interviewees, General Alejandro Barrera, head of Colombia’s National Police, further highlighted the magnitude of illegal gold mining’s environmental harm, referring to the problem of mercury use. While stressing that the activity can produce up to 3 kg of gold monthly –worth up to USD 750.000– the general says that “to extract one gram of gold, [illegal miners in Antioquia] use five grams of mercury,” gesticulating with his hands to symbolize the equivalence. Although he even goes as far as to mention other inaccurate metrics –e.g., “one gram of mercury pollutes 500,000 liters of water” or

[81] In 2005, UNEP created the Global Mercury Partnership, a group of governments, intergovernmental organizations, NGOs, private sector, academia and scientific community dedicated to reducing mercury pollution and protecting human health and the environment from the impacts of mercury. In 2013, the signing of the Minamata Convention formalized the voluntary work of the partnership and, ever since, UNEP and the Secretariat of the Convention oversee the official collection of data about mercury under the goals of the Convention.

"one gram of Hg requires (sic) 240 m3 of water" – he also referred to UNODC's report on deforestation in gold mining areas to further his attempt to stressing the magnitude of the problem in every possible way (UNODC 2021).

General Barrera's reference to the five grams of mercury per gram of gold ratio that allegedly characterizes gold mining in mining sites in Antioquia is far from exceptional in public debates about mining in Colombia and elsewhere, although not always in such weaponized and vague terms. In interviews and meetings with mercury scientists, mining engineers, government officers, and anti-mining activists between 2017 and 2019, I witnessed multiple versions of the estimated ratio of mercury use in illegal gold mining, with the commonality of all varying greatly. The variation has to do with various reasons. As said before, the calculation of a mercury ratio is not an easy task. Mercury is "lost" in the processing of gold in two moments –when the liquid metal is added to the ores, part of the substance is lost into tailings, and when the gold-mercury amalgam is torched, mercury vapor is emitted into the air- both in which measurement is difficult given that ASGM operations vary greatly and many of them operate in informality (UNEP 2017).

Also, miners can be wary of scientists whose findings could be weaponized to threaten their livelihoods, as General Barrera was trying to do. In some cases, resistance is explicit. "We have been chased out of towns when we have tried to do surveys or give a talk," says Luis Fernandez, a mercury scientist working in Madre de Dios in the Peruvian Amazon (Wade, 2013). In my fieldwork in Antioquia, miners and processing plant owners and operators displayed a less confrontational form of reluctance to share any hint of the quantities involved in their daily work. "If I tell you, you will either snitch me or start a competing operation," said a plant processing owner in Segovia while laughing and showing me his plant. Despite the impossibility of measuring each mercury-using mine site or processing center in a mostly informal sector that in many instances does not want to be measured, the mercury ratio of grams of mercury per grams of gold is –as Kevin Telmer from the Artisanal Gold Council stated in a side event at Minamata COP1– "the master parameter" to understand mercury use in ASGM.

Despite its potential for helping make legible and steer the ASGM sector, the ratio inevitably has limits as it was built based on various uncertainties, assumptions, and economies of credibility. As various mining engineers acknowledge, there has never been a systematic measurement of Hg use in the ASGM sector - research on mercury in ASGM has been "relatively poorly funded, and grossly unsophisticated relative to that carried out in the northern hemisphere" (J. O'Neill & Telmer, 2017; Telmer & Veiga, 2009). Therefore, various methods must be used to estimate or triangulate the possible ratio – e.g., direct measurement, estimation, or secondary sources. "Actual estimates are based on available data on mercury and gold exports and imports by country and reported production and technology of extraction from all the countries known to have active ASGM communities" (Pirrone et al. 2009, 27). Under the Minamata Convention, each mining site and eventually each country is expected to produce the best possible ratio to contribute to the production of a global figure, a challenging task given the varying quality of data across local and regional scales. [82] Local conditions can vary greatly, and

[82] During COP1 and COP2 the Ad-hoc Technical Expert Group on Effectiveness Evaluation met and recommended a plan integrating comparable results for future monitoring. That plan would include monitoring on three topics "on levels of mercury in air, biota and human, data are either available, or able to be obtained, and would be comparable

therefore data does too – e.g., in Segovia, Colombia, mining sites overlap with conflict zones, which until very recently limited the possibilities of direct measurement.

Rigorous calculations tend to be explicit about said uncertainties, especially when aggregating local data to the global scale, which is why figures like the ones presented by UNEP's Global Mercury Assessment always include the possible minimum and maximum value of the ratio or, when available, the total net amount of mercury emissions – UNEP reports in 2013 and 2018 specified the considerable range of uncertainty of global mercury emissions coming from ASGM (between 400 and 1600 tons per year). However, in the media and public debates about ASGM and mercury, the number that typically takes hold and circulates is the mean value of around 800 tons per year or the corresponding percentage ("ASGM is responsible for 38per cent of global mercury emissions"). This was also the case during Minamata COP1 and subsequent meetings, where the uncertainties behind the figures and the fact that a ratio is a snapshot of a moment in time and therefore not a continuous dynamic, tend to be concealed behind the expectation of accurate figures that warrant immediate action.[83] Despite the vast uncertainties associated with the figure, the ratio gives the impression of certainty. It helps frame the problem in terms of shares of responsibility, a question I will go back to in the following subsection.

In 2008 Telmer and Veiga made a first estimate of the mercury ratio in ASGM based on available data about mercury and gold exports and imports by country and from field reports from the countries known to have active ASGM communities (Telmer & Veiga, 2009, p. 132). In that work, the authors –two prominent mining engineers and reputed voices in the field– estimate that ASGM contributes "with 640 to 1350 Mg of mercury per year (averaging 1000 Mg) to the environment from at least 70 countries", with "a significant fraction" of 400 Mg directly emitted to the atmosphere" (Pirrone et al 2009, 27), a figure that equated to 19per cent of global mercury emissions in 2009, trailing behind the more than 800 tons coming from coal-fired power plants. The authors acknowledge that the quality information on amounts of mercury, size of operations, styles of operation in use around the world in ASGM sites, and the fate of mercury in the environment released from the sector "remains poorly understood" and "much of what exists is anecdotal" (139). Africa and South America are "inadequately described in terms of point sources," and Asia exhibits "large uncertainties" (Pirrone et al. 2009, 41).[84] Therefore, it is not surprising that the estimates for specific sites and regions, as well as the contribution of the ASGM sector to the global mercury budget, come from a single source: Telmer and Veiga's work (see Figure 1).

on a global basis. For water and soil, data are be available and useful locally, but may not provide trends on a global basis. Sediment monitoring is not widespread, and not easily comparable" (MCM Secretariat 2019).

[83] Practically all references to the figure in opening speeches, video promotions, booklets, side events, and informal chats at the COPs omitted to highlight the associated uncertainty.

[84] The figure presented as the "global estimate" in 2009 (400 tons a year, as seen in Table 1.28) was based on "relatively good estimates" of gold production and mercury use from pilot studies in 2 countries, Brazil and Indonesia; "reasonable information" from 7 more countries; "some but poor information (mostly anecdotal)" from 14 more countries; "enough information to hazard a guess at a specific level of mercury consumption" for 24 more countries; and gross desk estimates for other 22 countries (Telmer & Veiga, 2009, p. 132)

Table 6. Mercury consumption from ASGM by region and total mercury emissions to the atmosphere by source category

Table 1.16 Mercury consumption from artisanal small scale gold mining by region

Gold mining site	Period *(since)*	Average annual *(Mg yr^{-1})*	Total *(Mg)*	Reference
Amazon, Brasil	1979	180	3000	Telmer & Veiga, 2008
Mindanao, Phillipines	1985	26	260	Telmer & Veiga, 2008
Southern Brasil	1985	1	10	Telmer & Veiga, 2008
Puyango River, Peru	1987	3	24	Telmer & Veiga, 2008
North Sulavesi, Indonesia	1988	15	120	Telmer & Veiga, 2008
USA	1969	6	150	Telmer & Veiga, 2008
Canada	1976	1	14	Telmer & Veiga, 2008
Choco region, Colombia	1987	30	240	Telmer & Veiga, 2008
Narino, Colombia	1987	1	8	Telmer & Veiga, 2008
Victoria Fields, Tanzania	1991	6	24	Telmer & Veiga, 2008
Pando Dep., Bolivia	1979	20	300	Telmer & Veiga, 2008
Jia pi Valley, China	1938	2	116	Telmer & Veiga, 2008
Dixing region, China	1992	120	480	Telmer & Veiga, 2008
Guyana Shield, Venezuela	1989	45	360	Telmer & Veiga, 2008
Asmara, Eritrea	1907	0.1	10	Cinnirella and Pirrone*
Total		456.1	5106	

*estimates based on an historical paper on gold extraction in Eritrea (Zaccaria, 2005).

Source: Pirrone et al. 2009, 29

Table 1.28 Total mercury emissions to the atmosphere by source category

Region	Hg emission *(Mg yr^{-1})*	Reference year	Reference
Natural			
Oceans	2682	2008	Mason, 2008
Lakes	96	2008	Mason, 2008
Forest	342	2008	Mason, 2008
Tundra/Grassland/ Savannah/Prairie/ Chaparral	448	2008	Mason, 2008
Desert/Metalliferrous/ Non-vegetated Zones	546	2008	Mason, 2008
Agricultural areas	128	2008	Mason, 2008
Evasion after mercury depletion events	200	2008	Mason, 2008
Biomass burning	675	2008	Friedli et al., 2008
Volcanoes and geothermal Areas	90	2008	Mason, 2008
Total (Natural)	5207		
Anthropogenic			
Coal combustion, oil Combustion	1422	2000	Pacyna et al., 2006b
Pig iron and steel Production	43	2000	This work
Non-ferrous metal Production	310	2007	USGS, 2004
Caustic soda Production	163	2000	This work
Cement production	236	2000	This work
Coal bed fires	32	2007	This work
Waste disposal	187	2007	This work
Mercury production	50	2007	This work
Artisanal gold mining production	400	2007	Telmer and Veiga, 2008
Other	65	2007	This work
Total (Anthropogenic)	2909		
Total (Natural + Anthropogenic)	8116		

Source: Pirrone et al. 2009, 39

In an interview with Veiga about his involvement in mercury reduction initiatives in Colombia and elsewhere, we discussed calculating mercury ratios in ASGM and how the metric began to be widely cited as the best available estimation. Veiga recounts that when he started working on the topic in 1981, there were no studies on the subject. He and other researchers calculated some of the first ratios by asking miners directly or directly observing processing sites. However, most of them would be produced by consulting official or unofficial reports, estimation, secondary sources, and doing time extrapolation of direct measurements in specific mining sites or processing plants. Some of those measurements would logically vary across sites, but without better information, data collected in individual mines would eventually travel and be cited in meetings with institutions like the UN or the World Gold Council. Table 7 above, taken from Pirrone et al. (2009), confirms that back then, the varying timeframes of the ratios ranged from 1969 to 1992, as Veiga explained to me in his account of the process.[85]

Aside from trust and credibility in Veiga's judgment and field expertise, the success and wide circulation of his measurements and estimations also had to do with the fact that he and his co-author were not only describing the ASGM sector but also helping shape policy towards it, particularly regarding mercury trade. Here it is critical to note that measuring mercury flows in international trade shipments is difficult for two reasons. First is the lack of a harmonized code system for international trade, which explains why many mercury-containing products are double-counted or under-counted (UNEP 2005, 2017). Second, the fact that despite official figures reporting a decrease in mercury exports, local reports of illegal mercury trade suggest that there is a considerable sub-register of the mercury that keeps circulating in global and regional circuits of trade (IPEN 2019). The uncertainty was acknowledged and accepted. The Artisanal Gold Council published a guide to developing baseline estimates of mercury use in

[85] Interview 30 and Interview 31.

ASGM communities, which acknowledged explicitly that "estimations for the scale of the ASGM in terms of population and economy, mercury emissions and gold production are based on anecdotally used information and further research is required" (Persaud & Telmer, 2015). Aside from reiterating the method of calculating mercury use based on the estimated tons of extracted gold, the guide suggested complimenting it with earning-based estimates, that is, building sample sizes of miners to ask them directly about their earnings. In my interviews with mining engineers, the latter is always difficult and often yields unreliable data due to miners' mistrust.[86] The guide gives inapplicable instructions for contexts like Northeastern Antioquia, in which many mines are highly disputed and controlled by regular and irregular armies.[87]

Despite these limitations, Telmer and Veiga trusted mercury trade figures as a reasonable proxy. They suggested seeing mercury supply in ASGM as "any other contraband - they declared that since "regulating mercury imports is more difficult than regulating exports from developed countries, export bans from main sources will be easier and more effectively control mercury trade" (Telmer & Veiga, 2009). Telmer and Veiga even went on to advocate for "an export ban (…) accompanied by the development and implementation of viable replacement technologies or replacement economies for small scale miners", and argued that "field-based intervention programs must remain a priority." International trade restrictions, technical assistance, and field interventions would then be the mechanisms for decreasing the ratio (Telmer & Veiga, 2009). Therefore, although calculating the ratio entailed making assumptions about the availability of mercury supply in mining areas based on official trade records, Telmer's and Veiga's method became widely accepted and is part of UNEP's official guides (J. O'Neill & Telmer, 2017).

The focus on mercury trade and the challenges of doing systematic site measurements made comparing legal mercury imports estimates and gold production statistics the preferred method to estimate mercury use in ASGM. As if it was not limited enough already, doing that calculation was not within the reach of the general public – until the 2010s, the UN COMTRADE database on international trade was not open access and only available to UN agencies working on ASM – even today, given the massive amounts of data it stores, the UN charges a fee for access to unlimited amounts of data (UN COMTRADE 2022). Therefore, in the late 2000s, Telmer and Veiga had privileged access to restricted data thanks to Veiga's tenure at UNIDO and authorized users of the UN COMTRADE databases (1997-2004).[88] Once the UN COMTRADE database became public in 2009, calculating a global ratio based on trade estimates became possible.

That was precisely the goal of the Mercury Watch portal, an initiative led by the Artisanal Gold Council – the non-profit founded by Kevin Telmer in 2011 and focused on "creating sustainable business opportunities for investors and the bullion and jewelry markets while improving the economics, health, and environment of miners and their communities in collaboration with governments" (AGC 2022). MercuryWatch.org visualized the data on mercury trade and gold production coming from UN COMTRADE in interactive maps that could be filtered by the mercury emitting sector or the stats on each country when available. According

[86] Interviews 22, 27, 35 .
[87] "Conduct a physical count of shafts on site. The investigator should be led around the site by a local authority pointing out all active shafts." (Persaud & Telmer, 2015, p. 16)
[88] Interview 30, Interview 31.

to their creators, the goal was to "display and map estimates of mercury use in ASGM as well as numbers of miners, types of practices, and other important information relevant to researchers and policymakers"'. The portal was a response to "the lack of a global strategy, knowledge base, or clearing house for the growing issue of ASGM, its releases of mercury, and its need to formalize and enter the formal economy." (Persaud & Telmer, 2014).

Mercury Watch was the upgraded version of the influential inventory calculated by Telmer and Veiga in 2009, but now in a visual form that aggregated the available data on mercury imports and gold exports of all countries and made it available for the general public including experts, activists, and state bureaucrats. Through visual rankings of color indicating higher or lower mercury ratios calculated through access to restricted data, the portal produced visual landscapes of toxicity that proved widely influential. In the recount of his trajectory as a "world-renowned expert and a voice on the international [ASGM] stage," Telmer himself highlights "authoring the global estimate on mercury use in artisanal gold mining used to negotiate the Minamata Convention" (AGC 2022). Despite the uncertainties and assumptions, it relied on, the Telmer-Vega estimation did indeed play a role in the negotiations and helped justify ASGM having a stand-alone article in the treaty's text. Nevertheless, the Mercury Watch portal took a life on its own beyond UN halls. Between 2013 and 2017, the portal became a helpful tool that appeared cited or referenced in NGO reports, UN documents, media outlets about mercury use in ASGM, and even UNEP's Global Mercury Assessment report published in 2013.[89] AGC constantly updated the supporting data based on country-level projects they were developing (Persaud & Telmer, 2014).[90] The interactive maps available to the open public turned into what Latour calls *theaters of proof* (Latour 1986) or what Greenpeace director Robert Hunter famously called "mind bombs" – that is, images that "explode in the public's consciousness to transform the way people view their world (DeLuca 2012)".

[89] *"The updating of information on emissions associated with ASGM unregulated and illegal in some countries) official data and statistics regarding the extent of ASGM activities are generally lacking or incomplete. For this reason, emissions estimates were prepared by the Artisanal Gold Council, utilizing information that is compiled in and accessible through the Mercury Watch website (www.mercurywatch.org). This was the only component of the 2010 inventory that, for some countries, utilized information from earlier than 2008*."(UNEP 2013: 10)

[90] A notable instance of the credibility of the source is that in the 2018 report by the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) reviewing key trends and numbers in ASM (IGF, 2018), the issue of mercury use in ASGM is discussed exclusively on the basis of the Mercury Watch database.

Image 10. Mercury Watch portal



Source: Mercury Watch Project – UNEP and AGC: https://www.artisanalgold.org/our-projects/mercurywatch-org/

Telmer is one of the crafters and advocates of such a metric, and just like most actors in the gold supply chain, he sees the ratio not only as a way of quantifying harm but also as a "*capitalization ratio,"* that is, the quantification of a lost cost of opportunity. From this perspective, the mercury problem in ASGM is ultimately an economic one – the question of how to increase production and everyone's profits in the supply chain with the least amount of mercury. As one consultant bluntly put it, "you can do public health strategies, you can do training, finance programs, promise them mining titles or anything – they won't stop using mercury unless they are convinced it is more profitable not to do so".[91]

2. Inventories as baselining practices

The second form of quantification I examine is inventories of mercury pollution, specifically atmospheric emissions.[92] Inventories are premised on the ability to scale up individual data points to a bigger, statistical picture. In particular, state-led inventories are contemporary manifestations of a long connection between the administrative state and the statistical representation of its subjects, which dates back to colonial times (Anderson 1983) and persists in democratic societies in the form of administrative quantification (Miller 2005). With the encouragement of the UN and global development agencies, the global production of socioeconomic and environmental data and population surveys has expanded, with poor and rich countries investing in counting and measuring their people and landscapes (Merry, 2021). International organizations themselves have also adopted a form of knowing global problems

[91] Interview 37.

[92] Given the variety of mercury forms and species, an attention to the issue of releases to land and water would require a separate analysis. Since atmospheric mercury emissions have been the most important form of mercury pollution internationally, it is a good form of mercury toxicity to focus on.

mediated by technologies of quantification (C. A. Miller, 2005) – e.g., the World Bank's efforts to become a 'knowledge bank' by producing vast amounts of reports and statistics on social, economic, and environmental issues (Goldman 2004) and the widespread adoption of indicators in UN agencies and international human rights courts are only a couple of examples (Davis, Kingsbury, & Merry, 2012). In the US, inventories have become standard tools for toxics management and sites of political action for environmental health movements (Fortun, 2012).

An inventory is a form of *baselining* – an epistemic and political practice that renders the environment legible (whether it is a species, a landscape, or a resource) and creates both a 'historical' reference and a normative benchmark with which to assess any harm or impact to it (Ureta et al., 2020) (Craig 2014). Baselines play a political role by creating and enacting modernist ideals of perfect pasts and serving as an arena for highlighting specific temporalities and scales of harm to the detriment of others (Barandiarán, 2020). The assemblage of baselines is at the center of current efforts to deal with some of the most pressing environmental issues of our time, including climate change, biodiversity loss, and toxic pollution (Ureta et al., 2020). A pollution inventory is, therefore, a technology of quantification that *baselines* the best possible estimation boxed in a political unit for an epistemic jurisdiction (Winickoff & Mondou, 2016), whether national or global. Surprisingly, the extractive industries are a sector in which baselining and the infrastructures of inquiry, evaluation, and intervention that support them have not been studied (Ureta, 2018). Following the calls to study environmental inventories and information systems as sites of political action (Fortun, 2012), here I examine global and local mercury inventories and the place of ASGM in them as forms of baselining (Ureta, 2018).

As stated in the introduction, a global inventory of mercury emissions has been one of the "data needs" of UNEP's work, both through the Global Mercury Assessment reports since 2002 and, more recently, since the signing of the Minamata Convention. The first UNEP Global Mercury Assessment (2002) scarcely mentioned the role of ASGM in global mercury pollution and did not have a measurement to cite it in the report. Discussion of the issue was limited to a section on data gaps and footnote, which suggested that "special attention" should be paid to it (Siegel, 2007) (Marion Suiseeya, Zanotti, & Haapala, 2021). The updated 2013 report yielded estimates of 727 tons of mercury emitted into the atmosphere from ASGM operations worldwide and 800 tons released to soils and bodies of water (UNEP, 2013). The emissions figure of the 2013 report is double that originally reported in 2005, partly due to the expansion of the sector and due to the development of better estimation models (UNEP, 2013, Selin 2013). As the report states, "estimates were introduced for a major emissions sector associated with the use of Hg in ASGM that had not been included in previous global inventories" (UNEP 2013, 15).[93]

The update of global mercury inventories in the last fifteen years (first by the UNEP Global Mercury Assessment authors and also by UNEP and the Minamata Secretariat since 2013) has taken place in parallel to the negotiation, signing, and early implementation of the

[93] The 2013 inventory was generally consistent with the sector breakdown presented for the 2008 global inventory (UNEP Chemicals Branch, 2008) with one significant difference — in the 2008 inventory, emissions associated with fossil fuel combustion and ASGM were quantified at 878 t and 350 t, respectively, corresponding to 45.6% and 18.2% of total emissions, whereas in the 2013 inventory, ASGM accounts for a higher proportion of emissions (37%) than coal combustion (25%) (UNEP 2013, 18). The new data on ASGM and the related increase in emission estimates from this sector increased South America and sub-Saharan Africa's share of global emissions.

Minamata Convention. The signing of the Convention in 2013 served as a punctuation mark in baselining global mercury emissions in the sense that it served as a benchmark for progress in addressing them after more than a decade of voluntary action and scarce country-level legislation on the topic in most of the world. These practices of quantification, as well as the systematic compilation of national-level data in global environmental reports, are situated in a broader context of global anti-mercury action that involves judgment values about where to draw the line about what information counts to understand and address ASGM's contribution as a global environmental problem, as well as the problem of mercury more broadly considered. I highlight three ways in which such baselining operates.

a. Timeframe and unit of analysis

First, mercury emissions have been "read" in ways that sideline historical mercury legacies like the ones discussed in Chapters 2 and 3. More broadly, global governance for mercury has been framed as a problem of reducing current annual flows of emissions and not necessarily as a problem of environmental justice and economic compensation in the global chains responsible for mercury production, including the cumulative legacy of former colonial empires' mercury use as discussed in Chapter 2. Lake core sediment samples have revealed that pre-industrial mercury emissions have been largely overpassed by contemporary anthropogenic emissions by a factor of three (Selin 2009). However, evidence of atmospheric mercury deposition only dates back to the 1800s, and only a few models have attempted to reconstruct emissions before that date (Nriagu 1994). A large portion of "pre-industrial" emissions has been deposited, so they remain in soils. This medium has been considered a "local" problem and has not received the same degree of attention as the global atmosphere (Selin 2009). The discussion of pre-industrial emissions in UNEP's Global Mercury Assessment reports is mainly technical and focused on the limits of comparing current and past assessments (UNEP 213, 2018), with no reference to the history of mercury exploitation, trade, and use before the 1800s.

Due to the political agreement that made the negotiation of the Minamata Convention possible, the treaty's goals and timelines were set in the future and, therefore, devoted little attention to regulating historical mercury legacies. The only provision focusing on past contaminated sites (Article 12) encourages each party to identify and assess mercury-contaminated sites, which makes the problem a local issue but says nothing about cumulative impacts, compensation, or environmental justice. During the early stage of the treaty negotiations, some activists prepared a preliminary proposal to account for historical emissions. However, it was quickly dismissed and not even brought to the floor.[94] The 'origin stories' of international mercury action that were chosen are very recent – the Minamata Bay disaster in the 1950s and the increasing pollution found in the Arctic in the 1980s and 1990s, as explained in the first section of Chapter 3, have been established as the baselines of current global mercury governance. Therefore, the emphasis of contemporary mercury governance responds mainly to the twentieth-century industrial development embodied by coal-fired power plants, cement production, and, more recently, artisanal gold mining, and much less to colonial or 'pre-industrial' legacies. The Convention's motto ("Make Mercury History") and the calls to imagine

[94] Interview 6.

a mercury-free world symbolize the deliberate decision to leave historical, cumulative mercury legacies outside the scope of contemporary mercury governance.

When zooming into the local level, the overall disregard for historic emissions also reverberates widely and even extends to toxics more broadly. In the 1980s, the US approved the Superfund program to identify and manage the worst hazardous waste and toxic dumping sites. In the EPA's Superfund database, there are currently 1,311 out of more than 50,000 sites with one of mercury's eight chemical forms as one of the contaminants (EPA 2022). While the European Union as a bloc and several European countries have issued directives and legislation on contaminated sites, most countries in the world, including large polluters like China, have very vague or no legislation on the matter (Percival, Cooper, & Gravens, 2012). In Global South countries, the situation is even more critical, especially in those contexts where dependence on former colonial power's donations and goodwill weakens the possibility of developing a consistent and publicly funded scientific capacity (Geissler & Tousignant, 2016). In Colombia, as in most Latin American countries, there is no Superfund-like legislation and while the 2013 National Mercury Law did include a reference to the identification of contaminated sites, it does not follow with responses to manage them and the application of such provision has not even begun almost ten years after the Law was enacted (Brooks, Schwörbel, & Castillo, 2011). While there are ongoing attempts to develop and test methods to identify and risk-rank toxic pollution sites in low- and middle-income countries (Caravanos et al., 2014), in general, the most salient timeframe for managing mercury globally and locally is the present and mainly the future.

The lack of willingness to account for colonial ("pre-industrial") mercury usage is, of course, directly derived from mercury becoming globally relevant and actionable through the epistemic and regulatory mechanisms of the UN –e.g., global assessments, an international treaty, and agency-led project-based interventions in countries–, an architecture in which the nation-state is the main unit of analysis, measurement, and action. Under Minamata, each state is responsible for building its inventory and reporting it to UNEP and the treaty secretariat. Like the census's role as a symbol of nationhood (Anderson 1983), measuring mercury pollution requires numerical and political work to position the state as a good international citizen. This incentivizes particular forms of baselining that center the state as the polluting actor and that sideline the past or present contribution of various actors involved in mobilizing mercury (a perpetually persisting substance) through its global biogeochemical and economic cycles – e.g., the Spanish and the British empires, mining companies operating mercury-intensive gold mines in countries Colombia and Peru in the nineteenth and early twentieth century, transnational crime syndicates smuggling mercury across borders, and gold buyers in global markets with little regard for the origin and toxic trail of the gold they buy. Such an approach also obscures than transnational flows of investment of Northern countries in Southern countries that can result in mercury emissions counted far from the jurisdiction of the countries responsible for them – e.g., transnational oil pipelines.

In line with critiques of the calculations of current territorial carbon emissions that do not account for population size, the scale of emitting sources, and historical emissions (Hickel, 2020), one could ask the same in the case of mercury emissions. In the climate change regime, the principle of common but differentiated responsibilities evokes the idea of equal access to the atmospheric commons taking into account the difference that scale and population play (Hickel,

2020). Taking inspiration from the climate change regime, some have proposed the construction of an all-time anthropogenic mercury emissions metric as another "planetary boundary" (Selin 2022). This exciting exercise would constitute in itself an alternative form of baselining anchoring the benchmark to a much earlier and potentially undermining the centrality of the nation-state as the political and epistemic unit of analysis. However, given the insufficiency of global measurements and models and the uncertainties embedded in them (Basu et al., 2018; Gustin et al., 2016), national inventories remain critical.

b. Infrastructures of measurement and validation

Building national data on mercury has entailed constructing a methodology of calculation intended to facilitate the data aggregation work that UNEP and the scientific community have long pursued. The politics of the production and deployment of said methodology is the second form in which numbers contribute to the baselining of mercury. The call to produce national inventories or update existing ones has been recurrently mobilized by UNEP, the mercury science community, bureaucrats, activists, and state officials involved in knowing and governing mercury since at least 2002. Since 2013, when the Convention was signed, producing national inventories has been part of the parties' reporting obligations and a necessary task for implementing the treaty and assessing its effectiveness. The national inventories prepared since 1990 had the problem of relying on single emissions factors for sectors broadly considered (UNEP 2013, 10). The consequence was that it was possible to estimate a global inventory but at the cost of counting national inventories with problems of under- and over-estimation (UNEP 2013, 10). Also, the limited scientific capacity and dependence on external consultants and projects in Southern countries with ASGM sectors limit their chances of building systematic inventories by themselves (Geissler & Tousignant, 2016).

This scale problem was addressed to some degree in the approach adopted in the *UNEP Toolkit for identification and quantification of mercury releases*, first proposed in 2005 and updated in 2017 (J. O'Neill & Telmer, 2017).[95] The UNEP Toolkit is a series of guidelines and spread-sheet tools developed by UNEP that allow countries to identify and quantify their Hg releases following a standardized methodology with previously included emission factors for each mercury-emitting sector[96] (UNEP, 2011a,b). The Toolkit is designed using the mass-balance principle, which holds that the amount of mercury introduced into the system, or the inputs, will eventually exit the system in the form of emissions or releases (Burton and Evers 2019, 5). Since the most challenging sector to measure is ASGM, in 2017, UNEP published a guide *specifically* to give guidelines on how to do inventories of mercury use for the ASGM sector only. The guide - written by the Artisanal Gold Council- suggests breaking down the available data in each country on estimates of gold production, mining workforce, and mercury

[95] The UNEP Global Mercury Assessment reports revealed that many countries did not have quality data on mercury emissions nor data at all, which is why one of the main outcomes of UNEP's early work on mercury was the development of a Toolkit to calculate national inventories. Mining engineers at the Artisanal Gold Council developed a methodology that UNEP adopted as official (O'Neill and Telmer (2017).

[96] The Toolkit offers default factors for the calculation of inputs (termed "input factors", which are somewhat comparable to (unabated) emission factors); it also invites countries to introduce an additional factor (an "output scenario") to take into account a basic selection of Hg emission control technologies.

use by mining region (O'Neil and Telmer 2017). The Guide is, therefore, an input to fill out the spreadsheets of inventorying that UNEP's Toolkit, which covers all sectors regulated by the Convention, asks states to measure.

Although ASGM has been one the most significant contributors to mercury pollution recently, part of that status concerns the lack of measurements in other sectors. Emissions from biomass burning, natural mercury sources, and legacy impacts of anthropogenic emissions are not considered adequately in most models of the global mercury cycle (Gustin et al., 2016). In the first two Global Mercury Assessment reports in 2002 and 2008, sectors such as aluminum production, biomass burning, oil refining, and contaminated sites were not included. Other industries that have expanded in the twentieth century have also contributed significantly to mercury emissions – for instance, cement production has been rising as one of the pillars of growing urbanization and infrastructure development. Oil refining and gas extraction, two pillars of the carbonized global economy, also emit mercury as a sub-product of their operations (UNEP 2013). However, there are few inventories of these sectors' contributions to mercury pollution. One of the reasons is that some companies are reluctant to disclose their data or even to produce it, a typical move of corporate actors interested in preserving collective states of ignorance (Proctor & Schiebinger, 2008); Kirsch 2015).

Acknowledging that in many countries, some sectors have poor or no data, the Toolkit comes with a default emission factor for each sector, which helps make average estimations even if based on partial evidence. The Toolkit's most recent version (2017) offers the possibility for all countries to adjust the emission factors applicable to their situation – as opposed to a single uniform set of factors applied to previous global inventory estimates[97]. Despite the flexibility, states are expected to do their best to follow the guidelines. Even though the Toolkit was not widely debated with the countries before UNEP started using it, the fact that none raised objections to the tool and the emission factors is a testament to the trust in the agency's expertise for counting tons of mercury. However, UNEP acknowledges that "producing a global emission inventory using the Toolkit would require that all countries develop and use their Toolkit application, and all for the same year (or restricted period)" (UNEP 2013: 10), something unlikely to happen. However, the Toolkit has become the institutionalized form to do national mercury inventories - to date, sixty countries have used the Toolkit for baseline years ranging from 2004 to 2018 (Burton & Evers, 2019).

However, adopting a methodology is not only about deciding and agreeing on a set of emission factors but also about actually collecting the data, a task mediated by funding and capacity priorities.[98] My fieldwork in Colombia illustrated that the local application of the Toolkit could face significant resistance from state and non-state actors to produce and disclose the required data to generate a national inventory. The selective production and collection of data across economic sectors is another baselining practice that shapes the framing of the mercury

[97] The Toolkit's spreadsheet comes now in two versions or "levels." Level 1 is a simple and easier tool without the possibility of changing the underlying emission factors. Preparing a Level 1 inventory requires less data and effort but is more uncertain. Level 2 is a detailed and comprehensive tool where all underlying factors can be tailored according to the national information. Preparing a comprehensive Level 2 takes more time and effort, but it enables a better and more accurate analysis of the situation (UNEP 2021).
[98] Interview 20.

problem. Between 2017 and 2019, I followed Colombia's Minamata Initial Assessment (MIA) project. MIAs is an initiative under the Minamata Convention for signatory states to compile data on how much mercury they produce, trade, or emit, so they can prepare to comply with the treaty provisions once they ratify it. In other words, MIA projects aim to help countries' do a baseline of their capacity to implement the treaty while also giving it resources to carry out an inventory of emissions. Colombia had already done the first National Mercury Inventory in 2010. However, the new version to be presented in 2018 already incorporated the methodology adopted by UNEP and had the explicit goal of monitoring the progress of the Minamata Convention provisions.

Interviewees involved in the update of Colombia's National Mercury Inventory highlighted various instances of the epistemic selectivity of state agencies and industries that refused to disclose data, claimed that they did not have any data at all, or in the case of government agencies, made little to no efforts to press the oil, gas, waste, and coal industries to produce or disclose data about their mercury emissions.[99] In fact, the MIA project was opaque, too – its managers refused to concede interviews or disclose the methodology of the data collection process until the very end of the process.[100] As a result, the public event in which the updated National Mercury Inventory was presented to an audience of ministry officers, military, international agencies, experts, and observers was the first time when the general public saw that the succession of tables, chart pies, and excel spreadsheets that confirmed that ASGM kept being the largest user and emitter of mercury in the country, but contained very limited information about other sources in the country like biomass burning, coal-fired power plants, cement production, and waste incineration (Ministerio de Ambiente 2017). One of the former consultants in charge of running the MIA would later confirm that there were several sectors –like oil and gas companies– who refused to disclose any data for the inventory or claimed that it was not true that their sector emitted mercury, despite being part of the sectors included in UNEP's Toolkit and Global Mercury Assessment reports. While the consultant asked me to not cite the specific companies or government agencies, they did confirm that when they used UNEP's Toolkit for the inventory "they had to enter 'zero' in several categories of the spreadsheet and not necessarily because there wasn't any data, but because those who had it didn't want to share it".[101]

c. The politics of counting and valuing pollution

Even if we managed to overcome this case of produced ignorance (Proctor & Schiebinger, 2008) and achieved widespread adoption of harmonized measurement and data aggregation methodologies with full data from all mercury-emitting sectors, a third form of baselining is the underlying question of valuation – or, as Callon and Law (2015) call it, "qualculation". A parallel to international climate governance and science justice debates can, once again, be illuminating. Discussing the unfairness of proposals to burden India and China

[99] Interview 36.
[100] As a researcher and accredited observer to the Minamata Convention since 2017, I requested interviews and information about the challenges of applying the Toolkit, but the government officers in charge were reluctant to share information about this.
[101] Interview 36.

with carbon reduction commitments in the early nineties, Agarwal and Narain (1991) suggested there should be a distinction between 'subsistence emissions' and 'luxury emissions' when accounting for global carbon emissions and its corresponding politics of morality and justice. They were critiquing a WRI report that overemphasized developing countries' responsibility for greenhouse gas emissions based on data on deforestation, rice cultivation, and livestock, a questionable methodological choice given that then, data on those activities was very poor compared to the more detailed level of precision of fossil fuel use data. Agarwal and Narain argued that a ton of carbon from gas-guzzling automobiles in the North should not be equated to a ton of methane from subsistence farmers in the South. They advocated for a fairer accounting of carbon sinks and historical emissions and called Southern nations to develop their research given the unfair ethics of Northern-led calculations (Agarwal & Narain, 1991). Their work has been influential in various debates on climate justice, the diversification of the IPCC's body of experts and questions, and the dialogues between bodies of knowledge about biodiversity and other global commons (Corbera, Calvet-Mir, Hughes, & Paterson, 2016; Ho-Lem, Zerriffi, & Kandlikar, 2011; Jasanoff, 2017)

Controversies about how to account for greenhouse gas emissions in fairer ways necessarily resonate in the arena of mercury governance. Why should we treat mercury differently from carbon, methane, or ozone? As with carbon or methane, there is nothing natural or immutable about how we regulate chemicals globally, including mercury which is one of the most studied pollutants. Since 2002, quantification of mercury emissions and releases has been done by country and by source or sector. UNEP's call for a global mercury emissions inventory is a necessary step for global action, and the development and adoption of standardized methodologies are also necessary to build such action on reliable data that allows for tracking of progress. However, having limited the timeframe of relevant mercury pollution to "post-industrial" emissions and releases, letting each country set its baseline to assess its progress in implementing the Convention, and explicitly adopting a 'current emissions' approach are all decisions that instantiate how mercury molecules have been accounted in a way that *baselines* the problem leaving outside colonial and industrial legacies of mercury use.

Moreover, inventories and methodologies to construct them do not feature a discussion about different forms or criteria of valuation of mercury emissions. They all account for the same weight (a ton of Hg emitted by ASGM weighs the same in the total figure as a ton of Hg emitted by a cement production plant or a thermoelectric plant). Historical and economic inequality are not explicitly accounted for in this qualculation (Pine and Liboiron 2017). For instance, some mercury-emitting sectors like coal combustion for energy, biomass burning, oil refining, cement production, and plastic production which are directly linked to the expansion of cities and the demands of its richest dwellers could potentially be valued differently than those mercury emissions coming from a rural economy like ASGM that serves as an escape valve for the workforce that no longer has a shot in urban, formal economies (Verbrugge, 2015). Interestingly, the measuring infrastructure constructed by experts, UNEP, and the Artisanal Gold Council (including spreadsheets, courses, and consultants ready to teach them) has been accepted by states without a discussion about the valuation of mercury emissions coming from different parts of the world and economic sectors. In addition, no NGO has requested an alternative form of calculation or valuation of mercury emissions, and all states have accepted UNEP's

methodologies for constructing inventories, but that does not mean that adjustment requests could not potentially emerge.

Another illustration of the differential valuation of mercury emissions is the division between "intentional" and "unintentional" emissions. The first refers to processes where the release of mercury occurs because it is present in fuels or raw materials as "an impurity" - mercury emissions resulting from these impurities are sometimes referred to as "unintentional byproduct" emissions. The primary sources of atmospheric mercury in this category are coal burning (thirty-three per cent of total global emissions) and mining and smelting activities (twenty-two per cent), with minor contributions from the combustion of oil and natural gas (one per cent) and oil refining (one per cent). The second category refers to releases from products or processes where mercury is used intentionally. The largest source of atmospheric mercury in this category is small-scale gold mining (thirty-seven per cent), followed by disposal or processing of waste from consumer products (five per cent). Other intentional sources of mercury emissions arise from its use in the Chlor-alkali industry (one per cent) and release from dental fillings during human cremation (<one per cent) (Gaffney & Marley, 2014). The UNEP Global Mercury Assessment reports explain and use the distinction between "intentional" and "unintentional" emissions to classify, present, and interpret the available data. However, none of the reports dives further into the assumptions behind the category.

If Agarwal's and Narain's critiqued measurements that flattened the differences between 'subsistence and 'luxury' carbon emissions, the division between "intentional" and "unintentional" mercury emissions might be, on the contrary, creating an artificial distinction along the lines of an alleged spectrum of more or less agency (and therefore responsibility) in emitting mercury. While it is true that mercury is not intentionally added to industrial processes like burning coal to produce energy, smelting iron, or producing cement, if one considers the structural reasons why artisanal miners persist in the use of mercury, one could make the case that their "intentionality" does not necessarily require a separate category.

A final point on the question of valuation is that, interestingly, the international mercury governance apparatus under the UN did not embrace market approaches nor open the door for economic valuation and exchanges of mercury caps. There was an attempt to do it in the US, but it did not take hold. In 2005, the US EPA issued a Clean Air Mercury Rule, applying a cap-and-trade approach to mercury emissions regulations. Under the rule, mercury emitting sources like coal-fired power plants could trade tons of emissions in a market scheme. Although cap-and-trade systems have been used to regulate acidifying pollutants in the US and carbon emissions in the US and Europe, this approach did not take hold in the realm of mercury. The Sierra Club and other organizations challenged the rule arguing that a cap-and-trade would incentivize the creation of hot spots. In February 2008, the District of Columbia Circuit Court vacated the rule on procedural grounds, a decision later confirmed by the US Supreme Court (Noelle E. Selin, 2009).

3. Percentages, rankings, and per capita emissions

Numbers have multiple facets, including the repertoire of interpretations and actions that come with their use. In the context of toxics governance, numbers convey a sense of proportion and responsibility, whether it is predicated on specific sectors, companies, or nation-states (Fortun, 2012). As seen with the case of the mercury ratio and mercury inventories, quantifying pollution is not a straightforward process. When complexly produced numbers are turned into simpler numbers, they become more digestible forms of rendering intelligible phenomena. That, nonetheless, does not reduce their political significance. Here, I briefly discuss the case of *percentages, rankings, and per capita emissions*, which are alternative formulations of ratios and inventories but in different scales, magnitudes, and with additional political ramifications. Percentages emphasize economic sectors, whereas rankings and per capita emissions focus on the states and citizens. As I will explain, these three forms of quantification not only describe the ASGM sector and the states in which it takes place but also produce their status as polluting actors or places in ways that conceal or reinforce various forms of injustice. Inventories produced a global landscape populated by nation-states differentially emitting mercury but adding to a global budget. At the same time, percentages, rankings, and per capita emissions configured hierarchies among them and point to the shares of responsibility of the main mercury-emitting sectors in them.

Let us begin with *percentages*. Any quantity can be expressed in different ways and elicit a varied response. For instance, the number 250,000 could be expressed as a quarter million, increasing the relevance scale, or could be presented as twenty-five per cent of the million, emphasizing the share of the total (Castillo 2017). Another example could be election polls showing national voting intention and not regional or local percentages. In the realm of toxins and pollution, percentages usually come accompanied by moral judgments and calls to action as they are a form of determining the responsibility of political actors. However, assigning responsibility through percentages is far from straightforward. Complex questions of attribution, quantification and power asymmetry can be concealed behind a simplifying percentage. For instance, debates about historical carbon and methane emissions revolve around how to account for historical responsibility when most analyses focus on cumulative national-territorial emissions since this is the way available data is usually presented (Evans, 2021). Also, most analyses do not account for the "exported" emissions that large-emitting countries emit overseas at the present. Carbon Brief's report on national responsibility for historical CO2 emissions from 1850-2021, large post-colonial European nations, such as Germany and the UK, account for four per cent and three per cent of the global total, respectively. However, such a calculation did not include overseas emissions under colonial rule (Evans, 2021). In sum, percentages depict a ratio of a given moment while also concealing temporal and scalar variation unless explicitly stated.

An illustrative example is ASGM's contribution to global mercury pollution, frequently expressed as a percentage (thirty-eight per cent) that conceals the work behind its production. For starters, percentages usually conceal the unit on which they are being calculated, which is limited to the total of emissions calculated in the most recent inventory. Since the number of sources that have been measured over time has been progressively expanded, even comparing percentages can be deceiving. As Table 7 below illustrates, each mercury-emitting sector has a trajectory in the measurement of mercury-emitting sources, which has varied according to the available data at a given moment. ASGM went from not being counted in 2002 to becoming the largest emitter of mercury to the atmosphere in 2013 and 2018. In contrast, coal combustion

went from being the largest source of emissions with more than seventy-seven per cent of quantified emissions to accounting for twenty-two per cent in 2018. (UNEP, 2013, Selin 2013).[102] As the Global Mercury Assessment reports and its authors warned, the rise of ASGM as the largest polluter had to do with better measurements and estimations. However, as mentioned in the opening vignette, the percentage of ASGM's contribution to global mercury pollution presented by the UNEP GMA report pool of authors at Minamata COP1 circulated widely and consistently across the venue and beyond it in reports, booklets, and pie charts in PowerPoint slides not as the outcome of better measurements but as a symptom of the aggravation of the larger problem of ASGM.

Having "more data" about a sector like ASGM has political resonance because it counters the common perception about a sector considered "unknowable." Since the early 2000s, the UN and the World Bank created a measurement complex of censuses, consultancies, pilot projects, and other knowledge production practices aimed at measuring whether ASM communities were moving from poverty to well-being as their policies and programs directed toward the subsector intended (Siegel, 2018). After more than two decades of efforts to make it legible, ASM remains an understudied sector, and international agencies keep struggling with its social, environmental, and economic "data gaps." A recent World Bank report states that "*apart from a series of outdated employment and production estimates in select countries, little is known about the organizational structures of ASM, the backgrounds of those engaged, and the production networks the mineral ores they extract supply*" (World Bank 2019). In that vein, a figure like "ASGM contributes to thirty-eight per cent of global atmospheric mercury emissions" circulates and becomes successful in a context in which little is known about ASM more broadly, which speaks to the power and authority accumulated by UNEP, the Artisanal Gold Council, and a set of consultants and experts on mercury to speak about ASGM. However, as discussed above, said percentage builds on the measurements of a given year in which not all mercury-emitting sectors were measured and built on aggregations of widely varying national-level data.[103]

[102] The 2013 inventory was generally consistent with the sector breakdown presented for the 2008 global inventory (UNEP Chemicals Branch, 2008) with one significant difference — in the 2008 inventory, emissions associated with fossil fuel combustion and ASGM were quantified at 878 t and 350 t, respectively, corresponding to 45.6% and 18.2% of total emissions, whereas in the 2013 inventory, ASGM accounts for a higher proportion of emissions (37%) than coal combustion (25%) (UNEP 2013, 18). The new data on ASGM and the related increase in emission estimates from this sector increased South America and sub-Saharan Africa's share of global emissions.

[103] Another point would be to discuss the alternative of groping the sectors measured in inventories. The ASGM sector and the large-scale gold mining sector as usually presented as separate sources of emissions, with the former accounting for 38% of emissions and the latter for 5% of them. However, there are other possible forms of grouping sectors, such as merging both the small-scale and large-scale gold mining sectors (which would add to 43% of emissions and, presumably, to a different conversation), or merging mineral and nonferrous metal production, or highlighting sources of emission that feed urban growth or large infrastructure building like cement, iron, and non-ferrous metals. Such alternative groupings might put the reflectors on sectors that have not been as prominently featured in mercury policy as ASGM, such as oil refining or waste incineration.

Table 7. Estimated global mercury emissions in metric tons ($t.a^{-1}$) and percentages by sector

Atmospheric mercury emission source	**UNEP GMA 2002**		**UNEP GMA 2008**		**Pirrone *et al.* (2010)**		**UNEP GMA 2013**		**UNEP GMA 2018**	
	$t.a^{-1}$	**per cent age**	**$t.a^{-1}$**	**per cent age**	**$t.a^{-1}$**	**per cent**	**$t.a^{-1}$ *(min-max)***	**per cent**	**$t.a^{-1}$ (min-max)**	**per cent**
Coal (all uses)	1475	**77**	**880**	**45,5**	**810**	**38,5**	**474 *(304-678)***	**24.0**	**533**	**22.4**
Biomass combustion									51.9 (44.3-62.1)	2.33
Fuel and natural gas							9.9 *(4.5-16.3)*	1.5		
Foundries and mined metal production										
Primary ferrous metal production	165.5	8.65	55	2,9			4.5 *(20.5-241)*	2.0	29.8 (19.1-76.0)	1.34
Non-ferrous metal production (Al, Cu, Pb, Zn)	29	1.5	132	6,9	**310**	**14,7**	**193 (82-660)**	**10.0**	**228 *(154-338)***	**10.3**
Large-scale gold production			111	5,8			97.3	5.0	84.5 *(72.3-97.4)*	3.8
Primary cinnabar mining			9	0,5			11.7 *(7.3-26.4)*		13.8 *(7.9-19.7)*	0.62
Cement production	132	7	**189**	**9,8**	**236**	**11,2**	173 (*65.5-646)*	<1.0	**233 *(117-782)***	**10.5**
Oil refinery							16 *(7.3-26.4)*	4.0	14.4 *(11.5-17.2)*	0.65
Contaminated sites							82.5 *(70-95)*			
Artisanal and small-scale gold mining (ASGM)			**350**	**18,2**	**400**	**19,0**	**727 *(410-1040)***	**37.0**	**838 (675-1000)**	**37.7**
Chlor-alkali production			47	2,4	163	7,7	28.4 *(10.2-54.7)*	1.0	15.1 *(12.2-18.3)*	0.68
Waste from consumer products	0.1		120	6,3	187	8,9	95.6 (*23.7-330)*	5.0	147 *(120-223)*	6.6
Cremation (dental amalgams)			26	1,4			3.6 *(0.9-11.9)*	>1.0		
TOTALS*	1912 (900-6200+)		1919		2106		1960 *(1010-4070)*	100	2220 *(2000-2820)*	

Largest polluter	2nd largest polluter	3rd largest polluter

Source: adapted from Ministry of Foreign Relations and Ministry of Environment and Water, 2015.
*Note: Some emission categories were not included in all reports, so the totals reported do not coincide with the total values of emissions calculated in each report.

In other instances, the nation-state as a political unit takes precedence over specific sectors, and quotas of responsibility come to be expressed in terms of *country rankings*, the second metric I discuss here. Alongside indicators, rankings have become typical metrics of

international organizations collecting data about states, like the World Bank or the OECD (Davis et al., 2012). Rankings' seductive power lies in their capacity to facilitate comparison and ranking of countries and organizations, at the risk of oversimplification and homogenization if not grounded in qualitative, locally informed knowledge production (Mennicken & Salais, 2022, p. 4). In the realm of environmental governance, the Environmental Performance Index (EPI), originally built to complement the Sustainable Development Goals' precursor (the Millennium Development Goals), has become a technology for government ranking countries' performance on high-priority environmental issues (Hsu, 2016).

In toxics and pollution, there have been various forms of ranking, most of them focusing on specific sites. Between 2008 and 2016, Pure Earth and Green Cross Switzerland published an annual report of the top ten polluting sites based on each place's environmental health harm measured in Disability-Adjusted Life Years (DALY).[104] Air quality activists have also ranked cities depending on the quantities of particulate matter measured. In 2022, the UN Special Rapporteur on the environment and human rights and the Special Rapporteurs toxics and human rights issued a joint report on the world's "sacrifice zones", defined as places where communities are exposed to extreme levels of pollution and toxic contamination and suffer devastating physical and mental health consequences (Boyd & Orellana, 2022). Without any other criteria rather than regional representation and critical human rights violations worth highlighting, the report identifies around 50 sacrifice zones in the five continents in places like the Ventanas plant in Chile, La Oroya smelter in Peru, Chornobyl in Ukraine, among many others. Interestingly, although the Special Rapporteurs referred to ASGM as a source of contaminated sites in low- and middle-income countries, none of the sacrifice zones in the report are related to mercury or ASGM (Boyd & Orellana, 2022, p. 6).

Country rankings of mercury pollution first appeared around 2010, when the Mercury Watch tool became popular. Ever since, countries like China, Indonesia, and Colombia started to feature prominently in scholarly and media outputs about mercury as a significant polluter (UNEP 2018, 2018, 2019). Such rankings have tangible consequences on the ground and are typically contested. In the case of Colombia, the label of polluting country dates back to 2007, when a team of mining engineers and scientists sponsored by UNIDO did a study on atmospheric mercury levels in Segovia and Remedios, two towns located in the mountainous region of Antioquia, the largest gold producer in Colombia, and from which most of the mercury emitted by ASGM comes (Cordy et al. 2011). Northeastern Antioquia is also one of the epicenters of Colombia's armed conflict: every year, there are 600 murders per 100,000 habitants in Segovia and Remedios –the national average is 30 (Arango 2013). Given the long history of armed violence in Northeastern Antioquia –which can be traced back to the 1950s time known as *La Violencia*, the bipartisan conflict between liberals and conservatives that precedes the current conflict (Botero 2003)–, it should not come as a surprise that violence and toxicity ended up entangled at some point in Antioquia's more recent history. Being the gold mining region par excellence in Colombia and where mercury amalgamation was first used in the country in the mid-nineteenth century, Antioquia has also been one of the laboratories of the local and international efforts to address mercury pollution.

[104] See https://www.worstpolluted.org/

The UNIDO researchers found shockingly high levels of mercury in the towns' air (Cordy et al., 2011). The WHO limit for public exposure is 1000 ng/m3, and near some processing centers in Segovia, the study found levels that range from 2,000 to 10,000. These results brought about a public outcry that signaled Segovia as "the world's most polluted place by mercury" (Veiga, 2010). The report gave the country "the shameful first position as the largest world's mercury polluter per capita from artisanal gold mining" (Veiga 2010). Such a conclusion circulated widely in the media and public conversations about mining – the headline was that "the UN" had declared Antioquia as the most polluted place on Earth and, therefore, an intervention was urgent. This was the justification for including Colombia in UNIDO's Global Mercury Project (Bedoya-Builes, 2011), an international initiative raising awareness and training miners on mercury-free processing techniques in six countries, and for approving a National Mercury Law in 2013. Although the terms of the comparisons and rankings were rarely made explicit, Northeastern Antioquia came to be seen as a toxic landscape – the most polluted place in the country and the world.[105]

Pollution rankings are not just mere descriptions of toxic landscapes but also mechanisms that produce such landscapes and render them visible through varied criteria and generate particular kinds of intervention and responses. The signaling of Colombia as a leading global mercury polluter through a ranking had two tangible effects: it helped foster a national mercury policy, and it brought about collective feelings of shame, resistance, and resentment at both the national and the local levels. One of the report's leading suggestions for immediate action of the Colombian authorities was to prohibit the use of mercury in towns, either in informal processing centers (*entables*) or burning mercury in gold shops (Veiga 2010). Consequently, UNIDO's project fostered a discussion that ended in a bill in Congress. In 2011, then-Congressman Augusto Posada proposed a Bill to incorporate UNIDO's recommendations, which turned into the 2013 National Mercury Law. During the legislative discussion, the question of international shame and blame featured prominently. According to an observer of the legislative discussion, "Colombia already led in human rights defenders' killings, cocaine exports, and other not so dignifying forms of human rights violations – being the country that emits the most mercury to the world was not something that anybody wanted".[106]

Also, people in Segovia resented the label of allegedly being the most polluted town. Consistently, my interviews with miners and processing plant owners revealed that being seen by the media, scientists, and the rest of Antioquia as "the toxic region" of the country was received with disbelief or felt like another layer of oppression to struggle against on top of being one of the epicenters of the country's armed conflict and a symbol of the country's ASGM sector struggle for more favorable policies.[107] In 2017, peasants, small-scale miners, and unionized workers in Segovia and Remedios launched a 32-day strike against some proposed reforms to the formalization process. Although it was not the main claim, the miners protesting all over Antioquia's mining towns (including Segovia and Remedios) demanded that the government stop military crackdowns and criminalization of informal and artisanal miners based on mercury

[105] For some press coverage see, among many others, El Tiempo (Dic 16, 2015). "El drama de los 'hombres de mercurio'; RCN Radio (May 14, 2014). "Antioquia, uno de los lugares más contaminados por mercurio en el mundo";
[106] Interview 18.
[107] Interview 22, Interview 23, Interview 24.

pollution claims. Although the issue of the mercury use restriction in ASGM approved in the 2013 Mercury Law had not been enforced, miners in Antioquia saw it with concern.[108]

Local scientists also took issue with the label of the Northeastern of the Antioquia province as "the most polluted on Earth." Claims of the UNIDO study being an example of helicopter science, as well as struggles for funding, were some of the main issues that the local scientists I interviewed highlighted as motivations to counter the UN measurements or engage in tracking progress in reducing mercury emissions from the region's mining operations.[109] In response to requests from the *Mesa Minera* and APLABAS (the local mining organizations of Segovia and Remedios), chemists and environmental engineers from the Universidad de Antioquia took UNIDO's work as a baseline to work with – since 2013, the team worked with various processing centers and monitored emissions for more than eight years. In 2021, the team published their results, which indicated a considerable reduction in mercury levels in Segovia's processing plants. Although the mercury levels in the town's air are still high, the Universidad de Antioquia showcased their work as critical to declare publicly that Segovia "no longer was the most polluted town."[110] For Segovia's inhabitants, the news is a motive of pride, and some miners see it as a reflection of various processing plants' efforts to reduce mercury use in the last decade (O. García et al., 2015).

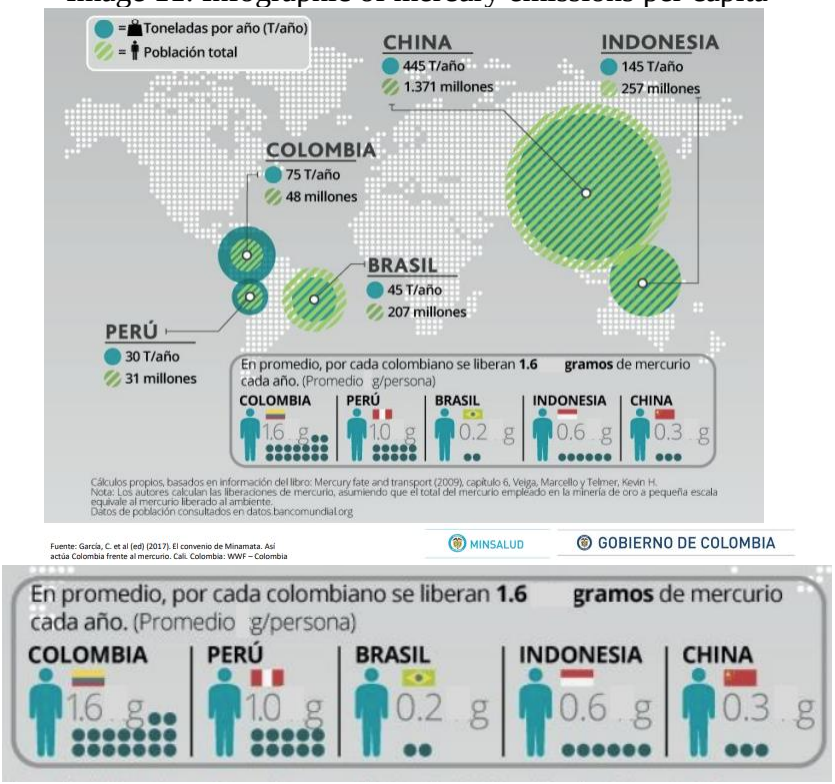
Finally, *emissions per capita* is another metric that has gained prominence in debates about global governance of toxics, and that can also be interrogated in the case of mercury. A per capita metric aims to compare a metric to a population. The most common are gross domestic product (GDP) per capita and income per capita. Pollution rankings do not account for population size, the scale of emitting sources, and historical emissions (Hickel, 2020). A per capita metric partially solves the problem by controlling population size and distributing responsibility for emission to an 'imagined community of polluters (cf. Anderson 1983) in which all members of a nation are equally responsible for the gross quantities emitted within the boundaries of the country they inhabit regardless of their involvement in the activity. Scholars have critiqued per capita metrics due to the flattening effect of responsibility and the limits of putting complex webs of pollution into the box of the nation-state (Liboiron and Lepawsky 2022). In the climate change regime, the principle of common but differentiated responsibilities evokes the idea of equal access to the atmospheric commons taking into account the difference that scale and population play (Hickel, 2020). Such critique, as was already hinted at in various sections of this chapter, is also relevant for thinking about how we measure global mercury pollution. Since massive anthropogenic mercury emissions date back to the times of the Spanish empire's massive extractive endeavors in the Americas since the sixteenth century (Saul Guerrero, 2017a; N. A. Robins, 2011), a per capita metric adds historical colonial emissions to the shoulders of current ASGM countries.

In the context of UNEP's and Colombia's work on mercury in ASGM, the furthest I have been able to trace the mercury emissions per capita metric was back to the UNIDO-backed study in Segovia and Remedios referenced above (Cordy et al., 2011) which labeled Antioquia,

[108] Interview 57, Interview 55, Interview 56, Interview 49.
[109] Interview 52, Interview 37, Interview 15, Interview 16.
[110] Universidad de Antioquia (Jun 2, 2020). "Segovia ya no es el más contaminado por mercurio". Available at: shorturl.at/imqtv

Colombia as the world's highest per capita mercury pollution. Through measurements around 15 processing centers and interviews with miners and mining processing owners, the study found the scandalous levels of mercury described above. However, it does not justify or elaborate on the emissions per capita metric. A few years later, when environmental organizations started to advocate for the ratification of the Minamata Convention, WWF Colombia launched a report summarizing the treaty and making a case for its ratification. The report highlighted that with 75 tons of mercury per year on average, Colombia had become the country that releases the most mercury in the world after China and Indonesia, which are reported to release 445 and 145 tons per year (Garcia, 2017). Interestingly, the mercury emissions per capita metric had not been used in any of the previous attempts to estimate the country's mercury emissions (Brooks et al., 2011; Rojas, Gamba, Forero, & Mejía, 2007). The WWF report did not elaborate on the metric, and there was no methodological annex explaining it. However, the text did include a visual depiction comparing tons of yearly mercury imports of various countries with their population through a map and a diagram of nationals from various mercury-emitting countries (see Image 2).

Image 11. Infographic of mercury emissions per capita

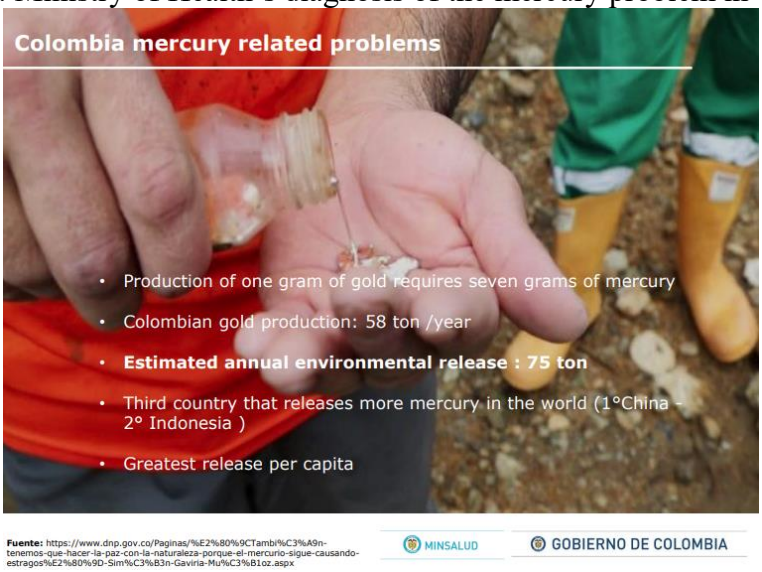


Source: Garcia et al (2017). WWF report on mercury in Colombia.

The diagram read, "*On average, for each Colombian, 1.6 grams of mercury are released each year*" and presented a row of human figures representing how much mercury was emitted from Peru, Brazil, Indonesia, and China. Although it is not explicitly stated, the metric intended to accentuate the international shame and reiterate the reaction that the UNIDO study on Antioquia had elicited during the legislative discussions about the 2013 National Mercury Law – various government officers and participants of that debate coincided in the same motivation

along the lines of "we were already international leaders in other shameful fronts, who wanted to add more shame especially when the government was carrying out peace negotiations?"[111]. Consequently, in the debate about the delayed ratification of the treaty (which took five years precisely due to legislative congestion related to other topics like the 2016 Peace Agreement with the FARC guerrilla), the rankings (both third place in net emissions and first place in per capita emissions) were widespread and recurrently invoked by activists, government officers, and experts.[112] A powerful testament to the power of these metrics is the fact that they became part of the Colombian government's repertoire to characterize the problem. A 2018 government report from the Colombian Ministry of Health about the implementation of the National Mercury Law summarized the mercury problem using five metrics discussed so far: the country's mercury-gold ratio, the national gold production, the estimated mercury releases to the environment, Colombia's third place in the ranking of net emitters, and the first place in the per capita ranking (see Ministry of Health and Social Protection (2018) and Image 3 below).

Image 12. Ministry of Health's diagnosis of the mercury problem in Colombia



Source: Ministry of Health and Social Protection (2018).

4. When less is more, but only for a few: certified mercury-free gold

The flipside of quantifying mercury use in ASGM or any given sector is estimating how much of that use can be avoided. The production of mercury-free gold –another way of accounting for avoided mercury emissions– is the last quantification device I discuss. The bulk of the international action on mercury led by UNEP's Global Mercury Partnership (2005-2013) and then by UNEP and the Minamata Convention parties focus on reducing and, when possible, eliminating mercury use in ASGM coal-fired power plants and every other sector. *Reducing* or *avoiding* emissions is part of the mantra that mercury projects repeat and aim for and is very often when of the preferred success metrics. As a well-known consultant on mercury issues with

[111] Interview 14.
[112] Interview 18, Interview 17, Interview 2.

experience in a dozen of countries, "ultimately, consulting work is premised on the idea that any reduction is worth working for – it is about scaling up small work in times where the market is hungry for certified gold."[113] For another consultant, the importance of reducing tons of mercury emissions is just one of how his work is characterized by measurable quantitative indicators like the number of people attending training sessions or the numbers of booklets and printed materials delivered.[114] Therefore, a final form of numerical work that shapes the status of ASGM in the realm of mercury governance is the amounts of gold that make it into global supply chains with the stamp of being "mercury-free."

That the burden of reducing mercury from ASGM falls on the actors least willing and able to manage it raised the question of what private and civil society actors can do to support or complement said goal (Sippl, 2015a). In that context, information-based forms of governance have gained space as an emerging form of "informational environmentalism" that puts part of the responsibility on consumers, retailers, or higher links in different supply chains to shift their behavior or preferences based on information about how the commodities they consume have been produced (Florini & Jairaj, 2014; Fortun, 2012; O'Neill, 2017). A specific type of information-based mechanism is labels and certifications, typically mobilized by alternative trade organizations. Since their emergence in the 1970s, these organizations have grown and expanded their reach to products like timber, fish, apparel, handicrafts, liquor, tourism, and most recently, minerals (Sippl, 2015a). In the mining sector, there are ten certifications, but only two regulate ASGM and the use of mercury in mineral processing. The creators of these two regulations are the civil society certification organizations Fairtrade International (FLO) and the Alliance for Responsible Mining (ARM). Since 2006, these two organizations have developed various standards to certify gold produced by ASGM in fair conditions for workers, buyers, and the environment (Sippl, 2015a).

Despite their growth, ASGM certifications face serious challenges. First, it is difficult to work in contexts in which the vast majority of the ASGM sector is informal or illegal, as it poses serious threats to the possibility of legally exporting gold. Also, since gold is a commodity bought by the consumer in low quantities at high prices, the flows that end up being certified are minuscule, which for some makes "the fair-trade gold more of a PR stunt than something can make an impactful difference."[115] Despite the premium price that miners receive for mining and processing gold following the certification, only a small elite of miners is capable of financing and sustaining changes in their production process standards –in this case, not using mercury– and therefore feeding the market with significant quantities of gold. Moreover, even when they do, gold supply chains are characterized by profound inequalities between miners, intermediaries, and buyers. Studies have shown that when gold producers sell their gold into the value chain, large-scale companies receive up to ninety-eight per cent of the price, whereas ASGM receives around seventy per cent (Sippl, 2015a, 2016). Also, when assessing the distribution of benefits from gold purchase, actors at the top of the supply chain (the wholesaler, the retailer, the refiner) accumulate seventy-five per cent of the value of a ton of gold. In contrast, roughly fifteen per cent goes to the miner. Such injustice illustrates bluntly "why some actors are enjoying market power, while others are relying on toxins to survive (Sippl, 2016).

[113] Interview 39
[114] Interview 37.
[115] Interview 9

A discussion about the limits of these certifications is beyond the purpose of this section, in any case. What I want to highlight here instead is how the shift toward information-based and market mechanisms to reduce mercury use in ASGM relies on a logic of quantification that promises to redistribute wealth, value, blame, and virtue in the gold supply chain, but in the end, does little to do so and it might even accentuate it. As described above, Minamata COP1 was heavily populated by powerful actors in the gold supply chain. COP1 was a site for mobilizing the mercury-free gold agenda with the expectation that implementing the Convention would open opportunities for gold buyers. This is a status quo that players in the field (like Transparence, ARM, the Jewelry Council, and the gold refiners and buyers) are aware of, just like they are of the problem of quantities – ASGM produces around twenty per cent of the world's gold supply, but less than one per cent has been certified. Aside from the concentration of certification capacity in a small elite of producers, another obstacle is that gold buyers in OECD countries deem certified gold quantities insignificant. A mining engineer and consultant in mercury issues highlighted his experience working with refiners:

> *Certified gold does not expand the supply of OECD-complying gold (…) The refiners will tell you "as much as much OECD-complying gold as you can give us, we´ll take it. Have you got one ton? Five tones? Ten tons? We'll take it". And if you say "well we've got a kilo and a half a month, but it is mercury-free. "Oh. Man, Ugh". So there is a disconnect between what the refiners want because their margins are pretty low actually they need volume. And the production of clean gold is too low to meet their minimum demands.*[116]

Despite this "disconnect," the market of certified gold is growing, but not at the expected pace. At COP1, I interviewed some NGO representatives working on gold supply chains who coincided with the problem of low quantities. However, some insisted on highlighting the importance of these low quantities of gold. For instance, the head of the Alliance for Responsible Mining said that they were helping ASGM in Colombia, Peru, and Bolivia sell 200 kg (0.2 tons) per year, which is a low but politically impactful quantity because it makes "*a lot of noise that is important because it creates awareness, recognition of the miners, of the sector, of the possibility of acknowledging that buying gold is not something negative, but rather something positive*".[117] Given that powerful industry actors like Apple, Microsoft, and Intel tend to believe that it is environmentally more responsible for buying recycled gold because it is not mined,[118] certifications also help counter the fever for recycling valuable minerals from e-waste and reiterate the importance of buying gold from ASGM but also to pay a fair price for it. The problem, again, is that trading a few hundred grams of gold per year does not incentivize buyers enough; therefore, the potential of certifications to reduce mercury use in ASGM is minimal.

III. Conclusion

There is nothing natural about how we count (and account for) environmental problems. As STS and political ecology scholars have insisted, how we choose to measure the problem is

[116] Interview 39.
[117] Interview 58.
[118] Interview 58.

connected to how we want to govern it. The chapter examined how numerical work shapes and is shaped by narratives of blame and virtue in the ASGM sector. Far from being mere descriptions of a fixed reality in the ASGM sector, of "things as they are" in mining sites – the quantification devices I discussed have played an active part in the construction of the problem framing and are themselves political processes. Specifically, in the case of measuring and quantifying mercury use in ASGM, I showed how decisions about measurement are inseparable from decisions about what dimensions of the problem we want to remain at the local level and which ones are we willing to address at the global level, how much can states be pushed or incentivized to collect data and act, how do we address states of uncertainty and lack of data produced by powerful actors with state acquiescence, and how do we respond to vulnerable actor's environmental blame when quantitative evidence (for some, 'objective') seems to put the blame and the burden on them.

In this chapter, I demonstrated said entanglement in four ways. First, the mercury use ratio in ASGM is characterized by various assumptions and extrapolations of local data and is an example of a qualculation: a metric that conveys quantitative certainty while also embedding assumptions of inefficiency. Despite the assumptions and values embedded in and expressed by the ratio, this metric helped assemble an infrastructure of pollution data at various scales and be prominently cited and referred to in the drafting of global assessments and corporate and NGO reports - in fact, the ratio was instrumental in supporting the negotiations of the Minamata Convention and, in particular, the provisions on ASGM and international mercury trade. The ratio has also been used, as the Caracol TV outlet on illegal gold mining in Antioquia illustrated, to underpin discourses of militarized conservation and accentuate the depiction of ASGM as a criminal sector.

Second, baselining through global and national inventories is a process that takes place in conditions of asymmetrical power to collect data and encourage powerful actors to produce it and disclose it. The success of specific forms of baselining is mediated by decisions about the relevant timeframe, the maintenance of infrastructures of validation, and an agreement on the valuation (or lack thereof) along the lines of historical responsibility and justice. Despite the possibility of adjusting emissions factors for specific sectors depending on local realities, the numerical work in producing and collecting data on the ASGM sector's contribution to the current global mercury cannot be understood without attentiveness to the political economy of data characterizing the production of pollution inventories.

Third, when complexly produced numbers are turned into more straightforward numbers, they become more digestible forms of rendering intelligible phenomena and create specific publics for them. Percentages, rankings, and per capita emissions have served as various formulations of ratios and inventories but in different scales, magnitudes, and with additional political ramifications. Percentages emphasize economic sectors, whereas rankings and per capita emissions focus on the states and their citizens. These three forms of quantification not only rank and classifies the ASGM sector and the states in which it takes place on a scale of international shame but also produce their status as polluting actors or places in ways that conceal or reinforce past and present forms of global economic and environmental injustice. In particular, the mercury emissions per capita metric, as it happens with the carbon emissions per capita, de-emphasizes the role of large structures of historical and present injustices beyond the

nation-state that help produce mercury emissions and its subsequent harm and risk for specific sites and communities.

Moreover, fourth, the minuscule quantities of mercury-free gold that circulates in global supply chains are inversely proportional to the political resonance they have. Despite the limited number of mines and miners enrolled in certification programs, the work of organizations like the Alliance for Responsible Mining, the Artisanal Gold Council, or Fair Trade Organization has attempted to maximize the value and economic promise of mercury-free gold with high-profile buyers. However, such a limited impact ends up reinforcing economic, and power asymmetry in gold supply chains and legitimizing the idea of mercury-free mining as an individual matter, whether it is at the production or the supply end.

Table 8. Overview of measurement, estimation, and visualization devices of mercury use in ASGM and their political significance

Device	Scope	Metric	Method	Example	Exercises power
baselines and inventories of pollution	General	Metric tons emitted per year across sectors	Secondary sources Voluntary disclosure Direct measurement Estimation	GMA reports UNEP toolkit MIA project in Colombia	-Fixed image of responsibility -Pressures states to collect and disclose data -a benchmark to claim progress, even if the basis is partial -Point zero effect, de-historicizes mercury pollution
rates of mercury use per gram of gold produced	Specific to ASGM	Rate of g Hg used per g of Au produced	Direct measurement Estimation Secondary sources	UNIDO AGC	-Render the problem legible and actionable locally -Scientific basis for technological intervention
Percentages and rankings	General Specific to ASGM	Metric tons emitted per year from each country	Ranking Visualization Per capita emission	Mercury Watch maps UNIDO Global Mercury Project	-Puts political pressure on certain countries -The nation state as the polluting actor -legitimizes interventions, funding projects, bilateral relations
certified pollution-free gold circulating in global gold markets	Specific to ASGM	Metric tons of mercury-free gold entering global markets	Certification	ARM AGC Transparence	-legitimizes power asymmetry in gold supply chains -exerts pressure on informal miners -reinforces the idea of mercury-free mining as an individual matter

CHAPTER 6. Conclusions

Summary of conclusions and contributions

The research made conceptual and empirical contributions to debates on the social dimensions of toxicity and ASGM as an extractive industry in Latin America. This work developed a conceptualization of mercury use in ASGM, attentive to the histories of colonialism, historic corporate extraction, state-sanctioned toxicity, and neoliberal mining policies in Latin America. Drawing on an interdisciplinary approach, I treated mercury not as an isolated molecule devoid of social history and politics, as depicted by Almaden's Mercury Museum 6-feet structure of the substance's molecular structure or the inflatable mercury "drop" installed by UNEP in Geneva, but as a chemosocial substance entangled in conflicting social orders at different scales. Thinking with Boudia, Liboiron, Murphy, and others, I demonstrated that mercury's toxicity is better understood as the maintenance for certain social orders (embodied by colonial, corporate, and state power, as well as contemporary gold markets hungry for green gold, but no so much for allowing a fairer share for ASGM) and the simultaneous transgression of others (the integrity of the atmosphere and a myriad of other landscapes and bodies).

Each of these forms of power share the reliance on mercury its constitution, and have been intimately intertwined. Mercury was essential for the colonial rule of the Americas as a commodity under colonial monopoly and critical for the global economy then. Data and archives about colonial mercury use are limited, and atmospheric chemists still debate the interpretation of lake sediment core samples and models, but there is agreement on the global reach of mercury during Spanish colonialism being unprecedented and massive in magnitude but not sufficiently studied. The corporate use of mercury in Colombia between 1853 and the late twentieth century was the continuation of a concession given to Great Britain and the US that was eventually passed on to the Canada multinational company that keeps exploiting El Cogote mine and reinforces criminalizing narratives against miners in the area. In addition, the active provision of mercury by the state (an issue that requires further archival investigation) also made possible the persistence of amalgamation as a standard and legitimate method in the gold mining sector.

A distinctive point of this work was the emphasis on situating mercury's chemosocial life in histories of colonialism and corporate extraction in the Americas, with a particular focus on Colombia. I demonstrated that mainstream narratives depicting mercury use in ASGM as a derivation of countries who are passive towards international contraband, conceal the long history of mercury imports by the Spanish empire, mining companies operating in South America, and the long-term acquiescence and active state-sanctioned mercury use and provision in Colombia and Peru until the 1970s. In UNEP's Global Mercury Assessment reports, "pre-industrial" emissions do not feature prominently. Very much like the IPCC recently acknowledged the role of colonialism in producing the current global climate injustice (IPCC WG 9, 2022), the next UNEP's Global Mercury Assessment and discussions about mercury use in ASGM more broadly, could and should acknowledge the role of various centuries of colonialism in the Americas in the production of contemporary toxic landscapes and injustices. A debate on reparations due to historic toxic colonialism in the Americas is therefore a pending task, and even if it is unlikely to emerge soon largely due to the slow nature of mercury’s toxicity, that does not mean it could not emerge further down the road. In other realms like

forestry, international organizations like the Food and Agriculture Organization (FAO) and initiatives like the Global Forests Assessment have also yet to address how their technocratic and managerial discourses of forestry management in tropical countries have reinforced networks of colonial forestry in Southeast Asia and elsewhere (Vandergeest & Peluso, 2006).

This dissertation constitutes a foundation for a research agenda addressing the politics of toxic heritage sites that bridges discussions on environmental politics and science studies on mining frontiers, and emerging debates in heritage studies of former extraction sites that extend to transformation into public museums or touristic parks. That conversation is already underway as I showed in Chapter 1. During my fieldwork, I collected accounts of the New Almaden cinnabar mines that operated in California for a century and that today have been closed and turned into a Museum (like Almaden in Spain). For less than a decade in the 1860s, when the cinnabar mine was active, New Almaden in Northern California occasionally provided mercury to silver and gold mining operations in South America. However, most of its output was used by mining operations in North America.

The dissertation nuanced the question of miners' resistance to abandoning mercury use in Colombia, in particular, and highlighted how such refusal rests on a sedimented history of past mining practices, dynamics of knowledge production and circulation, and mining policies in colonial and post-colonial contexts. Adding to a growing body of ethnography and qualitative research to study pollutants and toxicity, the case of Colombia and its relationship to COPs and other global managerial institutions illustrates how "following" mercury and mining through different temporalities and spatialities helps unravel their entanglements in those broader infrastructures and political ecologies. I paid particular attention to the global dimension of the problem (among other ways, by using the Minamata Convention COPs and UNEPs international scientific assessment of mercury as sites of data collection as well as components of what I called mercury's infrastructure), while also grounding my analysis in Colombia, considered one of the largest mercury emitters. There, I traced the layered histories of mercury toxicity in the most prominent and oldest gold mining regions in the country (Segovia and Remedios in Northeastern Antioquia) and mapped the trajectories of colonial, state, and corporate efforts to both import mercury and promote its use in-mining. In doing so, the work denaturalized and interrogated the representation of ASGM by the global policy community as the "world's largest mercury polluter". Moreover, it illustrated how certain substances such as chemicals are rendered toxic through their socio-natural lives that, in complex ways, render them desirable, unruly, and forbidden at particular moments of their biogeochemical, economic cycles.

The chapters contributed to debates in the sociologies and histories of science, expertise, and technology in the extractive sector on the production of knowledge about mining and metallurgy. I took these debates beyond the corporate mining sector’s expertise, centering the work of scientists, engineers, and bureaucrats producing or collecting knowledge and numbers on ASGM's use of mercury. I demonstrated how the production of knowledge (and ignorance) about chemicals and toxicity is multiscale, contested and has concrete implications for how the problem is addressed, in what scales and temporalities, and with what level of urgency. In addition, I brought a historical perspective situated in the Global South to the conversations advanced by STS scholars studying extractive industries. I located mining “experts” in trajectories of colonial infrastructures of extraction, and demonstrated how their numerical work

and quantification of ASGM's pollution across multiple scales ignores the knowledge of indigenous peoples both during the colonial period and today.

This contribution also expanded the critique that recent works in the political ecology have done of certain accounts of mercury use in small-scale mining as a problem to be intervened by technoscientific or supply-chain management approaches (Le Billon & Spiegel, 2022). As explained in the literature review, ASGM in most countries is characterized by a vast heterogeneity of production modes and land politics dynamics. This work expanded this critique to technological fixes of mining's environmental and social impacts through a closer conceptual and empirical engagement with bodies of literature that dive further into the politics of mining knowledge and technology production and circulation, and that brings to the fore the role of actors like engineers, scientists, and international organizations as part of the constitution of chemical infrastructures that enable mercury use in ASGM.

A brief note on broader implications

The social order in other scales sustaining the "disorder" of mercury toxicity are constitutive of the mercury problem in ASGM and can also critical for devising more integral, nuanced forms of addressing the problem. For doing so, certain orders or status quo in other scales or domains would have to be transformed in several ways. I have already mentioned the proposal for the next UNEP's GMA acknowledging the importance of including colonialism in today's international attempts to "make mercury history" (UNEP 2017). The second would be increasing miners' voices and agency. Although ASGM are politically marginal "actors" and are informal in many countries in which the state does not have the intention nor the capacity to transform the sector, that does not mean their voices are not essential or dispensable to address the problem. On the contrary, increasing miners' participation in national and international mercury governance would facilitate devising and implementing policies more effectively.

The narratives of international mercury trade as "any other contraband" should be countered by a more in-depth analysis of the long-term unacknowledged legacy of mercury use by some Northern countries and protracted flows of exports of mercury imports from them to Southern nations, like the one I presented in this work. There is evidence that the surplus of mercury extracted in the late twentieth century in the North has kept flowing into Southern countries despite the export bans in the US and Europe and the Minamata Convention's progressive trade restrictions. Nonetheless, China is also a leading mercury exporter. The fact that some of the regions of the world in which mercury was massively used centuries ago have recently become large mercury emitters and importers suggests that the story I told here is not as clear cut as a North-South problem in which the North produces the toxics and the South passively receives them. The shifting and politicized history of transnational mercury flows is enough to interrogate depictions of countries with ASGM in the Global South as unruly, toxic landscapes needing urgent intervention and miners as subjects who need to be educated. While I don't question the importance of technical assistance in mining and while that is one of the miners' demands, the multilayered nature of the problem requires analysis that highlight the problem's complexity and needed action beyond training workshops, formalization programs, and criminalization/

The politics of scientific practice have limited the geographic, disciplinary, and thematic diversity of international assessments of mercury, limiting the space for alternative and more holistic framings of the problem and its possible solutions. Very much in the same way that miners should have a seat at the table of decision-making and knowledge production at both global and domestic levels, the same is true for exposed populations like indigenous peoples, women, lactating people, children, and fetuses in mercury-polluted landscapes, which have been excluded from the production of knowledge about mercury in the most important and high-profile spaces devoted to that task.

In its latest report, the IPCC not only acknowledged the role of colonialism in producing the current global climate injustice but also highlighted the critical importance of local and indigenous knowledge to address them. In 2021, the Minamata Convention Secretariat published a brief, compiling data on the relationship between mercury and gender for instance, with data on the exacerbated vulnerability of women in general, lactating people, children, and fetuses in mercury-polluted landscapes (Minamata Convention Secretariat, 2021). This is a step in the right direction that should open the door for more engaging conversations and actions informed by the voices of those most affected by mercury toxicity, including those who help produce it, like small-scale gold miners.

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