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"Our gold is dirty, but we want to improve": Challenges to addressing mercury use in artisanal and small-scale gold mining in Peru

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ABSTRACT

Mercury use in artisanal and small-scale gold mining (ASGM) has captured global attention and concern for decades. Policy makers and development practitioners routinely promote awareness campaigns and technical assistance to address mercury use in ASGM; however, this focus obscures other barriers that stand in the way of addressing mercury emissions from the sector. Focused on the town of Relave, in the Ayacucho Region of Southwestern Peru, this paper examines the perspectives and practices of some of the community members who are involved with ASGM activities. It highlights their own views of the challenges related to ASGM and explores the ways in which they are addressing these challenges. Despite their efforts, this paper reveals that there are two key barriers to controlling mercury use in Relave, which lie outside of the communities' lack of awareness and technological capabilities. These include the deprioritization of mercury use and pollution among community members as compared to other community and public health concerns and inequities in the supply chain that position miners and mineral processors with little to no control over the distribution, use, and emissions of mercury. The implications of these findings for policy decisions, regulatory schemes, and development initiatives are not only relevant to Peru, but are also significant for other countries committed to addressing mercury emissions from ASGM.

1. Introduction

Mercury use in artisanal and small-scale gold mining (ASGM) has captured global attention and concern for decades. Approximately 1,350 tonnes of mercury per year are released into the environment from ASGM, making it the largest source of anthropogenic mercury emissions (Telmer and Veiga, 2009; UNEP, 2013a). In Peru, the total mercury releases to the environment from ASGM were estimated to be 70 tonnes in 2010, and this is now likely to be much higher (GEF, 2018). Mercury is added during different stages of mineral processing and binds with gold to create an amalgam. The amalgam is then burned leaving the gold and vaporizing the mercury. During this process, without proper capturing devices and personal protective equipment, mercury vapors are emitted into the atmosphere, it is lost to waterways and soil, and it comes into direct contact with animals and humans. In Peru, up to 150,000 people are exposed to mercury each year (IGF, 2017).

The research community has quantified the nature and magnitude of environmental pollution from ASGM releases of mercury, assessed and documented human exposure to mercury, and mapped mercury's use based on the scale of operations and the technological inputs (Velasquez-Lopez et al., 2010; Akagi et al., 2000; Appleton et al., 1999; de Kom et al., 1998; Martinez et al., 2018; Van Straaten, 2000). The environmental and human health impacts of mercury from ASGM are now widely understood, and policy makers and development practitioners routinely promote awareness campaigns and technical assistance to address mercury emissions (Clifford, 2011; Cordy et al., 2013; Sippl and Selin, 2012; Velasquez-Lopez et al., 2010; Veiga et al., 2014b).

Although there is broad support for community awareness campaigns about the risks of mercury exposure, there is often a lack of clarity on what these campaigns should include and the audience to whom they should be directed. Hilson et al. (2007) demonstrated various levels of awareness about the impacts of mercury among ASGM communities in Ghana, and Styles et al. (2010) explained that miners in Ghana knew mercury was detrimental to their health but did not understand the specific mechanisms of mercury toxicity and were generally unconcerned about its use, prioritizing efficiency and the cost of mineral processing. Spiegel (2009) reported

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that awareness campaigns in Tanzania were overshadowed by discussions about land rights and ownership. In sum, awareness campaigns that focus on the ways in which mercury harms the environment and is damaging to human health are not enough to motivate a change (Davies, 2014).

Technologically based mercury-free alternatives and mercury recovery systems, such as cyanidation, gravimetry, and retorts, have been introduced into ASGM mineral processing systems but have been met with unexpected challenges (Teschner et al., 2017). Retorts are one of the most widely used interventions, but miners have reported that they are slow and cumbersome to use (Amankwah et al., 2010, Hilson and Pardie, 2006; Hilson et al., 2007; Tschakert and Singha, 2007), and some have expressed fears that gold will be lost in these mercury recovery systems (Veiga, 1997). Others found that the color of the gold was different when applying alternative processing methods, and they worried that gold buyers would capitalize on this to pay them less for their gold. These interventions have failed to provide mercury-free solutions that are socially and economically sustainable in the long term (Hilson, 2000, 2006; Zolnikov, 2012).

Awareness campaigns and clean technologies are essential components of holistic policy and development strategies; however, there is a general consensus that training and education in mercury free technologies must be supported by government agencies and regulatory bodies if the acceptance of alternative technologies is to be widespread (Clifford, 2014; Davies, 2014; Hilson, 2009; Hinton et al., 2003; Smith et al., 2016; Veiga et al., 2014a; Zolnikov, 2012). Furthermore, efforts to control mercury emissions from ASGM must be informed by a more nuanced understanding of ASGM systems (Fischer, 2007; Hilson, 2006; Tschakert and Singha, 2007; Smith et al., 2017; Verbrugge and Besmanos, 2016).

This paper begins to address the need for a deeper understanding of ASGM by demonstrating that an exclusive focus on awareness campaigns and cleaner technologies obscures other barriers that stand in the way of addressing mercury emissions from the sector. By focusing on the town of Relave, in the Ayacucho Region of Southwestern Peru, this paper examines the social context of ASGM operations by focusing on the perspectives and practices of some of the actors involved with ASGM activities. It highlights their own views of the general *community* challenges and the more specific *public health* challenges related to ASGM and explores the actions they are taking to address these challenges. Despite their efforts, this paper reveals two key barriers to controlling mercury use in Relave, which lie outside of the communities' lack of awareness and technological capabilities. First, mercury use and pollution is deprioritized among community members as compared to other community and public health challenges. Thus, community resources are allocated to causes they perceive as more urgent, like security. Second, inequities in the supply chain position miners and mineral processors with little to no control over the distribution, use, and emissions of mercury. Gold buyers, who act as middlemen, control the mercury used in mineral processing, as well as the local market for gold in Relave.

These factors stand in the way of effectively addressing mercury emissions in ASGM and demonstrate that awareness programs and cleaner technologies will only be impactful if miner's challenges, priorities, and the supply chain dynamics are well-defined and also addressed. The implications of this for policy, regulations, and development initiatives are not only central to Peru's efforts at addressing mercury emissions from ASGM, but are also relevant for other countries who struggle with similar environmental and public health issues and where ASGM represents a critical livelihood strategy for rural populations.

The study presented here endorses the call in the literature on ASGM for less "effects-based" research (Hilson, 2006: 5). In other words, in addition to understanding the relative scale of contamination from mercury and the potential risks to humans and the environment, the mercury problem must be situated within the diverse and dynamic socio-economic contexts of ASGM communities (Hilson, 2006; Tschakert and Singha, 2007). It demonstrates that a systematic understanding of ASGM communities, including their challenges and priorities and the ways in which materials and resources are organized, is fundamental to effective and sustainable interventions (Veiga et al., 2014a). The young miner from Relave who stated, "Our gold is dirty, yet we want to improve," indicates that artisanal and small-scale gold miners in Relave want to change their practices. However, as this paper reveals, they allocate their resources to other, more pressing challenges and priorities, and they are victims of the power dynamics that govern the gold supply chain.

2. Controlling mercury emissions from ASGM

There have been a number of well-intended efforts by governments and development organizations to introduce artisanal and small-scale miners to mercury free mineral processing technologies that have failed to gain traction. As discussed in the introduction to this paper, the literature reporting on these interventions often points to miner's uncertainties about the effectiveness and efficiency of the technologies and perpetuates the notion that only if the technologies could be changed, miners would willingly accept them. Furthermore, the emphasis on quantifying mercury emissions and knowledge of mercury overshadows communities' own perspectives of the impacts of their activities and how this can translate (or not) into action.

In stakeholder workshops in Madre de Dios, Peru, Salo et al. (2016) solicited local perspectives on the impacts of ASGM and proposed "from below," management strategies for mitigating these impacts (Salo et al., 2016: 1065). The authors suggested that the collaborative management of impacts can benefit formalization efforts by avoiding a "stepwise procedure in which the failure to achieve one goal would block the pursuit of others" (Salo et al., 2016: 1065). The same logic may be applied to efforts to eliminate mercury from ASGM mineral processing systems. Through support and capacity building that addresses miners' primary impacts, challenges, priorities, and actions, whether they lie in the realm of mercury use or not, a forum can be created where ASGM communities work together towards shared goals fostering change on a system-wide level that improves practices and procedures to promote sustainable livelihoods.

Other authors have indicated that hierarchies and powerful actors within ASGM supply chains can influence the acceptance of cleaner technologies (Hilson, 2006). For example, Veiga et al. (2014a, 2014b) described how centralized processing centers served local miners by extracting gold from their ore for a fee. The owners of these operations often had access to larger sums of capital and ultimately controlled the necessary equipment and materials to extract gold, which gave them power and privilege over the miners. Many of these centers amalgamated whole ore concentrates and precipitated gold from a cyanide solution; often they were the worst polluters of mercury (Veiga et al., 2014a).

In a review of mercury abatement strategies globally, Gavin Hilson referenced evidence from Zimbabwe and Ghana that corrupt buyers prevented miners from improving mercury management, purchased gold at rates far below market prices, and often marginalized subsistence operators and minimized their opportunities for proactive environmental management (Hilson). In particular, Maponga and Ngorima (2003) discuss how middlemen in Zimbabwe regularly visited gold panning areas to purchase gold.

While they offered quick returns to the miners, they took advantage of local miners' lack of knowledge of the centralized market prices offered by Zimbabwe's Reserve Bank by paying lower prices, thereby perpetuating the need for miners to use cheap and reliable methods to process their gold.

These cases highlight the importance of understanding miners' priorities and challenges, as well as the hierarchies and power structures that govern the gold (and mercury) supply chain in parts of the world. As powerful actors exert significant influence over the flow of gold and other materials required to extract gold from ore, they undermine the effectiveness of educational and technological interventions. Overlooking these actors, who often operate informally and to a large extent control the movement of gold and mercury in ASGM systems can inadvertently perpetuate mercury use. Although this evidence indicates that a stronger policy and regulatory approach is warranted, failures to understand and address community members' priorities and the power dynamics that govern supply chains have resulted in a lack of effective policies and interventions leading to broad scale change.

3. Government approaches to controlling mercury emissions from ASGM in Peru

Peru is the world's sixth largest gold producer (USGS, 2018), with 15%–20% of the gold coming out of the ASGM sector (UNEP, 2013b). Estimates place the number of artisanal and small-scale miners in Peru at 85,000, but the number may actually be much higher, with up to 300,000 people in Peru directly or indirectly dependent on ASGM activities (UNEP, 2012). Although ASGM has been practiced in Peru since the time of the Inka (Berthelot, 1986), only in the last two decades has the government acknowledged the economic significance of ASGM for rural populations and the potential revenues that ASGM could generate. At the same time, however, there is also awareness that mercury use is widespread in the sector and concern about the environmental and human health risks that mercury poses. In response, the government has implemented a number of laws, decrees, and initiatives that attempt to regulate the sector and address mercury emissions.

In 2002, the government passed the Law of Formalization and Promotion of Small-scale Mining and Artisanal Mining (Law 27,651), which, for the first time, recognized artisanal and small-scale miners and introduced a legal framework for regulating ASGM in an effort to support the sector's formalization, promotion, and development.[1] This law outlined a series of steps for miners to become formalized, including obtaining a tax number and acquiring a mining concession or entering into a mining contract with a concession owner (GOREL, 2011). Although there was no specific mention of mercury use and its management in the law, to become formalized, miners were required to complete an environmental report that addressed how they were using and disposing of mercury.

Nearly a decade before this, in 1994, the Peruvian Ministry of Energy and Mines acted on their concerns about the use and impacts of mercury, by embarking on an ambitious campaign where they disseminated knowledge on the symptoms of mercury poisoning and methods for safely handling mercury. They also distributed free retorts and the instructions for use and adapted these to the different needs of the users (UNEP, 2012). Community acceptance of the retort technology was mixed. In Madre de Dios, the use of retorts increased from 1.9% to 60% from 1995 to 2000, whereas in the combined zones of Ica, Ayacucho, Arequipa, and Puno, the use of retorts increased from 2% to 10% in the same five-year period (UNEP, 2012). As a result of the relatively low uptake of the retorts in these regions, the ministry determined that a strategy that implemented communal retorts or "*refogado*" centers would be more effective (UNEP, 2012).

Communal retorts were supposed to have greater acceptance rates because amalgam is burned in an open cycle, where the mercury vapor is captured and reliquified by the producer of the gold or by an operator who is supervised by the producer to insure transparency (UNEP, 2012). The GAMA (Gestión Ambiental en la Minería Artesanal) Project, an initiative of the Swiss Agency for Development and Cooperation (SDC), lasted from 2000 to 2008, and provided trainings, capacity building activities, and community retorts to fifteen ASGM groups in Peru (UNEP, 2012). Communal retorts took hold in some communities, such as Cerro Rico, where the Artisanal Miners Association reportedly recovered an average of 30 kg of the mercury used in a month (UNEP, 2012). However, in other locales, like Relave, the focus of this study, community retorts were not a success because of the need to continuously train the operators and the long lines that miners had to wait in to use the retort.

In 2012, the government established a legal framework for the control of mercury and other chemicals used in ASGM through Legislative Decree 1103. Two years later, in 2014, they added a regulatory framework to this decree, which established mechanisms to monitor the distribution and sale of mercury and other chemicals used in ASGM. The Minamata Convention, signed into effect in 2013, further institutionalized the attention to mercury pollution by requiring ratifying countries to develop National Action Plans to control and reduce mercury use and emissions and regulate the import, export, and storage of mercury waste (Davies, 2014). Peru ratified the Minamata Convention in 2016 (Supreme Decree No. 061-2015-RE), and it went into effect in August 2017. They are currently developing their National Action Plan to comply with the terms of the Convention. Although Peru boasts that they are not importing any mercury into the country, mercury use in ASGM continues to be widespread. Once the National Action Plan is implemented, artisanal and small-scale miners will likely encounter more stringent controls on mercury.

4. Methods

Data for this study were collected over a 10-month period from September 2017 to June 2018 in Relave, an ASGM community in Southwestern Peru. Data collection methods included in-depth interviews and focus group discussions with community members directly involved in ASGM activities, including men who worked as miners and both men and women who worked as mineral processors. People who did not play a direct role in ASGM activities, but who were concerned about and potentially impacted by mining and mineral processing, like teachers, local leaders, and health care professionals, were also interviewed. Interviewees were recruited based on their type of involvement with ASGM activities (miner, mineral processor, health care worker, etc.) and their willingness to be interviewed. Some of the interviewees were identified through snowball sampling (Bernard, 2006), where the person being interviewed suggested others to interview.

[1] In 2011, Peru approved a national plan (Supreme Decree No 045-2010-PCM) with the goal of formalizing the entire ASGM sector by 2016 (GOREL, 2011). Under this decree, the government prohibited the sale and export of gold that lacked a "receipt," which was only given to companies that were operating legally or were in the process of formalizing. Because there were so few artisanal and small-scale mines that were able to meet the formalization requirements at the time, self-employed miners as well as large mines that employed hundreds or thousands of workers, found a number of ways to sell their gold, which was then laundered and exported (GOMIAM https://www.gomiam.org/laws-rules/peru/). The formalization plan was relatively unsuccessful. For example, as of April 2012, only 5 percent of a total of 30,000 requests for formalization from miners in Madre de Dios had been addressed (GOMIAM).

In total, interviews were conducted with thirty-five people including thirty men and five women. While this number is statistically low, the results are presented in graphical form to show the trends that emerged in the interviews. The first portion of the interviews and focus groups included closed-ended questions designed to obtain quantitative data related to demographics, perceptions of community and health challenges, and initiatives taken to address these challenges. These questions were followed up by a number of open-ended questions designed to collect qualitative data. Some of the interviews were recorded and later translated, transcribed, and entered into the qualitative data analysis software, Atlas TI. If an interview was not recorded, the interviewer took careful notes and then transcribed these notes into Atlas TI. All of the interviews were coded according to certain themes identified by the lead researcher, including community challenges, health challenges, community initiatives, and supply chain dynamics.

5. Results

5.1. The setting: ASGM in Relave

The town of Relave provides a provocative setting in which to study ASGM. Located in the Ayacucho region bordering the Arequipa region in southern Peru,[2] Relave's name comes from the Spanish word for *tailings*, a poignant reminder that the area was settled in the mid 1980's by Peruvian migrants who came to mine the waste left by large-scale gold mining operations that had previously operated in the area. Escaping violence in their home communities (Isbell, 1994), these newcomers came with the hope of making more money in mining than they had previously been making in agricultural endeavors. The estimated population of Relave is now around 3,000, and ASGM is the primary economic activity.

Relave is home to a few ASGM companies who are either formalized or are in the process of becoming formalized. These companies are comprised of up to hundreds of "members" who pooled their capital to acquire rights to mining concessions and build mineral processing plants. These plants are located on the hillsides overlooking the town. There are also individuals and small groups who operate within an industrial park (*parque industrial)*, a more recent, yet central feature of Relave. The industrial park encompasses an area of approximately 1–2 ha and was designated in 2013 when community members, recognizing the health risks from dust and mercury use associated with mineral processing, moved these activities from the backyards of their homes to a centralized location. At first, the industrial park was located in a part of town separate from the residential area, but now the town has expanded, and the industrial park is adjacent to homes, the community soccer field, and schools. There are about 400 operating units in the industrial park, and each of these may contain up to five quimbaletes, a grindstone that pulverizes finely crushed ore through a rocking motion (Florsch et al., 2016)[3]; the cornerstone of mineral processing activities in the park.

5.2. ASGM-related challenges

The challenges that community members face in Relave and the ways they were addressing these challenges provide a glimpse into their priorities, as well as their limitations. During the interviews, people were asked to identify the most significant problems related to ASGM (Fig. 1). The question was posed generally, with no suggestion of specific *types* of problems, so as not to bias the responses. Because the question was open-ended, most respondents provided more than one response. The most frequently cited challenge was mineral theft, appearing in over half of the responses (63%). People reported that theft was occurring from the companies' processing plants, as well as from the operators in the industrial park. Nearly a quarter of the respondents (23%) mentioned drinking water contamination as a challenge. Relave had two community wells. According to the health center authorities, one had a casing and was used for residential (drinking and household) purposes, while the other one lacked a casing and was used for mining activities. People feared that the residential water was contaminated and complained of a lack of water. Some of the respondents (16%) included the lack of separation between the industrial park and the residential area as a key challenge and proposed planting trees as a barrier between the two zones. Other challenges that emerged included achieving formalization (16%), the lack of control over the gold shops (13%), and the lack of an agreement with the large-scale mining company who owned the exploitation rights to the concession (13%). Finally, the lack of organization among the miners, mercury pollution, and the absence of a common retort each occurred once (3%). Although only one person directly identified mercury pollution as a significant community challenge, mercury was implicated in the responses about drinking water contamination and the lack of control over the gold shops.

5.3. Health concerns

A different trend emerged with regard to community concerns about mercury when the interviewees were asked an open-ended question about their major *public health* concerns related to ASGM (Fig. 2). Several respondents provided more than one response. Silicosis appeared in over half (54%) of the responses, and mercury was cited by nearly half (48%) of the respondents, although their exact concerns about mercury varied, with 17% concerned about mercury in the blood, 14% concerned about mercury emissions from the gold shops, 11% concerned about mercury use in the industrial park, and 6% concerned about water contamination from mercury. One person each included the practice of cyanidation near town (3%), stomach infections (3%), and a lack of support from the government (3%) as major public health challenges related to ASGM.

During an interview with the director of the health post, she addressed the severity of mining related health problems but claimed that giardia was the biggest health issue in the community, affecting at least 85% of the children from one to nine years of age. She reported that the health post tests people for mercury, but they have to send the blood samples to Lima or Ayacucho, the capital city of the Ayacucho region, for testing. She said that they do not follow-up with the people who test high, and she was skeptical of the test saying it was "*flawed*" and there was "*lots of room for error*." She used herself as an example and recounted the story of when she was tested for mercury in December 2015, the test came back normal; however, only a year later, a follow-up test showed high levels of mercury in her blood. She remarked that she did not think it was possible for her mercury levels to become so high in only a year's time.

In Relave, people were aware that mercury was a health threat,

[2] There was some debate among community members that certain areas of Relave may have been in situated in the Arequipa region. This could potentially lead to regulatory challenges due to uncertainty about the municipal boundaries.

[3] Evidence shows that quimbaletes are endemic to the Andes region of South America and in use before the Spanish arrived (Florsch et al., 2016). While quimbaletes have technical value, they also were integrated into the social and political environment of Spanish colonialism by demonstrating to Spanish businessmen that local laborers "possessed their own capacities for invention and innovation" (Florsch et al., 2016: 2).

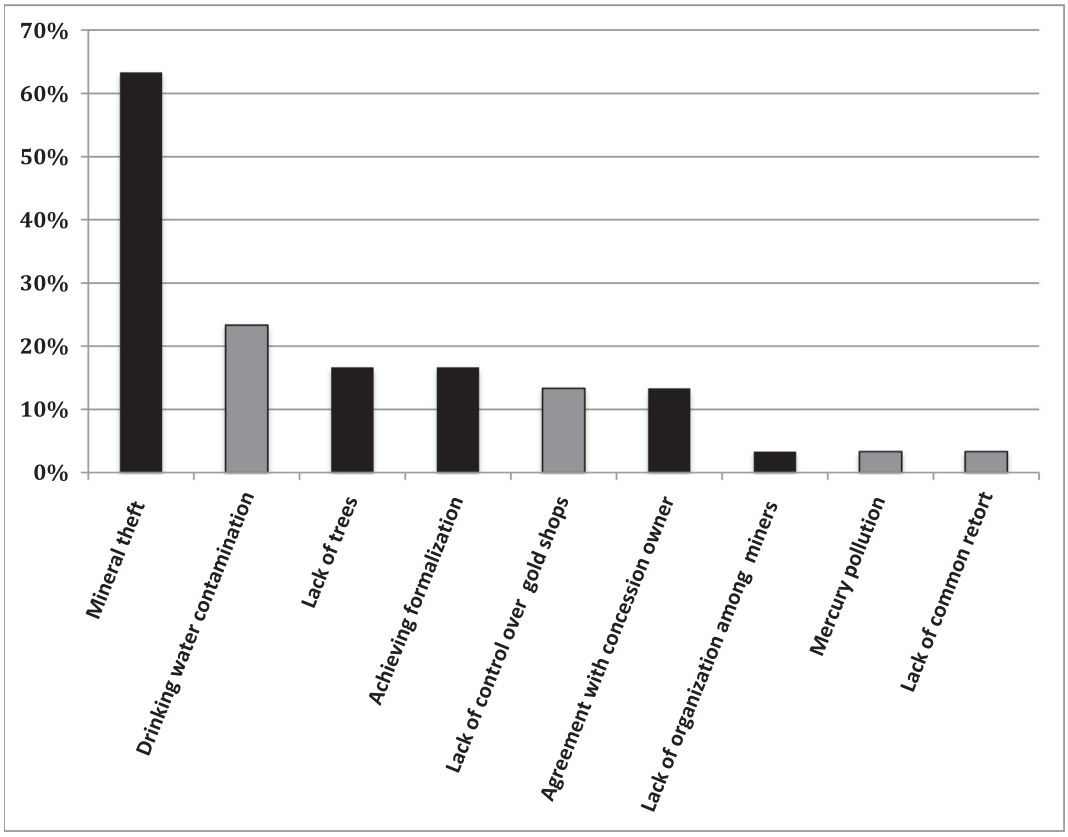

Fig. 1. The most significant ASGM-related challenges. Challenges implicating mercury are shown in grey. The percentages represent the total number of times each challenge appeared in the responses (n = 30).

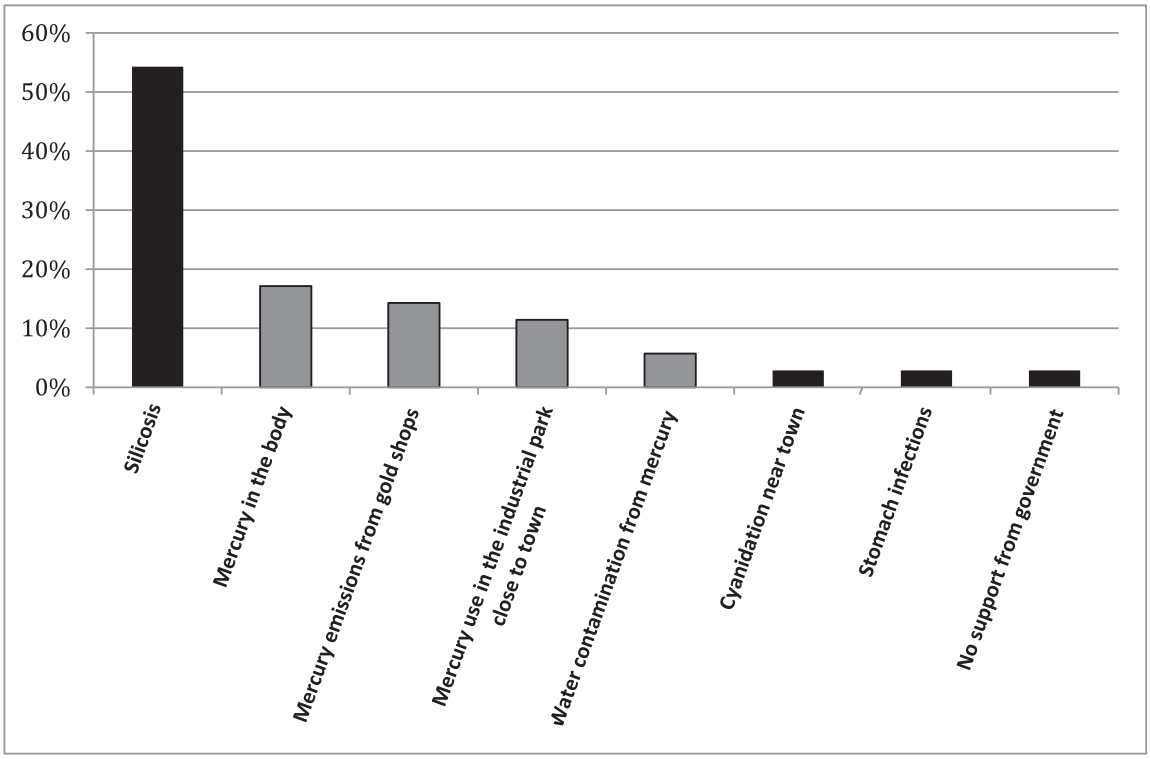

Fig. 2. The most significant ASGM-related public health concerns. Mercury-related public health concerns are shown in grey. The percentages represent the total number of times each challenge appeared in the responses (n = 35).

but some of the respondents were not aware of the exact pathways of exposure or the symptoms of mercury toxicity. One miner asked, *How does mercury contaminate us? Through what? Through the blood? The nails? Sometimes I wish somebody could explain to me what the pollution is. Do we have it in the blood? In the body? Does mercury enter through the pores?* Another miner reported that the health post had warned them about mercury exposure, and miners were aware they had high levels of mercury in their bodies. He thought that the real issue with mercury was that people just did not care enough to protect themselves or learn how to avoid it.

One miner who formerly held a position in the municipal government believed that the public health problems were rooted in the absence of a sense of community among the inhabitants of Relave. He remarked:

> *People have come here from everywhere and most people don't have a sense of belonging. The problem of mercury that is generated in the town responds to that lack of control and not feeling part of the town. All the quimbaletes were taken out of the town from the front of their houses, but it is not enough. If they don't establish themselves and make more rules, if the sense of belonging of the population is not worked with, the problem will not be resolved no matter how much they are taught about proper mercury management and alternative technologies.*

He went on to talk about the GAMA project which was implemented in Relave in the early 2000's and included the installation of a central retort where miners could burn their amalgam and reduce the emissions from and their exposure to mercury. The retort was located in a building they named, *la retorta* and was located on the outskirts of town; however, the town had since grown and la retorta is now situated in the center of a residential neighborhood. When the GAMA project ended, the retort was dismantled, and *la retorta* is now used for community meetings. This miner expressed his support for the GAMA project, but then lamented that after the funding period, "*there were no more projects and the communities' motivation died out*." He also claimed that while the retort worked, it lacked efficiency because by the time the miners brought their amalgam to the central retort they had forgotten how to use the equipment and had to be retrained. In addition, on any given day there were 20–30 miners in line to use the retort, which turned many away.

5.4. Community initiatives

The people in Relave were not succumbing to these challenges but were working to create sustainable ASGM livelihoods and a safer and healthier community. The interviewees were asked an open-ended question about what they were doing to address the general community challenges (Table 1). Many respondents provided more than one response, but nearly half of them (43%) mentioned a recent intiative to address gold theft, where miners and mineral processors each contributed money to hire guards for the company processing sites and the industrial park. Others (33%) described communications with municipal and central government authorities where they emphasized the need for support in becoming formalized, accessing new and cleaner mineral processing technologies, building a fence around the industrial park, planting trees, and constructing a drinking water reservoir. A few miners (10%) discussed initiatives they had taken to improve the conditions in the industrial park, although they were not explicit about the nature of these activities. Two miners (7%) stated that they had worked to organize the miners.

The community was also taking action to address the health risks associated with mineral processing (Table 2). The majority of interviewees (66%) cited that the health post campaigns were the most visible actions. Others (19%) referred to the relocation of the quimbaletes, and two (6%) people mentioned that the health post checked mercury levels in people. Two (6%) respondents cited the GAMA project for providing training in business skills, installing a communal retort, and aiding the community members in obtaining recognition of Relave as a population center. Finally, one (3%) person stated that they regularly have health checks.

Table 1
Local level initiatives to address the general ASGM challenges. The percentages represent the number of times each challenge appeared in the responses (n = 28).

Local level initiatives to address general ASGM concerns	
Fee for security	43%
Proposals to municipal and central governments	33%
Improved conditions in the industrial park	10%
Organized the miners	7%

5.5. The mercury supply chain

Despite community members' concerns about the health risks from mercury pollution and the actions they were taking to address these risks, the interviewees named significant barriers to reducing mercury use and pollution in Relave, in particular the role of the gold buyers. For example, one miner in particular, named "David"[4] operates on a relatively small scale and processes his ore in the industrial park. I spent an afternoon with David, observing him processing his ore. He shoveled ore into a ball mill grinder, and then loaded the finely ground material into the quimbalete along with a cocktail of water, mercury, and dish soap. He had hired a laborer for the day who maneuvered the quimbalete. After nearly four hours of agitating the quimbalete, they emptied the water from the basin of the quimbalete and scooped out the beads of amalgam. They added the amalgam to a shallow bowl of water where it congealed, they poured off the water, and then they wrapped the amalgam in a porous fabric to "choke" or squeeze it. They were left with a small ball of amalgam in the fabric, and they rebottled the liquid mercury that they had squeezed through the fabric.

After this process, I accompanied David to a gold shop in the center of town. This was the same gold shop from which he had "rented" the mercury. He gave the gold buyer his ball of amalgam and the bottle of mercury. The gold buyer weighed the amalgam, burned off the mercury, and the cost of the mercury that was lost through the amalgamation process and the burning of the amalgam, was subtracted from David's gold sale. The gold buyer told me that the open "retort" in which he burned the amalgam included exhaustion and condensing systems, although, it was unclear if this was actually the case. No less, if the mercury was actually condensed in this system, he could recycle it and resell it to the miners.

David's activities revealed his vulnerability. He described how the gold buyers refused to buy gold from the miners unless they brought it to the shops in an amalgamated form. He subject to the gold buyer's control over mercury and pricing schemes, and mineral processing put him into close contact with hazardous materials. Furthermore, because he operated in an informal context, he had few options for where to sell his gold. David's socio-economic status and his position within ASGM systems made him more vulnerable to the negative health impacts of mercury use, as well as political risks if was not complying with the regulations. Other miners directly implicated the gold buyers for being "*the real*

[4] "David" is a pseudonym used to maintain this miner's anonymity.

Table 2
Local initiatives to address community health challenges related to ASGM. The percentages represent the total number of times each challenge appeared in the responses (n = 32).

Local level initiatives to address health-related challenges of ASGM	
Health campaigns	66%
Relocation of quimbaletes	19%
Mercury tests	6%
GAMA project	6%
Individual health checks	3%

polluters of mercury." One miner explains:

> *The ones that handle everything here … are the ones that have money. The miner seeks the money. He brings his product, in a week he has two little grams, and if he doesn't sell it to the gold buyer, he would stop making money. He [the buyer] has the money and that's where the miner ends, that's when his mercury cycle ends.*

As this miner indicated and David demonstrated, the gold shop owners act as middlemen who, to a large extent, control the flow of cash and the mercury supply chain in Relave. Several miners reiterated David's claim that this arrangement was sanctioned by the gold buyers' refusal to purchase gold that did not come to them in an amalgamated form. One miner stated, "*The buyers are unregulated so there is a market inequity. They burn the gold. They have the power. Gold buyers are very tricky. If miners self-burn, the gold buyers will not take the gold.*" These data demonstrate that the gold buyers play a central role in the (in)ability for miners to change their practices and reduce or eliminate mercury from mineral processing systems.

Gold buyers are not specifically mentioned in the Peruvian mining law, although in 2012 the Ministry of Energy and Mines created a Special Register of Gold Traders and Processors (RECPO) through Ministerial Resolution No. 249-2012-MEM/DM. This resolution required all persons engaged in the sale and/or refining of gold to register and keep a detailed record of their suppliers and the destination of the gold. As part of the registration process, gold traders and processers were obligated to answer a question about gold refining—whether they were a trader, refiner, or both—but it did not specify the type of refining process or whether or not this process involved mercury. In 2016, the Ministry of the Environment established a plan to reduce or eliminate the use of mercury (D.S. 010-2016-MINAM), and included artisanal and small-scale mining in this plan; however, gold buyers and other middlemen were not mentioned.

Some miners in Relave had the resources and flexibility to avoid the local gold shops. One miner owned his own company that mined an area of 1,000 ha. The company was in the process of becoming formalized and was waiting for the government's final approval of their mine plan. He checked the price of gold every day on the Internet and stated, "*You like to wait until the gold … has a higher price to sell it. Sometimes the others don't have money and they have to sell everything. I wait until it goes up. When it does, I sell it.*" But he did not sell his gold to the buyers in Relave because he claimed that they stole peoples' gold. After his gold was processed in his plant using mercury and cyanide, he took it to a refinery in the nearby town of Chala for further smelting. He did not sell his gold locally in Relave, because he claimed that the buyers there stole peoples' gold.

Another miner who was in the process of becoming formalized, also did not sell his gold to the shops in Relave. He adamantly stated that he did not trust the local buyers, and he stressed the need for them to be regulated and registered with the state. He reported that in 2016, a government agency came to advise the miners in formalization, and all of the gold shops closed down before their visit, reopening only after they left. He addressed the role of multiple actors in combatting mercury emissions and stated, "*Who should regulate the mercury emissions from the gold buyers burning amalgam? It needs to be a cycle so everything works; there has to be a legal framework to control, to regulate this. The miner has to change and the gold buyer has to change*."

6. Discussion

These data demonstrate two key features of ASGM systems that are necessary to understand in order to address mercury emissions. First, they highlight the community members' perspectives on their own challenges and show how they have taken action to address these challenges. Mineral theft emerged as the top challenge. Although miners and mineral processors have pooled capital to hire security guards, they aspire to build a fence around the perimeter of the industrial park. A fence would not only address some of their security concerns, but it would also create a barrier between the industrial park and the residential areas, supporting their desires to separate the two zones. The importance of separating these two zones also emerged in people's concerns about drinking water contamination from mining activities and their aspiration to construct a reservoir for residential water.

Although the community members' expressed concern about mercury contamination, both indirectly through their apprehensions about water contamination and more directly through their public health challenges, there was a general lack of understanding of the exact symptoms of mercury contamination and the pathways of mercury exposure. Therefore, they were unsure of how to avoid contact with and handle mercury. Although this apparent lack of knowledge could be addressed by more robust awareness campaigns, it is evident that awareness campaigns alone are not the silver bullet. In fact, some people claimed that miners were very aware of the risks associated with mercury use, but they were not willing to protect themselves, criticizing their colleagues' lack of initiative. Despite the varying levels of awareness around mercury exposure and contamination, community members in Relave moved the processing activities from their homes to the industrial park. This and the other community-led initiatives described, demonstrate community members' motivation to move ASGM into a more sustainable realm.

The support from the GAMA project and the central retort initiative had the potential to curtail mercury emissions from ASGM. However the project was thwarted by the time and effort it took to train miners to operate the retort, the long waiting lines, the lack of long term planning for the location of the retort relative to the community's expanstion, and the length of the project period. Additionally, Relave is home to one of the early recipients of the FairMined certification, which coupled with the GAMA project may have raised awareness in Relave about mercury's impacts. The miner's sentiment, "Our gold is dirty, but we want to improve," may very well reflect his awareness of these initiatives, yet it is clear that these programs were not enough to facilitate broad-scale change.

The second feature of ASGM that these data uncover, which is critical to addressing mercury emissions from ASGM, is that obscure networks of people, places, capital, and modes of exchange animate the gold supply chain. This is the most valuable lesson that can be gleaned from this study. The complex web of relations between actors and materials (mercury) in ASGM systems were a significant barrier to addressing mercury emissions in Relave. As shown, the gold buyers "leased" mercury to the mineral processors and only agreed to purchase gold in an amalgamated form. They were unregulated and like the miners and mineral processors, also

operated in the informal sector; however, they carved out a niche in Relave where they exerted a significant amount of power and control over ASGM activities. While some miners had the ability to circumvent the local gold buyers, at some point, after they sold their gold to the plant in Chala or elsewhere, it becomes legible, moving from the informal to the formal market. Thus, we might question to what extent the gold buyers in Chala are able to capitalize on this and whether or not these miners actually receive a fair price for their gold? Although beyond the scope of this research, this suggests the need for a better understanding of the broader shadow economy in which the miners and gold buyers operate.

Efforts to raise awareness about the harms of mercury and introduce clean technologies may only be as effective as the supply chain allows them to be. Actors with various relationships with and access to power and resources, from miners to people who process the ore, and from gold buyers to policy makers and regulators, shape the ways in which gold "becomes," and demonstrate the ways in which ASGM operations are dynamic, non-uniform, socio-technical systems comprised of people, materials, policies, market forces, and social relations.

7. Conclusions

Echoing the call for less effects based research, this study demonstrates that to address mercury emissions from ASGM, there needs to be a more holistic understanding of the community members' challenges and motivations related to ASGM activities and the social, economic, and political dimensions of mercury use. It also indicates that policy and development initiatives must be designed and implemented with community participation and structured to outlast the funding term limits of a given project. Interventions that are crafted to address miners' challenges and priorities can be offered in conjunction with support, education, and training focused on mercury. Detailed mapping of the social, political, and economic landscapes in which these initiatives are introduced will lead to more effective policy and development interventions aimed at controlling and reducing mercury use among the ASGM sector.

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