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The mercury supply chain, stakeholders and their responsibilities in the quest for mercury-free gold

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ABSTRACT

For many years, the use of mercury in Artisanal and Small-scale Gold Mining has afforded an income for many persons without better options, but has brought with it extensive harm to the environment, the miners and their communities. Technical and financial assistance have focused on raising awareness of the affected mining communities and encouraging the transition to mercury-free techniques. However, relatively little research has examined the roles of the stakeholders in the mercury supply chain, and their ability to influence the mercury-free transition. This paper analyzes the stakeholders and their diverse roles with regard to the trade and supply of mercury for Artisanal and Small-scale Gold Mining. The paper applies a supply chain management approach to stakeholder theory. This is done through an extensive literature review, a qualitative content analysis, an online survey and the development of supply chain diagrams that were validated by experts in the field. By providing a comprehensive picture of the stakeholders and their roles, this paper helps governments, inter- and non-governmental organizations and others to better understand stakeholders and their interactions with the mercury supply chain at multiple levels, permitting the development of appropriate policies within the context of the Minamata Convention on Mercury, and the preparation of better adapted National Action Plans.

1. Introduction

In recent years increased attention has been devoted to the environment and health issues related to mercury (Hg) uses and releases worldwide (UNEP, 2008a, 2008b). Mercury is a natural element used in a great variety of applications such as dental amalgam, chlor-alkali production, thermostats and gold amalgamation (UNEP, 2013a, 2013b). It is also unintentionally emitted via industrial activities like coal combustion, cement production and metal smelting (UNEP, 2013b). Due to its high toxicity and hazard to human health and the environment, mercury has increasingly been regulated worldwide in order to reduce its trade, use and releases.

Today, the largest anthropogenic source of mercury emissions is Artisanal and Small-scale Gold Mining (ASGM). ASGM is a sub-sector of Artisanal and Small-scale Mining (ASM) and is defined as: "[…] gold mining conducted by individual miners or small enterprises with limited capital investment and production".[1] ASGM may be formal or informal and may be carried out by family groups, partnerships, cooperatives or associations, including men, women, seasonal workers and not infrequently, children (e.g., Basu et al., 2015; Ali, 2009; Philippine Government, 2011). ASGM workers typically use simple or rudimentary methods to explore, extract, process and transport minerals (WGC, 2015; OECD, 2012). Mercury is often used in this process because it readily amalgamates with gold particles present in the ore. However, the basic processing techniques generally employed lead to substantial emissions of mercury to the atmosphere and releases to waterways and the soil. ASGM attracts many people who have limited alternative employment opportunities, and many others who find it more profitable than work in agriculture, which is often the only option (Nyame and Blocher, 2010; Bryceson and Jønsson, 2010). It is estimated that up to 15 million people work in this sector in about 70 countries in Asia, Latin America and Africa. The most recent estimates of the Artisanal Gold Council puts ASGM annual gold production in the range of 400 metric tons, or nearly 15 percent of worldwide primary mine production.[2] Larger mining operations employ processes that do not involve mercury.

To encourage the ASGM transition to mercury-free techniques, empirical research shows that inter-governmental organizations

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[1] Art.2, Minamata Convention (UNEP, 2013a).

[2] 400 metric tons (Telmer, 2015); 25% (Cordy et al., 2013; Saldarriaga-Isaza et al., 2013; Chouinard and Veiga, 2008); 20% (The World Bank, 2013); 12–15% (Ismawati, 2014); 20–30% (UNEP, 2008b).

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(IGOs), non-governmental organizations (NGOs), researchers, mining associations and some local governments have provided a range of assistance to miners and their communities, with greater or lesser success, depending on the project. However, little non-empirical research has been conducted in the field, which is "the first necessary step for the design of policies […] to regulate both extraction and pollution", especially mercury pollution (Saldarriaga-Isaza et al., 2013). Much of the research literature makes reference to ASGM stakeholders, but this information has not yet been analyzed and presented in a single paper. This paper's qualitative analysis of the stakeholders associated with the trade and supply of mercury for use in ASGM, and their various roles, is a critical first step in developing appropriate programs (García et al., 2015, p. 252) and better understanding the sector, particularly in the context of the Minamata Convention on Mercury, which has an article specifically dealing with ASGM.[3]

The main research question addressed is: How can mercury supply chain stakeholders contribute to the transition of the ASGM community to mercury-free techniques? This implies other related questions, namely: Who are the stakeholders of the mercury supply chain? What are their direct and indirect roles? And at what level (local, regional, national, international) does each stakeholder interact with the supply chain? To answer these questions, this paper takes a supply chain (SC) perspective, which means that the producers, traders and users taking part in the mercury trade and supply (MT&S) system are all held up to scrutiny. Identifying and engaging SC stakeholders not only facilitates the overall sustainability of global SCs (e.g., Li et al., 2014; Müller et al., 2009), but also contributes to some of the Sustainable Development Goals (e.g., goal 17: strengthen the means of implementation and revitalize the global partnership for sustainable development). The methodology for identifying stakeholders and assessing their roles for this paper comprised an exhaustive literature review, a qualitative content analysis, an online survey of experts in the field and the development of SC diagrams whose findings were subsequently validated by experts.

There are certain limitations to this approach that must be noted. The authors themselves did not carry out field research for this paper, so the paper does not present, for example, a specific case study naming individual stakeholders, explaining their precise roles and detailing how they are organized in a given mining area. Not surprisingly, each mining area has its own unique relationship with the various stakeholders. On the other hand, the extensive input from experts – several of whom have spent decades in ASGM fieldwork – helped to insure against any oversights and/or any misinterpretation of research findings by the authors. Therefore, despite the lack of field work carried out specifically for this paper, the authors are confident of its potential contribution to mercury-free ASGM practices.

In the following text, first, the authors present the basic theory from the stakeholder and SC management fields on which the analysis is based. Second, the methodology is described in more detail. Third, stakeholders from both the ASGM community and the mercury SC are identified with regard to their direct and indirect roles in the MT&S. Finally, the findings and recommendations are discussed, conclusions are drawn and further research needs are outlined.

2. Research background

2.1. Stakeholder identification and supply chains

Stakeholder analysis is often used to better understand stakeholders from an organizational perspective. In order for an organization to develop appropriate policies and strategies with regard to its stakeholders, the interests of all legitimate stakeholders first have to be known (Donaldson and Preston, 1995). It is common to find analyses based on a set of predefined stakeholder categories and interests, such as Mitchell et al. (1997) have proposed. According to Friedman and Miles (2002), however, such classifications do not enable one to appreciate the specificities of an organization's environment. Additionally, as highlighted by Simmons and Lovegrove (2005) in reference to the work of Frooman (1999) and other researchers in the field, stakeholders' perceptions may change over time, and the interests of stakeholders in the organization may vary considerably (Savage et al., 2004). Günther and Hüske (2015) have asserted that Stakeholder Theory is particularly relevant nowadays to improving the understanding of complex environments where sustainability (in terms of environment, economy, society and ethics) is at stake. This includes the identification of stakeholders and their impacts (threats or benefits) on the organization.

When considering global sustainability issues and supply chains, taking a holistic perspective is seen as a challenging but fruitful way "to capture the multifaceted reality of [Sustainable Supply Chain Management] SSCM" (Touboulic and Walker, 2015). This suggests that when organizations have to face complex and challenging problems in large networks such as SCs, a holistic approach may help to engage and balance the different and sometimes contradictory stakeholder needs (Roloff, 2008). This approach is similar to "supply chain governance" (defined here as the engagement of internal and external stakeholders), which supports sustainability in global SCs, as mentioned previously (e.g. Li et al., 2014; Müller et al., 2009).

Among sustainability issues in SCs, chemicals and hazardous substances are of high priority. For example, to adequately manage chemicals in products and SCs, UNEP (2014) recommends that companies be "active" rather than "passive." Many downstream companies tend to follow a "passive strategy" of limiting their efforts and investments to simple compliance with regulations, and are hence unprepared for a potential chemical related crisis, which may put their reputation and financial viability at risk. An active strategy implies investing in "due-diligence chemicals management" (e.g., specific purchasing criteria, product design and/or supplier involvement) to better understand the chemicals in products and SCs, and to be prepared for shifts in demand and changes in regulations, thereby creating "long-term value for themselves, their shareholders, the public, and the planet" (UNEP, 2014). This is all the more necessary since the demand for transparency in products and SCs is growing (Meyer and Kirby, 2010). In this respect, Gold (2011) considers stakeholder management as an "extension of supply chain management" since it takes account of a multitude of stakeholders that are external to the SC but nonetheless have an impact on the SC, or may be impacted by the decisions taken within the SC.

Reed et al. (2009) contended that the stakeholder identification process has not received enough attention, especially as the rest of the stakeholder analysis relies on this first step. These authors reviewed the relevant literature and highlighted the importance of using an iterative process in the identification of stakeholders in order to avoid, among other things, the bias inherent in a top-down approach. They also recommended the use of special methods, in line with the research carried out by Chevalier and Buckles (2008, pp.165–177), to categorize and classify stakeholders "according to the degree they can affect or be affected by a problem or action". Reed et al. (2009) also proposed criteria (e.g., geography, demographics) that may be used to differentiate and group stakeholders, especially in cases where the list of stakeholders may be long and complex. According to Gardner and Cooper (2003), visual graphics may also be particularly useful to

[3] Art. 7 and Annex C, Minamata Convention, (UNEP, 2013a).

track and manage SCs in light of the increasing complexity and globalization of supply and delivery systems, while Bourne and Walker (2006) and Salado and Nilchiani (2013) recommended the same for stakeholder analysis. All of these are further addressed in this paper.

2.2. Stakeholder identification in the supply and trade of mercury for use in ASGM

The Minamata Convention on Mercury requires Parties that have determined that ASGM is "more than insignificant" in their territory to develop and implement a national action plan (NAP) that includes measures to reduce mercury exposure in ASGM.[4] Gibb and O'Leary (2014) have pointed out that health effects due to mercury exposure are an issue in this sector, but they should be taken into consideration within a wider range of sustainability issues such as the poverty-driven characteristics of ASGM. This observation implies also a wider range of stakeholders. Spiegel et al. (2014) added to this discussion by highlighting the lack of involvement of ASGM communities in developing mercury policies. Ali (2006) went beyond local ASGM issues and highlighted the need for a "shared responsibility of gold consumption patterns." Both developed and developing countries, as well as governments and companies all need to be involved in tackling environmental, social and economic issues in the sector. There is hence a need to look at the "entire life cycle of the metal and the shared responsibility" of mercury "producers, processors and consumers" (Ali, 2006). Ali (2006) furthermore illustrated and quantified the reserves of gold that were held by private investors, fabricators, banks and institutions, and contained in jewelry and geological reserves. His paper therefore identified additional stakeholders implicated in the gold SC such as end-consumers, recyclers, financing institutions and jewelers, but it did not link the gold SC with the mercury SC, nor did it distinguish between gold coming from Large Scale Mining operations and gold produced by ASGM. Nor did it make the link with the broader operating environment that includes Inter-Governmental Organizations (IGOs), governments, global trade organizations, etc.

The first focus on a SC associated with the ASGM process is found in Sippl and Selin (2012), where they discussed the gold SC. But they did not explore the mercury SC and they did not discuss the different ways that mercury and gold may be traded (e.g. legal, illegal and extra-legal). They concentrated on the role of the final consumer, whose choice among gold-containing products may be influenced by the use of a fair-trade label, as also observed by Ali (2006). The fair-trade label is intended to encourage a more "ethical" consumption, although its definition is the subject of some debate (Sippl and Selin, 2012). Sippl and Selin emphasized that technology transfer and the adaptation of mercury-free gold mining techniques to the local context are the core issue. While not denying that importance, this paper contends that the scope for helping ASGM to become mercury-free should be much broader than that, and needs to include multiple levels of stakeholders and multiple SCs.

3. Methods

Starting with a qualitative approach, this paper builds on that foundation using primary and secondary data to gain an in-depth understanding of the stakeholders involved in MT&S for use in ASGM, and their roles. The following methods have been used to identify and validate the stakeholders associated with this sector.

3.1. Participant observation

"Participant observation" is a methodology often used in qualitative research that refers to a close and extended relationship with a given group or team that permits special insights into their working environment, knowledge and practices. It is an approach that may be used for a variety of purposes (Murphy et al., 1998). In this case it took the form of a 4-month research position at the Chemicals and Wastes Branch of the Division of Technology, Industry and Economics (DTIE) of the United Nations Environment Program (UNEP) in Geneva, between April and August 2014. The objective was to provide the first author/researcher with an in-depth understanding of MT&S for use in ASGM from a holistic perspective (i.e., at the local, regional, national and international level). UNEP was for this purpose an ideal organization since it often acts as intermediary between governments and on-site activities.

Consistent with the guidance of Becker and Geer (1960), the research topic was initially broadly defined as mercury trade for use in ASGM. A broad definition avoids any premature identification of the research gap, and provides an objective and systematic means of identifying the issues that are most worth studying (Becker and Geer, 1960). The research was gradually narrowed to the identification of stakeholders in MT&S for use in ASGM, and the data collection was increasingly focused as described by Murphy et al. (1998), similar to the "funnel shape" in Hammersley and Atkinson (1995). As suggested in the literature (Denzin, 1970; Foster, 1993; Bryman, 1988), the first author participated in the daily activities of UNEP and came to see the issue from an "insider" UNEP perspective. In this manner, the first author gained not only an in-depth familiarity with the issue but also access to information not available to "outsiders" such as an unrestricted access to the Comtrade database; contacts for the online survey with government officials, IGOs, NGOs and experts in the field; and access to non-scientific peer reviewed literature (e.g., United Nations reports), guidelines, standards and valuable databases on MT&S. Above all, the first author was able to engage with UNEP experts[5] on the findings of the stakeholder identification process in an iterative manner, and benefit from their vast knowledge and experience (e.g. mercury waste, mercury amalgamation, mercury recycling) by adopting the role of "learner" (Fielding, 1993). As emphasized by Denzin (1970), the researcher typically uses a range of pragmatic data collection methods. In this case they included the online survey of Government officials, IGOs, NGOs and researchers; formal and informal interviews with UNEP experts; the use of the UN Comtrade database[6] to analyze global mercury trade; and a systematic literature review and qualitative content analysis. Of those diverse research methods, the ones that provided information of use to this paper (the literature review, content analysis, online survey and questionnaire to experts) are further discussed below.

3.2. Systematic literature review

In order to collect the supporting information for the development of SC diagrams and their subsequent validation by experts,

[4] Art. 7 and Annex C, Minamata Convention (UNEP, 2013a) and UNEP (2015).

[5] 1 Programme Officer (PO) working on atmospheric mercury emissions from anthropogenic sources, 1 PO working on the Global Mercury Partnership and reduction of intentional mercury uses, 1 PO working on mercury use in ASGM, 1 Project Officer working on chemicals use in supply chains, 1 consultant working on mercury stocks, 1 consultant working on mercury use in ASGM, 2 PO working on the mercury negotiations and Minamata Convention.

[6] United Nations Commodity Trade Statistics Database, http://comtrade.un.org/.

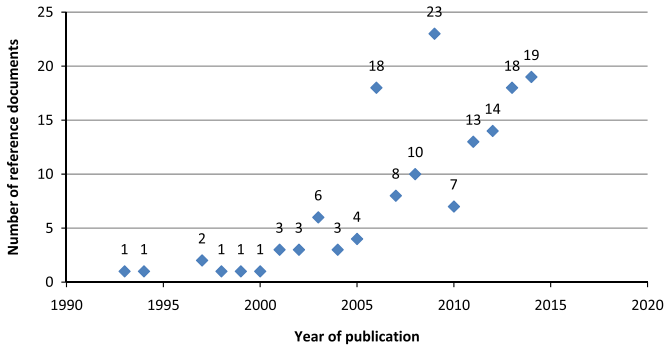

Fig. 1. Number of reference documents per year (N = 156).

peer-reviewed papers were selected according to the procedure suggested by Fink (2005). A search was carried out using the following keywords: "Artisanal and Small-scale Gold Mining", "Artisanal and Small-scale Gold Mining" AND "mercury", "mercury trade", "mercury" AND "gold-mining", "trade control", "illegal trade" AND "mercury", "mercury" AND "supply chain" in the title, abstract and keywords of the papers. The search targeted several online databases: "Scopus", "Web of Knowledge", "JSTOR" and "Google Scholars". The time period included publications from 2006 to 2014 – 2006 being the publication date of the latest and most complete report on global MT&S (UNEP, 2006a). Fig. 1 presents the total search results, showing the number of documents per year of publication, while Fig. 2 shows the same total in terms of the different types of documents identified, and the number of documents of each type.

The keyword search led initially to 77 English language scientific peer-reviewed papers. No restriction was set regarding the field of research. This search was extended by a snowball sampling as per Fink (2005) on the initial sample of 77 papers extracted. The inclusion of additional scientific papers stopped when it did not provide any new information on stakeholders and their roles, consistent with the grounded theory (Glaser and Strauss, 1967). In total, 99 scientific papers were identified, as well as reports on mercury and ASGM, guidance documents for reducing mercury releases and training miners, documents on responsible SCs, regulations on mercury and gold standards, books on MT&S and ASGM, and others (e.g., Masters and PhD theses, ASGM and mercury country analyses provided by survey participants, ASGM expert presentations, ASGM expert working papers) (see Fig. 2). In addition to the online searches, some of these additional documents were provided by UNEP experts or survey participants. The full list of reference documents is provided in the supplementary material.

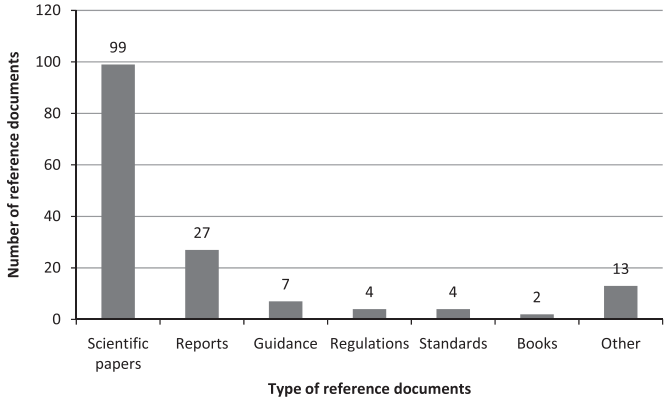

Fig. 2. Number and type of reference documents (N = 156).

3.3. Content analysis

The peer-reviewed scientific papers and other sources were analyzed as proposed in the qualitative content analysis method of Mayring (2008), using the MaxQDA software. Since the approach was explorative, the codes (i.e., stakeholders and their roles) were not set prior to the analysis but derived inductively from the analysis.

3.4. Online survey

An online survey was used to identify stakeholders with a role in SC mechanisms and to develop recommendations to reduce and control the MT&S for use in ASGM. The online survey was designed together with the UNEP Officer and UNEP Consultant supervising the first author. It included closed and open questions and covered five thematic areas: (1) questions related to statistics of imported and exported mercury; (2) questions about the ASGM sector (for countries with ASGM activities); (3) legal questions (only for countries with ASGM activities); (4) questions related to the Minamata Convention on Mercury (for countries with ASGM activities, as well as some questions for countries without ASGM activities); and (5) demographics. The survey was distributed amongst representatives of governments, NGOs, IGOs working on the issues of ASGM and researchers. These participants were identified from the list of focal points of the Strategic Approach to International Chemicals Management (SAICM) available online.[7] Additionally, the survey was sent to all of the participants who attended the 5th session of the Intergovernmental Negotiating Committee to prepare a global legally binding instrument on mercury (INC 5, 2013). A list of 1078 persons was compiled, of which the e-mail addresses for 180 were not available. Hence, the sample consisted of 883 persons, of whom 135 e-mails were returned to sender and 748 persons were contacted. Following a reminder, the survey achieved a participation rate of 18% (131 responses out of 748 contacts). After a total survey period of four months in 2014, 44 of the 131 participants fully completed the survey, 5 partially (answering only the compulsory questions) completed it, and 83 responses were not completed sufficiently to be usable. Hence the outputs from the online survey are based on information provided by 49 respondents, whose profile may be found in the supplementary material (Table S1).

The SAICM and INC7 lists included country representatives, NGOs and IGOs working on ASGM, and other stakeholders from all countries concerned with chemicals and mercury. Several stakeholders who were not on those lists, such as some experienced researchers and experts with extensive field experience in mercury and ASGM, were consulted separately (see Section 3.6 Questionnaire to mercury and ASGM experts).

3.5. Development of supply chain diagrams

The findings from the qualitative content analysis and the online survey informed the development of SC diagrams with the help of yEd, a diagramming program.[8] These diagrams contributed to the formal and informal exchanges with UNEP experts during the participant observation and the questionnaire sent to ASGM and mercury experts. The diagrams included the identified stakeholders (e.g., formal and informal traders, gold shops), their various roles (e.g., supply, storage of mercury) and the possible

[7] http://www.saicm.org/index.php?option=com_content&view=category&layout=blog&id=143&Itemid=528 (accessed 14 May 2014).

[8] yEd is free diagraming software from yWorks GmbH available at: http://www.yworks.com/products/yed (accessed 29 May 2016).

mercury flows from these stakeholders to the ASGM miners – represented by arrows. No weighting was applied or included in these diagrams since the aim was not to identify which stakeholders are most relevant but simply who the stakeholders are. The diagrams were updated in an iterative manner with the inputs of the different experts consulted. Such an approach may be integrated with the so-called "stakeholder-issue inter relationship diagram," where defining the relationships between the stakeholders themselves, and the relationships between these stakeholders and the issue under consideration, enables the identification of actual and potential areas of cooperation or conflict through an understanding of the different interests of the stakeholders (Bryson, 2004). The approach taken in this paper builds on the stakeholder-issue inter relationship diagram (by considering the issue of MT&S for use in ASGM), but starts at the product level, i.e., mercury. This somewhat novel approach enables a more objective and comprehensive identification of direct and indirect stakeholders since it does not focus on the responsibility of a specific stakeholder, but rather concentrates on the analysis of the mercury supply chain.

3.6. Questionnaire sent to mercury and ASGM experts

In order to offset any bias induced by only validating results with UNEP experts, external mercury and ASGM experts were consulted to validate or amend the SC diagrams. A qualitative questionnaire was designed, and the selected experts were asked if they agreed with the findings or if any stakeholder or stakeholder role had been omitted. The list of external experts was prepared with Expert 9 and by identifying authors of the selected reference documents who have several publications in the field or have other close dealings with ASGM (e.g., The Artisanal Gold Council, S&P Trading, Alliance for Responsible Mining). In total, 31 experts were identified. All were contacted initially to review the SC diagrams, and 9 responded (see expert profile in Table A1). The SC diagrams were updated with the information provided. The same 9 experts were asked to review the updated SC diagrams and 5 responded a second time. One (Expert 5) agreed to a one-on-one interview which lasted about 2 h and provided further detailed information.

4. Findings

The content analysis identified several interrelated SCs (see Fig. 6). This paper focuses on the local ASGM stakeholders, the mercury SC stakeholders and the operating environment, since these are the stakeholders most important to the Minamata Convention on Mercury. The broader environment (e.g. technological change, socio-cultural forces, global economic forces and global political/legal forces) that should be considered in a stakeholder analysis, according to Harrison and John (1998), is integrated in the specific roles of each stakeholder.

4.1. Local ASGM stakeholders

Local stakeholders affecting or being affected by MT&S for use in ASGM may have one or more roles depending on the formal or informal legal status of MT&S on the one hand, and the legal status of the ASGM activity on the other hand.

As shown in Fig. 3, 13 different local stakeholders are recognized, of which two may directly affect or be affected (orange ellipses), four may directly or indirectly affect or be affected (gold ellipses), and seven may indirectly affect or be affected (blue

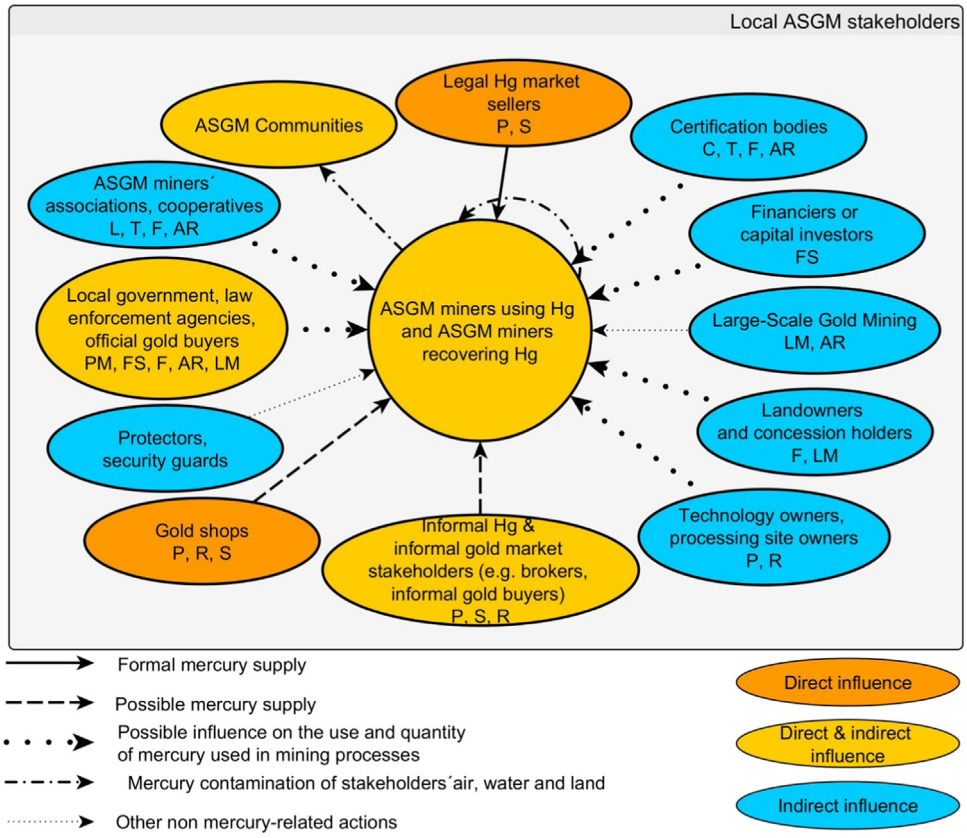

Fig. 3. Overview of local ASGM stakeholders (P: mercury provider; PM: policy-making; T: training; R: mercury recovery/recycling; S: mercury storage; C: gold certification; FS: financial support; F: formalization; AR: awareness raising; L: lobbying; LM: land management) (source: the authors). (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

ellipses) by MT&S for use in ASGM. It should be noted that this diagram results from the content analysis and questionnaire to experts, and represents the stakeholders currently involved, although these relationships are subject to change due to multiple factors (e.g., timeframe, location of the activity, etc.). The complexity of some of these roles and interactions for MT&S (details of each stakeholder are provided in Table A2) is discussed below.

Miners are often identified as the main stakeholders and the only ones responsible for mercury releases (Spiegel, 2009b). However, as mentioned, other stakeholders are involved and may have a direct or indirect influence on MT&S for use in ASGM. Local stakeholders involved in mercury supply, mercury recovery/recycling, mercury storage and policy-making may also have a direct impact on MT&S for use in ASGM, whereas local stakeholders involved in lobbying, awareness raising, land management, certification, training or financial support may have an indirect impact. Some local stakeholders may have both direct and indirect impacts, such as governments, ASGM miners, and informal mercury and informal gold market stakeholders.

These stakeholders have very complex interactions. The formal supply of mercury to ASGM may take place only in countries where ASGM activity is allowed, but several governments like Brazil and Colombia have prohibited mercury use in ASGM (Telmer and Veiga, 2009; Spiegel and Veiga, 2010; García et al., 2015). Others like China have outlawed ASGM activities altogether (Zhao et al., 2015) rather than formalizing the sector, which would permit better transparency and control of MT&S to ASGM (Hruschka, 2011). Hence formal mercury supply to ASGM is very limited, so it often takes informal paths that may start in sectors where mercury is permitted, such as dentistry (Sousa and Veiga, 2009). In the future, one may hope that dentistry will play a decreasing role in MT&S since UNEP and the World Health Organization (WHO) are encouraging the sector to phase down mercury use (UNEP and WHO, 2014), and the Minamata Convention also includes measures to be taken by Parties to phase down the use of dental amalgam.[9] It should be stressed that the Convention includes some exemptions for some mercury-added products used for different purposes such as civil protection, military uses, traditional and religious practices[10] that may be used to justify ongoing mercury imports and a risk of diversion to ASGM.

Informal mercury and informal gold market stakeholders (e.g., smugglers, gold shops) may have a direct or indirect influence on MT&S for use in ASGM by providing mercury, storing or recycling mercury in a way that is not easily traceable, or by trading mercury for gold (see Table A2). They therefore represent an important barrier to the reduction and elimination of MT&S for use in ASGM. They facilitate continued use of mercury by miners even when mercury is prohibited or the ASGM activity is prohibited (Staples and Rumore, 2015). When MT&S for use in ASGM is informal, the mercury may only appear in official data (sometimes) at the time of import into the country, and in any case the end-use will not be indicated as ASGM. In this case, field studies and interviews with miners and local stakeholders are necessary to understand the mercury SC and to identify other stakeholders (Experts 1, 2, 3, 4, 7, 8).

According to Saldarriaga-Isaza et al. (2015), there is now a general consensus that the legalization of ASM by local governments and the development of ASM specific regulations are key actions to support the mercury-free transition and this applies also to ASGM since it is a sub-sector of ASM. Governments could, for instance, support the creation of centers to train miners in cleaner and safer gold processing techniques (García et al., 2015) instead of relying mostly on temporary training programs organized by mining associations, NGOs or IGOs. Without active local government involvement in the ASGM sector, initiatives to technically, financially or socially support miners have a much higher risk of failure. Local governments need to invest time and money in formalizing miners, in the sustainable management of resources, in the stabilization of fiscal regimes and in the integration of ASGM into the economic activity of the country – activities that form the key pillars of "good governmental policy" in ASGM (Hentschel et al., 2003). Under these conditions, mercury use can be better controlled, reduced and eventually eliminated.

The World Gold Council (WGC, 2015) has affirmed that the Large Scale Gold Mining (LSGM) industries, the international community, civil society and other stakeholders should nudge governments in this direction. Although mercury use in ASGM is a global issue, however, the specificities of each country, region and even mining site do not permit a common approach to the issue. As stated by Spiegel (2009a), there is a need to consider the "links between technological developments, trade relations, trust-building, environmental health awareness and community governance" to adequately understand the sector. A holistic perspective of ASGM is therefore necessary to understand the stakes of all stakeholders before intervening in ASGM García et al. (2015), but is seldom acknowledged in the scientific literature or implemented in projects and programs.

Table A2 responds to this need by providing a comprehensive table of stakeholders and their roles that will help local governments, mining associations, NGOs and the stakeholders themselves to better understand the local context, and to provide technical and financial solutions better adapted to ASGM communities' needs and the local context. The complete list of stakeholders shown in Table A2 is not expected to be applicable to all ASGM contexts, but provides a sound basis in nearly any context for a more nuanced identification of key stakeholders and their roles, avoiding the need to reinvent the wheel in each case.

4.2. *Stakeholders in the mercury supply chain*

The sources of mercury for use in ASGM may involve a number of different stakeholders in the mercury SC. The Minamata Convention on Mercury identifies six different sources of mercury: primary mercury mining,[11] mercury compounds,[12] mercury-added products,[13] mercury stocks,[14] mercury wastes[15] and recovered/recycled mercury. When in liquid/metallic form, the mercury emanating from any of these sources may be used in ASGM (Expert 5). These six sources involve different SCs that are interrelated as illustrated in Fig. 4. The ellipses identify the stakeholders responsible for these different mercury sources, the rectangles show a process (e.g., mercury waste generation) or a status (e.g., mercury storage, disposal or loss), and the diamond shapes represent

[9] Annex A, Part II of the Minamata Convention (UNEP, 2013a).

[10] Annex A, Part I of the Minamata Convention (UNEP, 2013a).

[11] Mining in which the principal material sought is mercury (Art. 2, Minamata Convention).

[12] "Any substance consisting of atoms of mercury and one or more atoms of other chemical elements (e.g., mercury chloride, mercury oxide, mercury sulphate, mercury nitrate and mercury sulphide) that can be separated into different components only by chemical reactions" (Art. 2 and 3, Minamata Convention).

[13] "A product or product component that contains mercury or a mercury compound that was intentionally added" (Art. 2 Minamata Convention).

[14] Parties must "identify individual stocks of mercury or mercury compounds exceeding 50 metric tons, as well as sources of mercury supply generating stocks exceeding 10 metric tons per year, that are located within its territory" (Art.3, Minamata Convention).

[15] Substances or objects consisting of mercury or mercury compounds; containing mercury or mercury compounds; or contaminated with mercury or mercury compounds. Mercury wastes shall be handled "in an environmentally sound manner" as stipulated in the guidelines of the Basel Convention (Art.11, Minamata Convention).

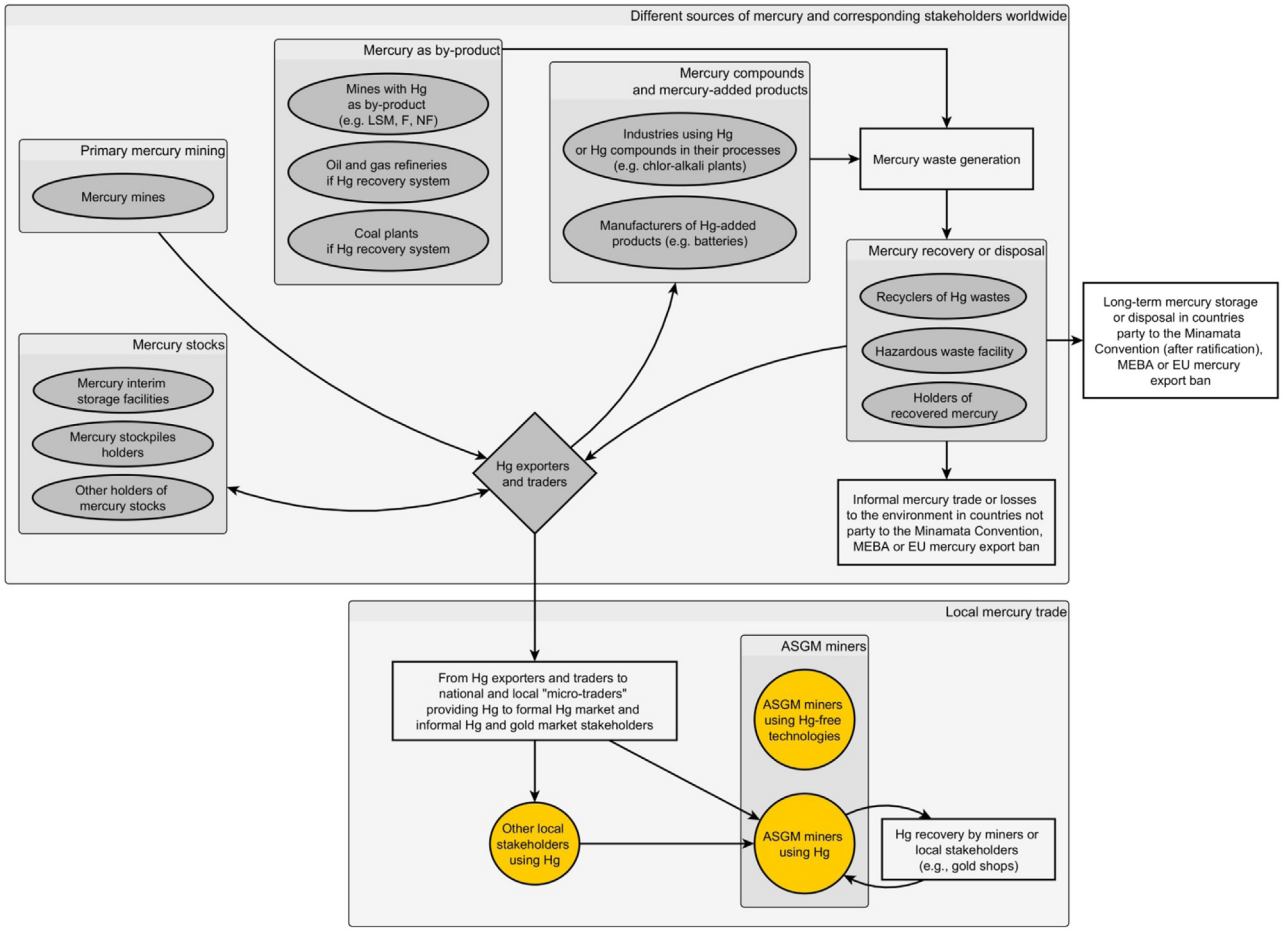

Fig. 4. Stakeholders in the mercury supply chain (Hg: mercury; LSM: Large-Scale Mining; F: Ferrous: NF: Non-ferrous; MEBA: Mercury Export Ban Act; EU: European Union) (source: the authors).

the intermediaries between the different mercury SC stakeholders (e.g., mercury exporters and traders). The lower part of the figure shows how mercury may end up in ASGM, e.g., through international exports and trade of mercury to ASGM countries, and via local stakeholders as explained in Section 4.1 (Local ASGM stakeholders).

One of the overarching objectives of the Minamata Convention is to better control MT&S worldwide, requiring all Parties (following ratification) to identify the stocks of mercury and mercury compounds in their territories; to take measures to ensure that mercury from chlor-alkali plants is stored/disposed of in an environmentally sound manner and not reused; and to closely control the import and export of mercury and mercury-added products.[16] The Minamata Convention also stipulates that mercury from primary mining and decommissioned chlor-alkali facilities cannot be used in ASGM.[17] Of course, the Convention is legally binding for Parties only after ratification (Expert 9, March 2016). Primary mercury mining still takes place both in countries like China, that have signed the Convention, as well as in countries like Kyrgyzstan, which has not (yet) signed (USGS, 2015). More importantly, East Asia has become an important mercury trading hub (Zero Mercury Working Group, 2016), while the opening of new mercury mines in Mexico and Indonesia has been reported. This may be "*a result of shortages of mercury and resulting higher prices due to the US and EU export bans, in addition to increased demand for gold*" (Expert 9, March 2016). This suggests that stakeholders from the gold SC may also have a responsibility for the amount of mercury traded and supplied to ASGM.

The Minamata Convention requires environmentally sound management of mercury wastes consistent with the Basel Convention on the transboundary movement of hazardous wastes (Basel Convention, 2016). This means that all countries party to the Basel Convention that wish to ship mercury wastes to another country shall inform the respective authorities, which helps to prevent illegal trade of mercury. Most countries are signatories to the Basel Convention, although not all signatories have ratified it, which means that it has not yet been integrated into national legislation. This latter group includes several countries with ASGM activities such as the Philippines, Nigeria and Panama, not to mention the USA, which does not have ASGM but does have large amounts of mercury waste (Analysis of the UN Comtrade database conducted by the first author during the participant observation; Basel Convention, 2016; USGS, 2015). This leaves an opening for MT&S, in some cases, through waste recycling and industrial sources that may be diverted to ASGM (Bell et al., 2014), or through the illegal diversion of mercury wastes. In countries not party to the Minamata Convention, or subject to the MEBA[18] or the EU export ban,[19] recovered mercury may be sold back to the market or be at risk of disposal that is not environmentally responsible (Expert 9, March 2016).

[16] Art. 3, 4, 10 and 11, Minamata Convention (UNEP, 2013a).
[17] Article 3 (paragraphs 4 and 5b), Minamata Convention (UNEP, 2013a).
[18] Mercury Export Ban Act (US GPO, 2008).
[19] European Union mercury export trade ban (The European Parliament and the Council of the European Union, 2008).

Although mercury is a hazardous substance, information on mercury stocks and reserves is often outdated or not publicly available (USGS - U.S. Geological Survey, 2015), which makes any study of MT&S more difficult. This is reflected in databases such as Comtrade, which is a compilation of statistics submitted by UN member states, where data on mercury imports and exports are sometimes missing or not consistent (Analysis of the UN Comtrade database conducted by the first author during the participant observation). Also, some countries producing mercury do not have good statistics on their production, or do not report it, and many countries do not have accurate data on mercury stocks, especially where there is informal mercury trade (Zero Mercury Working Group, 2016). Hence building a transparent and reasonably comprehensive database for worldwide mercury trade is essential and has been foreseen in the Minamata Convention (Zero Mercury Working Group, 2016).

Prior to the Minamata Convention, the European Union and the United States implemented regulations that forbade the export of mercury (i.e., MEBA, EU mercury export ban), aiming, among other things, at limiting MT&S for uses like ASGM (USGS - U.S. Geological Survey, 2015; Wilburn, 2013). Before the implementation of the MEBA in the USA in 2013, some firms in the European Union transferred mercury-containing wastes to the USA to recover elemental mercury for sale outside of the European Union (Wilburn, 2013). This confirms that regulations targeting elemental mercury leave a loophole for recovered mercury to be diverted to ASGM. In 2005, the global demand for mercury (circa 3000–3900 metric tones) was primarily for ASGM, vinyl chloride monomer production, chlor-alkali production, batteries, dental use, measuring and control devices, electrical and electronic devices and lighting (Maxson, 2006). Some of these sectors are known to divert mercury to ASGM (Expert 5), but it is often difficult for field researchers to identify the source as the mercury may be sold to artisanal miners in old beverage bottles (Ban Toxics, 2012, p. 7) or plastic bags (UNEP, 2005, p.122–123).

Several researchers have promoted mercury regulations as the solution to control, reduce and/or eliminate mercury use in ASGM. They contend that a total or partial ban on mercury exports leads to an increase in the price of mercury and hence more ASGM interest in mercury-free alternatives (Bell et al., 2014; Veiga et al., 2006b) such as retorts (INC 5, 2013; Spiegel, 2009a; UNEP, 2006b). This would be accompanied by government support for miners including education, techniques and finance (INC 5, 2013). Other researchers, however, have pointed out that regulations and policy-making are not sufficient. If ASGM communities do not have access to mercury, miners could turn to other hazardous substances such as cyanide, which would also be problematic for the environment and society (Veiga et al., 2009; Expert 5). Some researchers have even argued that a ban on MT&S might be ineffective since ASGM would depend even more on informal sources of mercury (e.g. Spiegel, 2008).

According to Selin and Selin (2006), formulating new regulations should be accomplished through an in-depth consultation among experts, governments and other stakeholders, and that all mercury reduction activities should be supervised, progress should be evaluated and countries should be assisted where they most need it (Selin and Selin, 2006). Among countries with ASGM activities, the focus would thus be on domestic capacity building for responsible mercury management (Selin and Selin, 2006). Global mercury reduction strategies would have as their main objective to be "equitable and effective" in addressing the specific needs of miners (Spiegel, 2009a; Childs, 2008). As noted by Hinton (2007), it is critical to understand the interrelated issues of policy, regulations, environment, human health, culture, society and economics in ASGM to ensure that measures are effectively implemented and eventually transform the "vicious circle of poverty" and mercury dependency into a "virtuous" one by approaching the issue of MT&S for use in ASGM with good governance and appropriate policies that integrate measures for environmental protection, fair distribution of revenues and diversification of economic activities for ASGM communities (Hinton, 2007).

To adequately address the issue of MT&S in ASGM, it is necessary to coordinate initiatives at multiple governance levels: locally, regionally, nationally and internationally (Selin and Selin, 2006; Drace et al., 2012). The engagement between local governments and ASGM communities is a precondition to the success of local mercury reduction strategies (Spiegel et al., 2014). One of the critical improvements needed, as compared to past approaches, is to design mercury policies based on bottom-up rather than top-down initiatives (Expert 5), which should be developed in the NAPs for mercury reduction and elimination in ASGM (Spiegel et al., 2014; UNEP, 2013a[20]). Ismawati (2014) even goes so far as to urge governments to "stop the mercury use, trade and importation, review and enforce the regulations, include all stakeholders in the process, introduce alternative livelihoods that are more sustainable, and remediate the devastated environment."

This analysis shows that although some regulations are in place, it is necessary to address mercury SC stakeholders from a broader perspective, i.e., primary mercury mining operators, companies recovering, trading or storing mercury, mercury compounds, mercury-added products and mercury wastes. In addition, the online survey emphasized the need for:

- developing awareness programs for traders, miners and the public on the reduction/elimination and the potential health effects of mercury on ASGM communities;
- pursuing mercury-free technology transfer;
- reinforcing controls of mercury imports at the entry point and subsequent distribution via custom officers, trade ministry, security agents, lawyers, etc.;
- implementing mercury tracking systems (see Table S2) and enforcement of regulations specific to ASGM via, for instance, registration of mercury traders, distributors and users; and
- developing harmonized mercury regulations on trade, use, imports and storage worldwide (see Table S3).

4.3. The operating environment

Beyond the local stakeholders and the mercury SC stakeholders, the issue of MT&S for use in ASGM needs to consider the stakeholders active in the operating environment, as described by Freeman et al. (2010) (Fig. 5).

Most governments look to international collaboration as an effective way to reduce MT&S. Nevertheless, it is politically difficult to coordinate local, regional, national, and global initiatives (Selin and Selin, 2006), especially in light of different local, regional, etc. circumstances. In this context, NGOs and IGOs are active in promoting alternatives to mercury, clean techniques, capacity building and awareness raising (e.g., UNEP, UNIDO, ILO, World Bank, ARM). They provide training, guidance and technical and financial assistance. Due to the variety of organizations working in ASGM and mercury, special coordination is necessary in order to avoid duplication of effort (Metcalf, 2008; Staples and Rumore, 2015; INC 5, 2013). This may even be true within a single government when different ministries oversee activities related to ASGM (e.g., Ministries of Environment, Health, Mines). Additionally, the activities of IGOs and NGOs are often restricted by the donors financing these activities, whether governments, the

[20] Annex C, Minamata Convention (UNEP, 2013a).

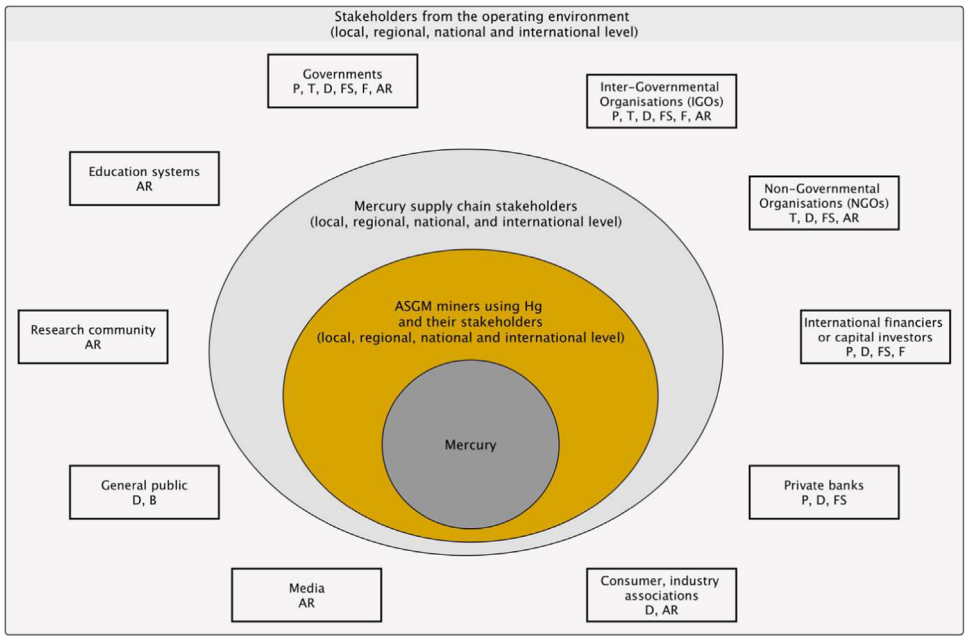

Fig. 5. Mercury trade and supply stakeholders from the ASGM operating environment (Hg: mercury; P: policies; T: training; D: donations; FS: financial support; F: formalization; B: boycott; AR: awareness raising) (source: the authors).

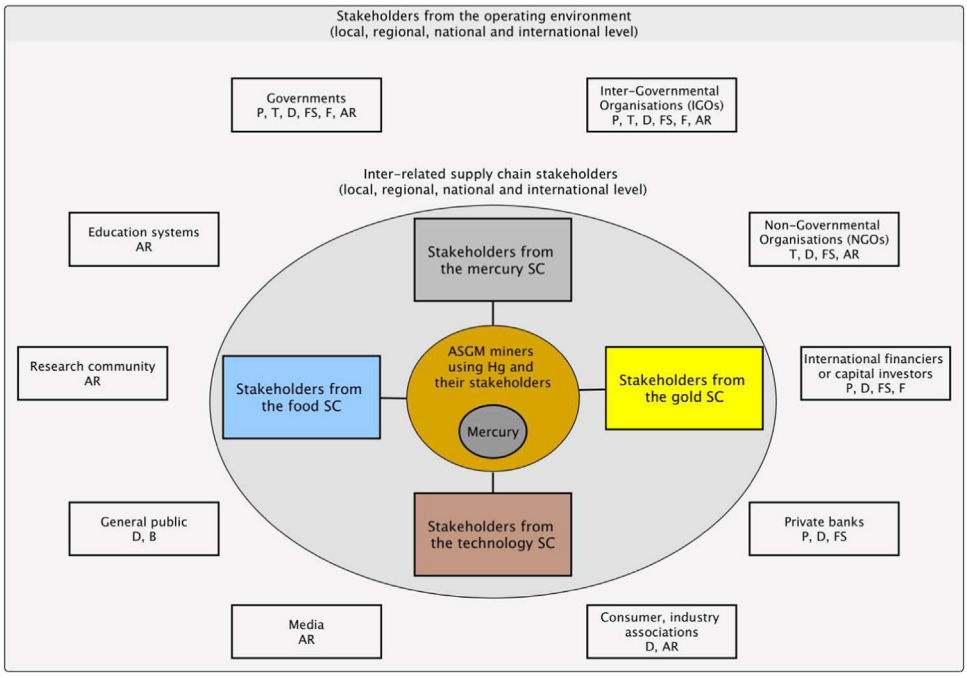

Fig. 6. Stakeholders in the operating environment of mercury trade and supply for use in ASGM and interrelated supply chains (SC: supply chain; Hg: mercury; P: policies; T: training; D: donations; FS: financial support; F: formalization; B: boycott; AR: awareness raising) (source: the authors).

private sector, international financiers or capital investors. They typically specify the kind of activity to be conducted, with whom, how and how long (UNIDO, 2015), the type of technology to be transferred/tested (Expert 5), and often want to reach the largest possible audience as a measure of the success of their activities (Metcalf, 2008; Dennison, 2013), but the quality and sustainability of the approach must not be neglected.

As an example, a project in Tanzania that focused on transferring to ASGM communities the mercury-free technology of using retorts was subsequently judged to be a failure (Jønsson et al., 2013). It may be argued that the project would have been more effective if the donors had insisted on first understanding how the miners worked, what their needs were and how they could be convinced that retorts were necessary. Mining communities, and women in particular, could play a significant role if the message focuses on the health of children, for instance, thereby obliging miners in the family to be more cautious with mercury use. This implies a need for more preliminary empirical research on-site to demonstrate the impact of mercury on the community and inform them about it. Stakeholders including government, local researchers, students, NGOs, etc., who can approach the relevant communities with "empathy" should be engaged in such longer-term projects or, in the case of government, on a permanent basis (personal communication, J. Jønsson, May 2016).

Policy-makers also need to understand and consider the long-term effects of international and national policies in other sectors such as agriculture, gold mining or diamond mining. For instance, in the mid-1990s the decrease in cotton prices and the increase in subsidies by governments to European and American farmers contributed to the bankruptcy of many Malian cotton farmers (Hilson, 2012). ASGM was one of the limited economic alternatives for farmers and their families.

Some researchers have shown that a shift between mining activities is also possible. As pointed out by Nyame and Grant (2012) in the case of Ghana, the temporary diamond export ban in Ghana and the Kimberley Process Certification Scheme led to a reduced profit for diamond miners and some of them decided to shift to gold mining. In Angola a similar trend has been observed and as a consequence, both ASGM and large-scale gold mining activities are expected to increase (Nyame and Grant, 2012). This might towel be damaging to the environment (Nyame and Grant, 2012) if mercury amalgamation is the main ASGM technique used to extract gold.

Gold policies also appear to influence the number of ASGM miners and MT&S (Expert 8; Davis, 2014). In Zimbabwe, for example, the increased profitability of gold mining resulting from the United States' decision to drop the gold standard in the 1970s, and concurrent Zimbabwean subsidies to increase mineral exports, led to an increase in the number of gold mining operations (Metcalf, 2008). Since ASGM miners in Zimbabwe commonly use mercury (Metcalf, 2008), this certainly included an increase in ASGM and the use of mercury. This underscores the observation that even beyond national policy-making, governments have an interest in effectively cooperating and exchanging information that may affect mercury polices and strategies for ASGM. Cooperation should also extend to global corporations and networks that tend to impose their own standards and rules in cases where the governance system is weak (Elbra, 2014).

The lack of accessibility to many ASGM sites is another factor that influences mercury SCs (Expert 8; Expert 9, March 2016). Many ASGM activities are located in remote areas where little or no support is available (Bell et al., 2014; INC 5, 2013). Market mechanisms operate in such a way that mercury tends to be more expensive and gold prices are lower in remote areas due to the transport distances and sometimes additional intermediaries. These challenges may be enough in some areas to encourage ASGM use of alternative technologies (INC 5, 2013). Nevertheless, the effective support, engagement and communication between mercury importing and exporting governments is needed to monitor MT&S developments covering these areas (INC 5, 2013).

The research community is expected to contribute to a better understanding of MT&S, especially in "commerce and trade in mercury and mercury compounds and mercury-added products."[21] The Minamata Convention defines some research areas, mainly linked to technical and economic research (e.g., analyzing the technical and economic viability of mercury-free products and processes and best available technology (BAT), mercury inventory methods, monitoring levels of mercury use, harmonizing methodologies). But as underlined by researchers like Spiegel (2009a) and Metcalf (2008), researchers and policy-makers also need to take some distance from the technology focused approaches and expand their research to better understand the socioeconomic factors that drive the behavior and poor environmental practices of miners. Hence research should also contribute to a holistic understanding of mercury trade, supply and use, and the identification of local stakeholders in order to come to a better appreciation of mercury related systems, stakeholders, and stakeholders' roles and interactions. Students and researchers may be more effective in collecting site-specific information and building relationships with miners due to their neutral role in the ASGM context.

The Minamata Convention emphasizes the importance of a broad range of stakeholders contributing financially to reduce and eventually eliminate MT&S for use in ASGM.[22] Interestingly, a number of stakeholders rarely addressed in the literature, such as the private sector or consumer associations, may have a role to play. For example, private sector stakeholders from the gold SC such as gold refiners, jewelry and electronics manufacturers are implicated since their business activities add to the gold demand which influences the activities of LSGM and ASGM. It may be anticipated that many would be willing to dedicate a small percentage of their revenues to mercury-free ASGM initiatives, which could comprise an important contribution (Expert 5). But first they need to be better informed of the mercury problem and their roles and responsibilities as stakeholders, which is the job of governments, educational systems, researchers, associations, NGOs, IGOs and the media.

According to experts in the field of ASGM, SC management, in particular for certification, is currently a "hot" topic (Expert 5; Expert 2) along with other urgent ASGM issues such as legalization and formalization, conflict minerals, contribution to local development and appropriate technologies (Expert 5). Hence guidelines and regulations under development tend to approach the issue from a SC perspective to ensure the supply of gold from "legitimate" activities is in line with the Conflict-Free Gold Standard (WGC, 2012) or the Dodd Frank Act. The Swiss Agency for Development and Cooperation has stated that stakeholders like governments, industry, civil society, ASGM, consumers and development agencies need to be engaged in formalization processes (Hruschka, 2011).

Likewise, the general public has considerable power to push companies and global supply chains to act more responsibly (Rotter et al., 2013). Consumers may push companies to implement due diligence in their supply chains, which would require them to engage with stakeholders and mobilize resources like technology, information and services in the activities taking place between gold mining and the end consumer (OECD, 2012).

There is a risk that imposing a mercury-free standard for gold production and gold sourcing may exclude many ASGM miners from the gold market (WGC, 2015; Expert 5), which poses an ethical problem since many have limited economic alternatives. One could imagine the emergence of an "ASGM-free" SC for gold which, for many companies, would comprise the easiest way to comply with a mercury-free standard like it is the case for other chemicals (Expert 5; UNEP, 2014). As a result, awareness raising among the general public needs to be conducted with care in order to avoid a situation similar to the conflict-free mineral initiative, where ASGM gold may simply be refused in favor of mercury-free or fair-trade gold. This is already the case with some refiners (Expert 5), although at present such "certified" gold represents only a small share of gold from ASGM (Expert 5). As observed by Eshun (2005) in the case of Ghana, when the ASGM status quo is disrupted, it is important to provide alternative economic opportunities in parallel with the engagement of all stakeholders, formalization of the sector, training, land management, understanding of informal practices, fund raising, technology and education. This reiterates the need to engage multiple stakeholders at multiple levels and understand their stakes in MT&S for ASGM.

[21] Art. 19, Minamata Convention (UNEP, 2013a).

[22] Art. 13, Minamata Convention (UNEP, 2013a).

5. Discussion and further research

Research in ASGM often emphasizes the need to raise awareness of miners, formalize their activities and rely on technology transfer to reduce mercury use. When taking a SC perspective to identify multi-level stakeholders and their roles, it becomes evident that these miner-focused initiatives are insufficient due to a lack of holistic understanding of the interactions between multi-level stakeholders. As shown in Table A2 and Section 4.1 (Local ASGM stakeholders), multiple local stakeholders may play direct or indirect roles in MT&S for use in ASGM. The wider the scope (regional, national, international), the more stakeholders are involved.

Although the relevant stakeholders and their roles cannot be generalized (due to the specificities of each local situation, but also due to the limited number of experts consulted for this research), the findings of this research provide a better understanding of MT&S for use in ASGM, which facilitates the provision of awareness raising activities to the various stakeholders. Awareness raising for governments and law enforcement agencies is particularly important in countries where mercury use in ASGM is strictly forbidden, since the formalization of miners is a key factor in reducing MT&S for use in ASGM. Awareness raising among LSGM companies may also be valuable to demonstrate how they can enhance their image with the ASGM community, how they can support the mercury-free transition of ASGM, or how their reputation may be at risk (see Table A2), any of which should encourage them to commit to the mercury-free transition of ASGM activities (e.g., via consultation, suggestions to manage and minimize risks) (ICMM, 2009). As an idea for possible further study, an LSGM company could even oversee demonstration of mercury-free (and cyanide-free) ASGM activities on a part of its property, with technologies adapted to the local geology and needs of ASGM miners, to increase capacity building among miners.Since mercury traceability, customs systems and harmonization have been identified as key success factors to reduce and control MT&S for use in ASGM (Table S2), the development and cost of such measures should be shared among local and international governments as well as a range of mercury SC stakeholders (see Fig. 4), all of whom would benefit from improved transparency of the mercury SC (UNEP, 2014) and better control of MT&S for ASGM.

Awareness raising of miners with regard to health and environment effects of mercury use is essential, but needs to be complemented by other activities (e.g., public information, education on alternatives, development of training and collaboration activities between IGOs, NGOs and local populations), as stated in the Minamata Convention.[23] To support this, donors' project scopes, timeframes, objectives and resources may all need to be revised, as a number of shorter-term projects have proven to be ineffective (e.g., Jønsson et al., 2009). An enhanced understanding of the local context, the stakeholders and their needs by way of bottom-up analysis would lead to an expanded list of critical activities including investigating the role of women in ASGM communities and their direct or indirect influence on MT&S; the role of culture and beliefs in ASGM communities (UNEP, 2008a, Module 5); supporting the different government bodies in building adequate policies and coordinating actions (e.g., Ministries of Mine, Environment, Trade, Finance); encouraging local researchers and students with more intimate connections to ASGM communities to collect the necessary information to quantify mercury use and impacts, and develop NAPs; and engaging with gold SC stakeholders (e.g., refiners, jewelers, electronics industry) to discuss the advantages for them to finance new activities. Stakeholders that are not part of the mercury or gold supply chains may also have an interest in being more closely involved due to corporate image issues (e.g., companies producing or selling beverages locally, whose bottles are being used to store mercury).

The decision of some countries to ban MT&S for use in ASGM poses ethical problems if miners are not aware of mercury-free alternatives, as they typically cannot get technical or financial support, and alternative economic activities, even when available, are often not adequate to earn a living. Programs to control and reduce mercury trade and use should hence be complemented by socio-economic activities designed to develop viable economic alternatives adapted to the local context, like the creation of a local market to produce mercury-free technologies with materials available locally (Expert 5). This could be related to research regarding a sustainable business model, for instance.

In addition to mercury SC stakeholders, other researchers have implicitly shown the need for a closer study of other stakeholders and supply chains such as in the gold sector (Ali, 2006), technology sector (e.g., pilot plant projects for which the scope is defined by donors, Expert 5), and food sector (Telmer and Veiga, 2009; Expert 5), although any additional SC of course adds complexity (see Fig. 6).

The identification of stakeholders and their roles has focused on MT&S for use in ASGM, although stakeholder roles are apt to change over time (Savage et al., 2004). When considering the issue globally or with a different perspective (e.g., industrial mercury emissions), additional or different stakeholders and roles may be identified. Also, making the link with stakeholder analysis techniques, it may be observed that the number of roles identified for each stakeholder could be a way to identify legitimate or priority stakeholders, which may also help governments to set priorities in their NAPs. If so, local governments, informal mercury and gold stakeholders, certification bodies and ASGM associations would be among the most relevant local stakeholders to engage for mercury-free transition (in addition to ASGM miners), each having more than three different key roles (see Fig. 3). In the operating environment, the priority stakeholders would be Governments, IGOs, NGOs and international financiers or capital investors (see Fig. 6).

As mentioned in the introduction, the results of this research may also be linked to the UN Sustainable Development Goals (SDGs), which depict a sustainable world in terms of social and environmental challenges. Policies to improve the sustainability of ASGM clearly contribute to the SDGs. For instance, the right of the ownership of land (target 1.4) is a critical issue for ASGM. The use of mercury-free techniques would also contribute to several SDGs, especially goal 3 (ensure healthy lives and promote wellbeing for all at all ages), goal 6 (ensure availability and sustainable management of water and sanitation for all) and less directly, goal 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development). At the same time, advances in some of the SDGs will improve the situation of workers and local communities in ASGM: goal 8 (promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all) and goal 9 (build resilient infrastructure, promote sustainable industrialization and foster innovation) could be supported via certification schemes for gold based on environmental and social criteria, promoting alternative sources of income like tourism, access to financial services or the support of local production of machines and equipment like retorts. To reach such targets, this paper emphasizes the need to strengthen the means to implement a mercury-free transition by engaging multiple stakeholders at multiple levels, and revitalizing or creating partnerships for sustainable development (goal 17).

[23] Art. 18, Minamata Convention (UNEP, 2013a).

6. Conclusions

This paper identifies and discusses local, regional, national and international stakeholders that are affected by, or may directly or indirectly affect MT&S for use in ASGM. By considering the mercury SC and the operating environment, this paper identifies stakeholders that are not systematically addressed in other ASGM literature. The paper provides a holistic picture of these multi-level stakeholders, and formulates recommendations for IGOs, NGOs and local governments that help to shift ASGM activities towards a mercury-free future. The identification of multi-level stakeholders and their roles also enables national and local governments with ASGM activities to understand certain supply chain mechanisms that may directly or indirectly affect MT&S for use in ASGM. This is particularly relevant for the development of NAPs. By taking a supply chain perspective, the authors are able to identify stakeholders in an objective manner that highlights their shared responsibility for mercury use in ASGM, and reaffirms the fact that miners are not the only group that should be expected to address the mercury problem. And equally important, the authors conclude that without the active engagement of other key stakeholders, the problem of mercury in ASGM will not and cannot be adequately addressed. This realization is absolutely fundamental in a context where further awareness needs to be raised among a wider range of stakeholders, not least the private sector and the general public.

Acknowledgements

The authors would like to thank all the stakeholders that actively participated in this research, especially the UNEP, DTIE, Chemicals branch, Geneva and the experts.

Appendices

(See Tables A1 and A2).

Table A1
Profile of mercury and ASGM experts who participated in the research.

Expert number	Expert identity	Organization/type of organization	First round	Second round
Expert 1	Confidential	Government (Environmental Protection Agency)	x	
Expert 2	Ludovic Bernaudat	Lead - Artisanal and Small-Scale Gold Mining, UNEP Global Mercury Partnership (UNIDO at the time the questionnaire was received)	x	x
Expert 3	Dr. Benjamin Mapani	Associate of the Artisanal Gold Council. Researcher and Senior Lecturer at the University of Namibia	x	
Expert 4	Professor Marcello M. Veiga, P.Eng., Ph.D.	Professor and researcher, University of British Columbia	x	
Expert 5	Dipl.-Ing. Dr.mont. Felix Hruschka	Formerly assistant professor in the Department for Mining Engineering and Mineral Economics of Leoben University. Currently consultant at tbb.hru	x	x
Expert 6	Patrick Schein	Chief Executive Officer of S&P Trading (company trading and refining gold from ASGM)	x	
Expert 7	Confidential	Inter-governmental organization	x	x
Expert 8	Yuyun Ismawati	Environmental Health Specialist on mercury and ASGM/Mining, co-founder and Senior Advisor of BaliFokus Foundation (NGO) and co-founder of the Indonesia Toxics-Free Network	x	x
Expert 9	Kenneth Davis	Program Officer, UNEP Chemicals Branch (IGO), coordinating the Global Mercury Partnership and supporting UNEP's role in assisting countries to implement the Minamata Convention on Mercury	x	x

Table A2
Local stakeholders and their roles and influence regarding mercury trade and supply for use in ASGM.

Influence	Stakeholders	Role(s)
Direct	Legal mercury market sellers	**Mercury provider.** When mercury use in ASGM is allowed, authorized mercury sellers sell mercury to miners (Expert 5; Expert 4, 2015). The stakeholders involved are very site-specific (Expert 5; Expert 4, 2015).
	Gold shops	**Mercury recovery, mercury provider.** Gold shops refine the amalgam received from ASGM operators and commonly trade mercury informally (Spiegel and Veiga, 2010; Expert 5; Expert 4, 2015). In some locations, the owners of gold shops sell the recovered mercury to miners after the mercury-gold amalgam is processed using retorts or fume hoods (Expert 9, 2015).
Direct and indirect	ASGM miners	**Direct influence: mercury use, mercury recovery.** Most miners use mercury because it is a relatively cheap technique to capture the gold from their ore and because they are unaware of alternatives, or they cannot afford alternatives they are aware of (Telmer and Veiga, 2009; Spiegel, 2009b; Metcalf, 2008). Miners are often unaware of mercury dangers (Jønsson et al., 2009; Spiegel, 2009b). Some miners think that the more mercury is used, the more gold is recovered (Metcalf, 2008). Depending on the type of technology used and the processing phase when mercury is used, the ratio of mercury used compared to gold produced may greatly vary (UNEP, 2006b; Spiegel, 2009a). Some miners recover mercury with retorts which enables mercury emissions to be contained and up to 95% of the mercury to be reused (Spiegel, 2009a). When ASGM leaders adopt better practices, other ASGM miners from their social network may be encouraged to do the same (Saldarriaga-Isaza et al., 2015). Veiga et al. (2006b) show for instance that by examining past projects in ASGM, "the most effective method to convince miners to change their techniques has been via a social or cultural approach".

Table A2 (*continued*)

Influence	Stakeholders	Role(s)
		Indirect. In countries where no legal frameworks for ASGM exist, miners are prisoners of the "vicious circle of informality" (Hentschel et al., 2003, p.9). This means that formalization, training and awareness raising of miners are not possible due to the illegal status of the activity (Hilson, 2008; Verbrugge and Buxton, 2014). The formalization of the activity is essential to enable miners and their community to operate formally and as such allow the development of strategies to control mercury trade and use. Since the opportunity for ASGM miners to formally obtain a concession is limited, they work on abandoned mining sites, LSGM sites, etc. (Teschner, 2013; Spiegel, 2009a; ICMM - International Council on Mining & Metals, 2009). As they always bear the risk of being removed from their site by military forces for instance (Dondeyne et al., 2009; Hilson, 2008), they do not invest in cleaner techniques. In some cases, miners are "not interested to formalize because they do not want to pay for it" (UNEP, 2011). The rising price of mercury has to some extent made miners more cautious about the quantity of mercury they use (García et al., 2015).
	ASGM communities	**Directly impacted.** Local air and food chain are highly contaminated by mercury emissions and releases that end up in fish (Hinton et al., 2003; Velásquez-López et al. 2010; Wong et al., 2006), rice (Hinton, 2007), and other crops (Babut et al., 2003). As stated by Telmer and Veiga (2009), "Global food chain contamination is likely to be occurring through long range atmospheric transport, deposition, and accumulation in global fisheries - global ecosystem damage is likely to be occurring." **Indirect influence.** Culture, beliefs and habits of ASGM communities (UNEP, 2008a, Module 5; UNEP, 2005) may constitute a strong barrier to the adoption of alternatives to mercury (Metcalf, 2008).
	Informal mercury and informal gold market stakeholders	**Direct influence as mercury provider, mercury storage, mercury recycling.** Provide ASGM miners with mercury diverted from different sources like local industries using mercury-added products (i.e., in some locations, dentists or chlor-alkali plants) (UNEP 2013c; Sousa and Veiga, 2009; Expert 5). May have different roles and are named differently in literature (Spiegel, 2009a). "Middlemen" buy gold from miners, smuggle mercury and may be involved in money laundering or criminal activities (Hilson and Ackah-Baidoo, 2011; Hruschka, 2011; Spiegel, 2009a). "Brokers" help in mercury trade and unknown or undeclared mercury storage and mercury recycling activities (Diaz, 2011; Ismawati, 2014). "Smugglers" or "illegal dealers" also buy gold (Hinton, 2007; Spiegel and Veiga, 2010), promote the use of mercury and bargain the price of gold in exchange for a reduced price or "free" supply of mercury (Dondeyne et al., 2009). **Indirect**. These roles affect the gold revenues of the local governments, which is an incentive for governments to fight against gold smuggling (Dondeyne et al., 2009; Kambani, 1995) and (indirectly) informal mercury supply.
	Local government, law enforcement agencies, official gold buyers	**Direct influence via policy-making, financial support, formalization, awareness raising.** Decide upon the local status of ASGM and the authorization or prohibition of mercury use in ASGM. If they are Parties to the Minamata Convention, they must build National Action Plans (NAPs) that include "strategies for managing trade and preventing the diversion of mercury and mercury compounds from both foreign and domestic sources to use in artisanal and small scale gold mining and processing" (UNEP, 2015).[a] Simplification of licensing procedures, decentralized support and effective and regular communication between local governments and miners are also keys for success of mercury policies in ASGM (Veiga et al., 2006b). Although formalizing is one of the basic steps, it is in most cases not sufficient and requires in addition enforcement policies and controls (Hilson, 2008). **Indirect via policy-making (on gold).** Sometimes focus only on revenues from gold extraction and do not believe that mercury is a threat to human health and the environment (Metcalf, 2008). Such governments would hence not support policies and programs for mercury-free transition (Hilson, 2008). But often the revenues from gold are highly important for local governments, and informal mining is an issue since it deprives them of the revenue generated by the payment of taxes (Hentschel et al., 2003, p.9). Communicating on gold revenues may be the best way to get local government support for formalization, and indirectly control and reduce mercury trade and supply. Local governments decide upon the local sales price of gold which has an impact on the bargaining power of informal mercury and informal gold market stakeholders and the MT&S for use in ASGM (Kambani, 1995; Dondeyne et al., 2009). When the price of gold is fixed too far below the global gold market price, the number of smugglers tends to rise (Metcalf, 2008) and hence the informal mercury supply to ASGM miners too. **Indirect via land management.** Leasing lands to LSGM is often preferred to putting effort into formalization of ASGM miners (Hirons, 2011). But without formalization the trade and supply of mercury for use in ASGM cannot be controlled.
Indirect	Technology owners/Processing site owners	**Mercury provider, mercury recycling**. They may be informal mercury and informal gold market stakeholders (Siegel and Veiga, 2009) and hence have a direct role as described above. Technology owners (e.g., mill owners) need to trust alternative technologies to promote them and hence useful to train them and raise their awareness (Spiegel, 2009b; Veiga et al. 2006a). "Millers would be responsible for sound mercury management on their premises and for ensuring compliance with regulations" (Spiegel, 2009b).
	ASGM miners' associations or cooperative	**Lobby, awareness raising, training, formalization.** Lobby for miners on security, training, or financing issues (UNECA, 2002). Intermediates between NGOs/IGOs and ASGM miners for awareness raising, training activities and formalization (Hilson and Ackah-Baidoo, 2011; Sousa et al., 2011; Metcalf, 2008). Rather than relying only on ASGM miners' associations/cooperatives that often represent ASGM miners (Hilson, 2008), awareness raising actions also need to be targeted at the ASGM miners directly to enable "transparent consultation" and emphasize what the needs of miners are to "ensure fair and efficient project administration" (Metcalf, 2008). The effectiveness of these intermediates is limited due to planning and management difficulties; a lack of trust (from miners) in their leaders – especially when the association is strongly supported by the local Government; insufficient technical facilities; and limited financial resources (Hilson, 2008; Fisher, 2007; UNECA, 2002).

Table A2 (*continued*)

Influence	Stakeholders	Role(s)
	LSGM	**Awareness raising.** Hilson (2007) depicts large-scale gold mining companies as "cash-cow seekers" with a huge bargaining power against the local government and communities. LSM have to increasingly consider ASM as a stakeholder since both sectors are expanding (ICMM - International Council on Mining & Metals, 2009). A greater involvement of LSGM could help raise awareness among ASGM miners and the local population, or by providing ASGM miners with mining sites owned by the LSGM but not being operated (Hilson, 2007). According to Boatri et al. (2015), CSR activities in the mining sector may help ASGM miners become more aware of the environmental, social and economic impacts of their activities. LSGM is however not always exemplary or environmentally friendly regarding tailings disposal, for instance (Spiegel & Veiga, 2010). This lack of commitment to sustainability discredits the initiatives aiming to reduce ASGM impacts on the environment. **Land management.** There is a need for a consensus between LSGM companies and ASGM with regard to land management, due to its scarcity and inefficient use (Hilson, 2007). Several experts in ASGM consider that LSGM and ASGM are complementary (Expert 5; WGC - World Gold Council, 2015). ASGM miners could play a role in the pre- and post-mining phases of LSGM (e.g. exploration work; processing of non-profitable areas for LSGM) (ICCM, 2009). The role of LSGM may vary depending on the local context but LSGM may ease the dialogue and engagement of ASGM miners so that ASGM miners are for instance supported in the development of viable activities (WGC - World Gold Council, 2015). As for many voluntary initiatives, LSGM may only support ASGM towards a mercury-free transition if the local governments allow it (WGC - World Gold Council, 2015), which implies that the activity must be authorized and miners must be formalized (Hilson, 2008).
	Landowners and concession holders	**Land management.** In some countries, lands may also be informally traded between local landowners, miners and other groups (Nyame and Blocher, 2010). If the use of mining sites by ASGM miners were better organized and formalized, the techniques used could be controlled and hence the negative impact on the environment could be reduced (Dondeyne et al., 2009).
	Financiers/capital investors	**Financial support.** May include a variety of people like "former miners, local merchants and agricultural elites, army and rebel commanders, and engineers (often previously employed in large-scale mining)" (Verbrugge and Buxton, 2014). They often do not collaborate with ASGM miners because they are not formalized and/or because the activity is informal in the country. If the legal context allows, financiers or capital investors may support ASGM miners by lending them the money they need to get formalized and invest in cleaner technologies (Spiegel, 2009a). However, the types of operating licenses that ASGM miners usually get are often short-term and not renewable, which is unattractive for financiers (UNECA, 2002, p. 23).
	Certification bodies	**Certification, training.** The Fairtrade and Fairmined Gold Standards from Fairtrade Labelling Organizations International (FLO) and the Alliance for Responsible Mining (ARM) require that miners abandon progressively the use of chemicals, in particular mercury, while processing their ore (ARM – Alliance for Responsible Mining, 2014). The certification organization provides training to support miners towards this goal. Buying gold from gold miners at a fair price may significantly contribute to reduced use of mercury (García et al., 2015). But to be certified, miners must be legalized and formalized, and since ASGM gold contributes to host governments' revenues, these are not likely to support the transition towards a direct gold sales system between ASGM miners and gold buyers (Hilson, 2008).
	Protectors, security guards	The role of "Protectors, security guards", may be limited to the surveillance of gold production and transportation from ASGM sites to gold shops but "*with transport of a high-value good like mercury, which may even be illegal, it's very likely that there will be security personnel involved*" (Expert 8, 2015; Expert 9, March 2016).

[a] UNEP (2015) and Annex C, Minamata Convention (UNEP, 2013a).

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.resourpol.2016.07.007.

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