

Mercury Use and the Socio-Economic Significance of
Artisanal and Small-Scale Gold (ASGM) Mining in Senegal:
A Mixed-Methods Approach to
Understanding ASGM

by

Anthony W. Persaud
B.A. York University, 2008

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

Master of Arts

in the Department of Geography

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Supervisory Committee

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Abstract

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Artisanal and small-scale gold mining (ASGM) continues to grow in more than 70 countries in the developing world, creating thriving local rural economies but also causing significant environmental contamination and health issues, with one particularly problematic issue involving the use of mercury in the gold extraction process. With the advent of the United Nations *Minamata Convention on Mercury* in 2009, a legally binding treaty aimed at reducing and where feasible eliminating mercury use, countries with significant ASGM populations require solutions for this sector. In April 2014, a mixed-methods rapid appraisal study was carried out over a three week period in the gold mining region of Kedougou, Senegal. During this time 80 structured interviews, 120 household surveys, physical measurements, observations and numerous informal interviews were utilized in conjunction with a comparative data analysis in order to create a national inventory of the ASGM sector for Senegal, to explore the sector's socio-economic contribution to rural development in Senegal, and to provide a basis for discussing policy approaches needed to improve the sector. The results of this study show a thriving ASGM sector composed of approximately 67,000 people, producing an estimated 4.5 tonnes of gold per year and releasing approximately 5.2 tonnes of mercury into the environment. The methodologies used to create these estimates also provide in-depth information that illustrates an ASGM sector that is highly inter-connected with customary tenure practices and traditional agrarian livelihoods, and that is important for rural inhabitants in Senegal and other countries. This information can be utilized by the Senegalese and other governments to inform the policies that are being developed for the ASGM sector as they implement the obligations created by the Minamata Convention.

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1 Chapter 1

1.1 Introduction

The significant impact of artisanal and small-scale gold mining (ASGM) on socio-economic development, health and the environment is quickly becoming recognized by environment and development policy-makers both locally where ASGM occurs in rural areas of developing countries, and internationally. This is in part due to its contribution to rural employment and economic development in the developing world¹, but also because it is now estimated to be the largest anthropogenic source of mercury emissions and releases to the environment, affecting the health of millions of local people, the environment, and contributing to contaminating fish stocks globally – it is a global pollutant (UNEP, 2013). ASGM is also a source of land tenure conflict between large industrial miners and local land holders (Hilson, 2002a, 2002b). The sector is thus controversial and has for the most part been neglected and rejected by governments, both rich and poor, as a viable source of rural economic growth. Despite its potential for rural development, a poor understanding of the sector, high levels of informality and challenging environmental problems have generally caused ASGM to be an easy target of the media, governments and other groups that consistently portray the sector as criminalized and anarchic (Tschakert & Singha, 2007; Hirons, 2011; Hilson, 2013), and some macro-economic scholars have even referred to ASGM as a “plague” to investment (Spiegel, 2012). Such depictions have only served to further marginalize the sector. Rather than look for solutions for ASGM, most governments have alienated and oppressed the sector and the tens of millions of people that

¹ ASGM occurs in more than 80 countries, however those with the largest and the most significant ASGM sectors generally score low on the UNDP Human Development Index (Hilson & Maponga, 2004)

depend on it. However, this is beginning to change through the development of global efforts and awareness of the impacts and importance of ASGM.

With the signing of the *Minamata Convention on Mercury* by more than 128 countries and its anticipated ratification, efforts to improve the ASGM sector, and to reduce and, where feasible, eliminate mercury use have become prioritized for international environmental and development programs, and will become legally binding for participating governments (“Minamata Convention on Mercury,” 2015). It has become clear that simply ignoring or suppressing the ASGM sector will not eliminate or improve it and rather the imperative for change is to develop sustainable solutions that can lead to its formalization and subsequent health and environmental improvements. The obligatory National Action Plans under the Minamata Convention require governments to develop inventories of mercury use in the ASGM sector and practical plans for delivering improvements (Minamata Convention on Mercury, 2013). In order to accomplish this, both clear and transferable methodologies for investigating the sector are required. However, there is also a need for a general understanding by policy makers that quantitative data on mercury use and correlated factors are only part of the requirements to find solutions for the sector.

Hentschel, Hruschka, and Priester (2002: 43) suggested that in ASGM “the implementation of technical changes, modifications, and improvements require in almost any case detailed knowledge of the cultural, social, economic and organizational context of the miners”. Indeed, it appears many past technical interventions in ASGM have failed (e.g. see section 3.4.6) because of a poor understanding of conditions on the ground (Hilson, 2005), and as such, building a

stronger understanding of the socio-economic structures in ASGM communities can help to direct practical interventions and policy while also providing valuable information that increases the confidence of any quantitative information such as estimations of mercury use. Ultimately, using mercury inventory methods as informational tools to gather a range of information on the sector can inform policy both for broader rural development issues, and in particular the policies required for the obligations of the Minamata Convention.

The goal of this thesis therefore, is to address the problems facing governments in the developing world that require holistic solutions to address mercury use in the ASGM sector. This is in many ways a unique challenge. The Minamata Convention has a singular target – reduce mercury use – but requires a holistic approach to obtain it, and coded into the convention’s obligations for the ASGM sector are many broader development goals such as health, formalization, and markets (Minamata Convention on Mercury, 2013). There is very little reliable information that can inform the needed solutions. The mixed-methods, rapid appraisal methodology presented here, will demonstrate how governments or other groups with few financial resources can produce reliable socio-economic and environmental information that can form the basis for policy decisions – with mercury reduction being a main one. The country of Senegal, a geographically small ASGM area that is similar in most respects to other ASGM sectors in Africa, and one in which the research team had significant prior experience (see section 1.3), is used as an ASGM case study. The results will illustrate the significance of the ASGM sector in Senegal through an investigation of its size and scope, its relationship to other sectors, including particularly the agricultural sector, and its significance to the rural economy. Thus, rather than using the ASGM mercury inventory as evidence of environmental mismanagement with which to further

marginalize the sector, such data can provide the necessary information for governments to create responsive, pragmatic, and supportive National Action Plans under the Minamata Convention, that lead to supporting the sector's potential while at the same time reducing mercury use.

In addition to its practical application for policy makers and ASGM practitioners, this research contributes to the literature on international development studies. For the last 15 years ASGM has become increasingly recognized as an important sub-topic in development studies, particularly in what some refer to as the 'sustainable livelihoods' approach to development (Scoones, 1998). Some authors have to a limited degree begun to bring ASGM into this research and policy framework (Hilson, 2005), and this thesis aims to broaden this debate. More specifically this work engages the literature on rural livelihood diversification and nonfarm income (Barrett, Reardon, & Webb, 2001; Ellis, 1998; Jønsson & Fold, 2011; Niehof, 2004), demonstrating the connection between poverty alleviation and livelihood diversification in the form of ASGM. Additionally, it builds on the steadily growing body of literature that explores the connections between agriculture and ASGM (Cartier & Bürge, 2011; Kamlongera, 2011; Okoh & Hilson, 2011), illustrating the complementarity between the two sectors.

The specific research questions to be answered here include:

1. How do we estimate mercury-use and other correlated data of a largely informal and little-understood sector like ASGM?
2. How significant is ASGM to rural development in a country like Senegal?

In order to accomplish this, the objectives of this research aim to: (i) define and develop a replicable and widely applicable methodology for estimating mercury use in ASGM communities, and; (ii) analyze the socio-economic significance of ASGM and its potential for development in relation to other rural sectors in the developing world. The data requirements for this include informal and structured interview responses; direct observations and field measurements including physical counting of miners and measurements of mercury amalgamation burnings; survey data; census data and an extensive review of secondary source data.

The remaining portion of Chapter 1 will include a background of ASGM and related issues, and a discussion of the study area and positionality of the researcher, followed by a review of the literature surrounding both the socio-economic significance of ASGM, and methodologies for estimating mercury use in ASGM. Chapter 2 will present the results and discussion of the present study on the socio-economic significance of ASGM, and Chapter 3 will present a national inventory of ASGM and a mercury use estimate for ASGM in Senegal. Chapter 4 will include a broader policy discussion, followed by a conclusion in Chapter 5.

1.2 Background

1.2.1 ASGM

The ASGM sector is estimated to produce between 15-25% of the global production of gold annually, providing direct livelihoods for between 10-15 million people, and indirect livelihoods for as many as 100 million people in more than 70 countries around the world (Veiga, Maxson,

& Hylander, 2006; Telmer & Veiga, 2009; Cordy et al., 2011; Telmer & Persaud, 2013). The majority of the ASGM economy operates within the ‘informal sector’ (International Labour Office, 1999; Hentschel et al., 2002), often in a state of legal ambiguity and beyond state control. Despite this, the sector plays a strong economic role in many developing countries and represents a significant direct global economy estimated to be as large as 20 billion USD annually, with a secondary economy as large as 100 billion USD per year (Telmer & Persaud, 2013). Today, in Africa alone the sector is estimated to employ between 4-6 million people, and indirectly support as many as 40 million people, amounting to 1 in every 20 people in Africa (UNIDO, 2010).

1.2.2 Mercury

Although associated with various environmental problems including deforestation, heavy river siltation, poor tailings management, and habitat destruction (Hinton, 2005; Lobo, Costa, & Novo, 2014), ASGM has come into the environmental spotlight most recently as a result of its recognition as the largest source of mercury emissions and releases to the environment at approximately 1600 tonnes (AMAP/UNEP, 2013). Mercury is used in ASGM for a variety of reasons ranging from its low cost to its relative effectiveness and accessibility. Perhaps most importantly, mercury is used because of a lack of knowledge amongst miners of the dangers associated with its use and due to a lack of accessibility to alternatives (Hinton, Veiga, & Veiga, 2003; Hilson, 2006; Telmer & Veiga, 2009).

Mercury is used by ASGM miners to extract gold from ore through the formation of an amalgam that is then evaporated through a burning process. At this stage, those directly exposed to vapours can suffer severe health effects. However, the main environmental concern of mercury is

its transformation into toxic methyl-mercury and its bioaccumulation in the food chain globally (Hilson, Hilson, & Pardie, 2007). It can be transported through the atmosphere and through aquatic pathways thereby affecting humans and wildlife both locally and globally (Gibb & Leary, 2014; Marins et al., 2000). Methodologies for detecting mercury contamination in land, water, and human and other species have been widely used and refined for ASGM and it is now accepted that areas with ASGM activities have anomalously high levels of mercury (Appleton et al., 1999; De Lacerda, 2003; Limbong et al., 2003; Cordy et al., 2011).

There is also a large body of literature showing that mercury use in ASGM has deleterious health effects on a variety of organisms including plant life and humans (e.g., Akagi et al., 2000; Taylor et al., 2005; Hilson et al., 2007; Betancourt et al., 2012). Mercury vapors in the air around ASGM sites almost always exceed the World Health Organization limit for public exposure of 1 microgram/m³, posing a threat to both miners and their wider communities (Gibb & Leary, 2014). In ASGM communities, miners and their families are exposed both directly, mainly due to the presence of elemental mercury vapours released through the amalgam burning process, and indirectly through contact with mercury contaminated surfaces and latent off-gassing from these surfaces which leaves the local atmosphere levels dangerously high (Richard, Moher, & Telmer, 2014). Chronic exposure to elemental mercury can cause nervous, digestive, and immune system effects, while acute exposure causes respiratory, cardiovascular, urinary, and nervous system effects in adults (Betancourt et al., 2012; Gibb & Leary, 2014) The recognition that mercury releases from ASGM are causing severe environmental and health impacts makes studies such as the present one ever more relevant and important. Through an improved methodology that enables a more holistic understanding of ASGM and a quantitative mercury

use estimate, effective action plans can be developed to support and monitor improvements to the sector.

1.2.3 Minamata and National Action Plans

The significant problems associated with the sector and its potential as an important rural development activity have brought ASGM to the forefront of human-environmental policy debates. This attention has most recently resulted in the *Minamata Convention on Mercury*, a legally binding convention that, among other things, aims to regulate the informal sector of ASGM and aims to accomplish this through a requirement for each country to develop a National Action Plan (NAP) for ASGM. Key to such NAPs is the development of mercury inventories and baselines of the ASGM sector in order to monitor improvements, and to establish regulatory standards for reduction (Minamata Convention on Mercury, 2013).

The government of Senegal is now a signatory of the *Minamata Convention on Mercury*, as well as of the 2004 *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade*, the latter of which relates to prior informed consent procedures for importing and exporting hazardous substances including mercury. They are also signatories of the 1989 *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal* and of the 1998 *Bamako Convention on the ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa*, which both aim for cross-border control of hazardous substances including mercury (Sow, 2014). Combined, these treaties present a series

of international obligations on the part of the Senegalese government to reduce and where feasible eliminate the use of mercury use, and to reduce and control the transport, and import/export of mercury. Fundamental to meeting these requirements is a better understanding of the ASGM sector and responsive policy that will help to improve its environmental performance.

1.2.4 Informality

In order to produce valid information on the ASGM sector and to better interpret the results, particularly on mercury use estimates and correlated socio-economic data, a general understanding of the informality of the sector is required. It is a predominantly informal sector. In Sub-Saharan Africa, for example, it is estimated that 90% of ASGM workers operate informally (Clausen, Li, & Barreto, 2011), and in 1999 it was estimated that 80% of all ASM workers globally operate without authorization, indicating at least some degree of informality (International Labour Office, 1999). This high level of informality in the sector makes most macroeconomic methodologies and quantitative estimates for ASGM difficult to form, employ and deliver. By understanding the largely informal socio-economic structures and mining culture that compose the ASGM sector, researchers, practitioners, and policy makers alike will have a better appreciation for the requirements and shortcomings of traditional approaches to investigating and improving ASGM practices.

The status of an ASGM community varies geographically and contextually, from very few legal miners with mining permits and authorizations, to illegal miners who operate in contravention of

a specific law, to predominantly informal miners who operate in the absence of any appropriate legal framework (Buxton, 2013). An additional term that may be appropriate in defining informal ASGM activity is “extra-legal” (De Soto, 2000), where essentially self-organized miners with often comprehensive, albeit unofficial norms and regulations work outside or in the absence of a legal framework (Siegel & Veiga, 2009; Telmer & Persaud, 2013). This self-organization, as will be shown, is often the result of customary tenure and resource governance practices. As such, in ASGM, what is considered informal may in many cases still involve a set of customary rules.

The reasons for informality in the ASGM sector are generally due to: the lack of other formal employment opportunities, the regressive tax systems that deter the declaration of incomes, the complex bureaucratic impediments to formalization, the remote nature of ASGM activities, the lack of status or recognition of the ASGM sector by governments, and the poorly elaborated, expensive, and complex to navigate property rights systems (De Soto, 2000; Siegel & Veiga, 2009; Tschakert, 2009; Hilson, 2013; Telmer & Persaud, 2013). Informality in ASGM can also be the result of macroeconomic policy, where overvalued currency or the unavailability of foreign exchange resources cause distorted prices which lead miners and traders to use gold in the place of local currency for more security wealth management and in commercial transactions (Kumar & Amaratunga, 1994). Informality in ASGM means there is thus far little official and secondary data upon which to base gold production estimates and subsequently mercury use estimates.

Although information on ASGM has advanced over the last decade through the work of both international development and environmental researchers and NGOs, modern ASGM has been operating since the 1970s when the gold standard was abandoned and the price of gold skyrocketed, and there is still relatively little high quality information on the sector. As reported by Telmer in AMAP/UNEP (2013), and in Telmer and Veiga (2009), this is particularly the case with regard to information on amounts of mercury use, how mercury is used and the scale of mercury use operations in ASGM. Also difficult to obtain, is data on gold production and the population of the ASGM sector. However, these can be more easily collected than that of mercury use, and, as we will see, are key proxy sources of data for estimating mercury use. However, the fungible nature of gold and the porosity of borders with regards to gold trade complicate macroeconomic estimates of the sector. Disagreement between official trade data and field information clearly indicate that gold readily moves across porous borders (Veiga, Maxson, and Hylander, 2006; Telmer & Veiga, 2009). In the gold producing region of Senegal for example, anecdotal evidence point toward large amounts of ASM gold moving covertly across the Malian border daily, where sellers can get higher prices. Another recent example of this has been reported in the Philippines, where an analysis of trade data shows that official exports of gold from the Philippines to Hong Kong in 2011 account for only 3% of the official gold imports from the Philippines recorded by Hong Kong authorities, indicating large amounts of gold leaving the country through clandestine channels (Francisco, 2012).

Obtaining the truth about mercury use or gold production directly from field interviews is also complicated due to the workers fear of government interference given that their use of mercury is illegal, and there are motivations to conceal gold production for security, tax and simply privacy

reasons – most people are not amenable to openly telling their incomes to strangers or officials. Understanding the legal status of the ASGM sector is important to information gathering approaches. Where ASGM mining is marginalized or criminalized often due to land rights conflicts with large-scale mining companies or because of environmentally harmful practices, the problems of gathering information are exacerbated (e.g., Bugnosen, 2003; Burke, 2006; Tschakert & Singha, 2007; Jønsson & Fold, 2009; Hirons, 2011). As De Soto (2001) points out, collecting information about informal economies cannot be approached through traditional methods, including how we survey and map it. Others extend this notion to the ASGM sector (e.g., Siegel & Veiga, 2009; Geenen, 2012; Hilson, 2013; Telmer and Persaud, 2013). Estimating mercury use in ASGM is similar in this regard, meaning that atypical approaches including an ability to understand and quantify informal economies are important.

1.3 Area of Study

Senegal is a Sub-Saharan country located in West Africa (Figure 1: Map of West Africa, surrounded by Mauritania, Guinea-Bissau, Guinea, and Mali). The area of study is the Kedougou region of Senegal (Figure 2: Map of Senegal - Kedougou Region in the South-East of the country, bordering with Mali and Guinea).

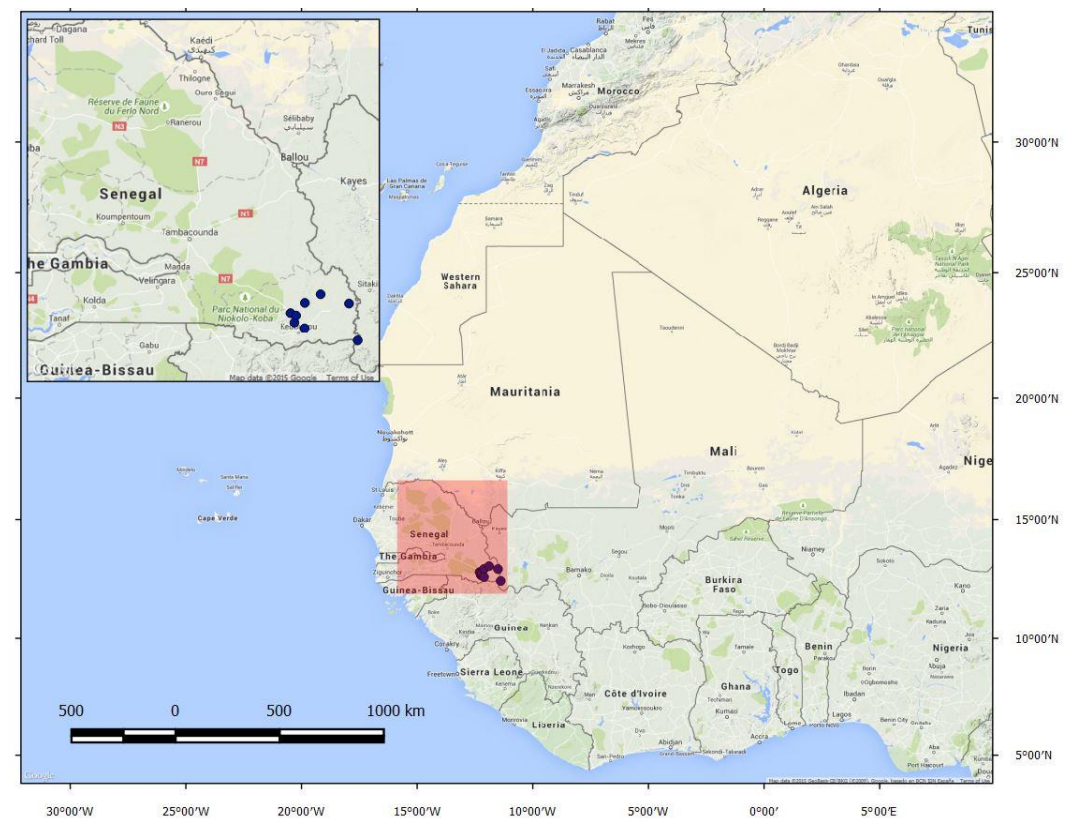


Figure 1: Map of West Africa

In 2013 the population of Senegal was 14.13 million people, and the Gross Domestic Product (GDP) \$15.15 billion USD (World Bank, 2014). The main exports are Petroleum oils, Diphosphorous Pentoxide and phosphoric acid, and gold, with the latter in 2011 valued at \$247.7 million USD in exports (UN COMTRADE SENEGAL, 2011). In 2013 the Gross National Income (GNI) per capita was \$1070 USD, and the Purchasing Power Parity (PPP) per household was \$1910 USD. The agricultural sector is considered a key driver of economic development in the country, with approximately 60% of the rural population working in agriculture; yet, much of this population suffers from acute poverty (World Bank, 2013).

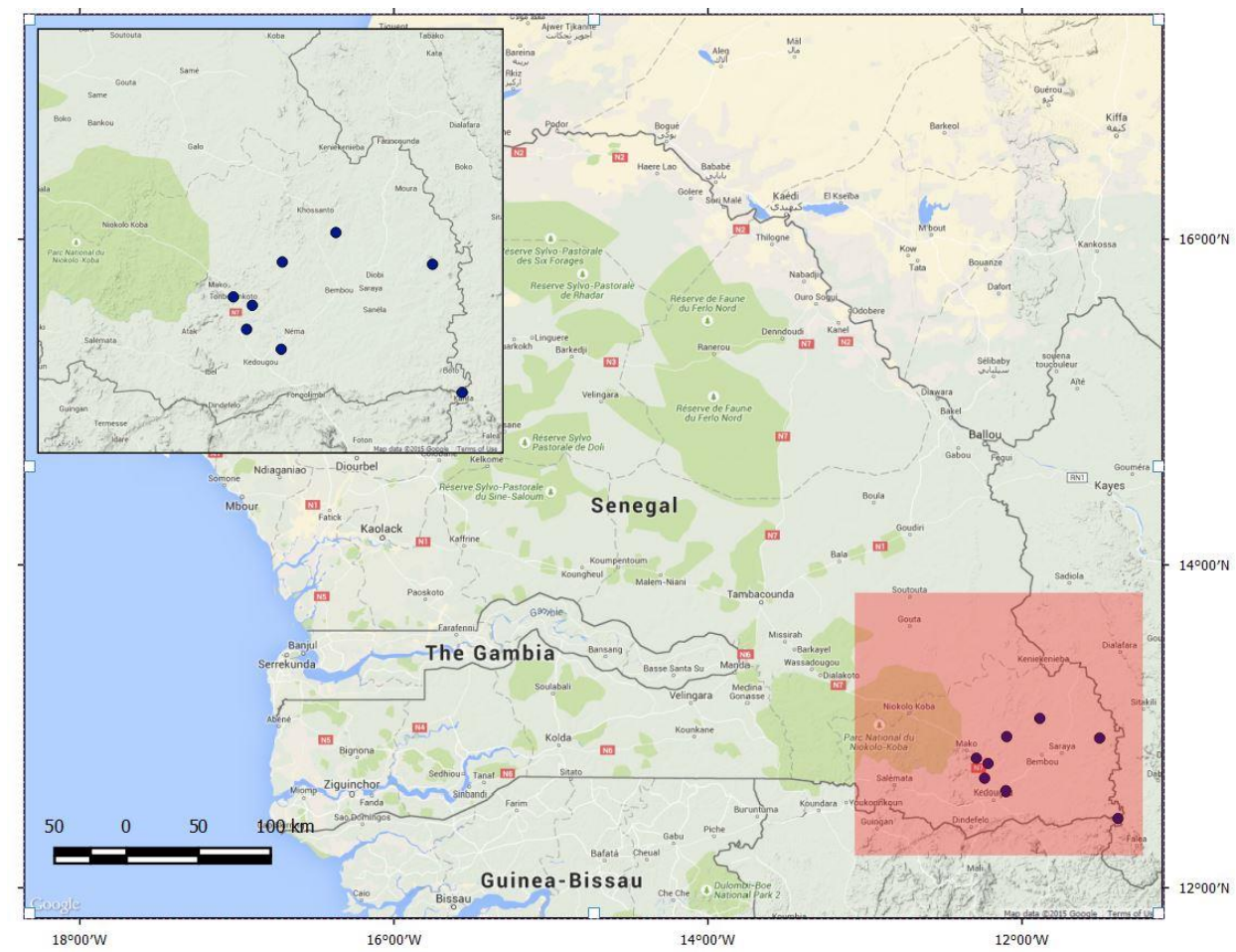


Figure 2: Map of Senegal - Kedougou Region

ASGM has been an ongoing activity in Senegal for at least the last 50 years. Through previous work of the author through the Artisanal Gold Council², it is known to be concentrated along the Malian/Guinean border in the South-East corner of the country, in the region of Kedougou, which falls within the Birimian Greenstone Gold Belt. This region of Senegal is considered one of the poorest of the country, with official statistics placing more than 70% of the 151,000 people below the poverty line (Agence National de la Statistique et de la Démographie ANSD, 2013).

² The Artisanal Gold Council (AGC) is a not for profit organization dedicated to improving the livelihoods, environment and health of artisanal and small-scale gold miners in the developing world.

The majority of inhabitants in this area are believed to be relying on subsistence agriculture and ASGM as livelihoods. According to a 2008 study, ASGM in Senegal was estimated to employ between 30,000-50,000 people directly, on 55 sites, producing approximately 1 tonne of gold per year, and 61% of the sector was believed to be composed of Senegalese, 28% Guinean, and 13% Malian (UNIDO 2010).

1.3.1 Positionality

Senegal was selected as a case study for a variety of reasons including its geographically small ASGM area, its similarity to other ASGM sectors in Africa, and because of previous relations with local actors built by the author prior to carrying out this study. The small geographic area enabled ease of transportation and other logistics in what is a very remote and under-developed area, and the similarity to other ASGM sectors in Africa enable the findings and recommendations to be more easily generalizable to the continent. Work carried out by the researcher in Senegal and other West African countries between the years 2012-2014 through the Artisanal Gold Council, enabled prior connections to be built with local actors and ASGM communities, further facilitating the ease of implementing this study. This prior experience in the region allowed the author to build the required level of knowledge and understanding needed to meaningfully engage with miners in Senegal, and it also allowed the author to make an informed comparison, in consultation with other experts, on the appropriateness of Senegal as a case study for research of this nature.

1.4 Review of Literature

1.4.1 Socio-Economic Significance of ASGM

The body of literature related to the socio-economic significance of ASGM to rural development policy remains relatively limited in comparison to that of other traditional rural sectors, particularly agriculture. However the increasing recognition of ASGM's contribution to rural livelihood portfolios - the suite of activities that generate household income (Niehof, 2004) - is beginning to provide an illustration of ASGM as a vital component of Sub-Saharan Africa's rural economy. With the price of gold hovering at approximately \$1200 USD per troy ounce at the time of this study, this relatively accessible and pervasive resource has been, and will remain, an important source of income for rural Africa's poor, and one that can often lift households above the poverty line and strengthen the position of rural inhabitants, including those also involved in agriculture.

ASGM and agriculture

Rural livelihood diversification is an important strategy used by households to decrease their vulnerability and maintain a sustainable livelihood (Niehof, 2004), and ASGM has progressively become a larger part of diversified household portfolios. Agriculture has for a long time been considered the predominant driver of rural economic growth and development in the developing world, and many countries in Sub-Saharan Africa continue to focus development plans and resources on growing the agricultural sector (Hilson & Garforth, 2012; Okoh & Hilson, 2011). This development policy focus is based on the understanding that agriculture plays a vital role in rural household and national economics, but as Hilson and Garforth (2012) point out, this understanding is often premised on a misinterpretation of data based on the contribution of

agriculture to GDP, which does not directly correspond to or provide a complete picture of a household's quality of life or level of agricultural capacity. From a macroeconomic perspective that is based on the GDP, it is easy to see how agriculture is considered the most important opportunity for ending poverty in Sub-Saharan Africa, as more than one third of the GDP and 65% of the labour force comes from agricultural activities (World Bank, 2014). However such macro statistics are often misinterpreted as full-time paid employment in agriculture, when on the contrary the majority of farmers are now relying on non-farm activities as their main source of income (Kamlongera & Hilson, 2011), as well as producing less and engaging in mainly subsistence farming (Sarah, 2012). Simply put, agricultural incomes alone are not sufficient for rural populations, the majority of which in Senegal remain in a state of acute poverty (World Bank, 2013)

Today, de-agrarianization and diversification are playing an ever more important role in rural household economics in Sub-Saharan Africa (Maconachie, 2011). Estimates from more than a decade ago account for between 40-45% of average household incomes in the region coming from non-farm incomes (Barrett, Reardon, & Webb, 2001), and this trend has likely grown since then as small-holder farming in Sub-Saharan Africa has become more competitive and less able to provide for rural households (Hilson & Garforth, 2012), and as technology has lowered the real prices of agricultural commodities (Wye Group, 2011). Previous studies distinguish between farm and non-farm income sources; however they clearly overlook ASGM and its significance. This oversight is the result of a lack of information on ASGM before just a few years ago, and the lack of consideration of ASGM as a significant non-farm rural livelihood. The omission of ASGM from previous studies on rural non-farm income diversification is evidenced in the fact

that non-farm earnings were considered to be unequally distributed to those with the most agricultural assets and incomes, which, it was believed, impeded the upward mobility of marginalized (impoverished and low or non-educated) populations (Abdulai & CroleRees, 2001; Barrett, Reardon, & Webb, 2001). However, ASGM is a low-capital, entry level livelihood that is accessible to the most impoverished and uneducated populations, many of which are typically subsistence farmers (Hilson & Garforth, 2012). Therefore, past conclusions about the unequal distribution of non-farm incomes may be wrong, as ASGM provides an opportunity for the poorest and most marginalized of agricultural workers to diversify their incomes and become upwardly mobile.

Research, mainly over the last five years, has begun to illustrate the important economic connection between ASGM and agriculture. The first connection is an indirect market driven one, where agriculture and mining are complementary markets. Whereas small-holder farmers require improved access to agricultural markets to raise their farm productivity and living standards (Sarah, 2012), mining areas inversely increase the demand for agricultural products that can be satisfied through local production. The same correlation can be drawn between ASGM and agriculture, particularly with the high requirement for food in most places where ASGM takes place. In fact, Cartier and Bürge (2011) argue that agriculture and mining are somewhat of a perfect combination that create a robust and tightly sealed local rural economy, where local miners, traders, and farmers all interact, allowing for beneficial prices for agricultural producers, and creating links between miners, farmers, and traders. In areas of Ghana, ASGM is known to have contributed to vibrant economies that have enabled farmers to fetch better and fair prices for their produce, as they are able to sell locally to miners and to those

earning decent wages from the secondary ASGM economy (Okoh & Hilson, 2011). Godoy (1984) also shows how in rural Bolivia, agricultural intensification occurred in the highlands in response to the growth in small-scale mining activities and the market that was created by it. Additionally in Sierra Leone, research shows that agriculture in mining areas is supported and in fact bolstered by dependents of mining buying produce from local farmers (Maconachie, 2011). In most rural areas where ASGM takes place, secondary economies are created and agricultural markets thrive.

The second economic connection between ASGM and agriculture is one of livelihood diversification, in which the two are complementary activities. This diversification assists rural households in attaining sustainable livelihoods - those that enable them to cope with and recover from hardship and shock (Maconachie, 2011). Households involved solely in agriculture are less able to sustain themselves at adequate and dignified levels (Barrett et al., 2001; Cartier & Bürge, 2011; Okoh & Hilson, 2011). Between 1980 and 2003, the world price of agricultural raw materials reduced by 60%, and under structural adjustment programs, developing country governments re-shifted their focus from staple crops to large cash-crops that provide the exports desired by developed countries (Hilson & Garforth, 2012). Concurrently, subsidized staple products from developed countries have saturated poor country markets, making the market too cheap for small-holder farmers to compete and earn. In Sierra Leone for example, some cases of cost-income ratios on agricultural production are as low as 1:2, or in the worst cases 2:1 (Cartier & Bürge, 2011). Studies in Mali show that at the end of the dry season, in July, August and September, more than 50% of families lack sufficient food to support themselves (Teschner, 2014). Kamlongera (2011) concludes from his studies in rural Malawi that those localities where

households have diversified income portfolios that include ASGM, families are better able to combat poverty. Hilson (2010) also asserts that it is almost always this inability of farming to sustain people and the resulting “agricultural poverty” that leads them to become involved in ASGM, although, as will be shown in the present study, decisions to diversify into ASGM can be more calculated than simple desperation.

The supplementary income generated from ASGM often allows rural inhabitants to continue as farmers, as they otherwise would not gain enough to stay engaged in this activity (Jónsson & Fold, 2011). For example, evidence now points toward ASGM supporting agriculture by generating finances for agricultural households to buy fertilisers and herbicides that are no longer subsidised by the state in Ghana (Okoh & Hilson, 2011). In Sierra Leone, women built agricultural networks and financed the creation of agricultural businesses with the money that they made from gold panning, rebuilding trade networks after the war and contributing to formalizing the sector (Maconachie, 2011). Thus, although those involved in mining are usually involved out of economic necessity, and not just to get rich quick as is often suggested (Hilson & Garforth, 2012), ASGM has now become a part of an integrated economic system that complements agriculture (Teschner, 2014). In many ways ASGM can be considered a positive coping strategy for agricultural based households, as they can avoid weakening their present or future position and avoid limiting their livelihood options by not selling off their productive assets, which, studies show, households often do during times of distress, and which can significantly weaken their economic position and sustainable livelihood (Arachchi, 1998).

ASGM and customary authority

The interaction between ASGM and customary land title is highly important for understanding the governance and organization of the sector, which is directly related to the development of effective policies; yet little research has been done to date on this topic. As of 2003, it was estimated that up to 90% of land in Sub-Saharan Africa was held under communal or customary tenure (Chimhowu & Woodhouse, 2006). This means that there exists no formal documentation of rights or title, and, in West Africa particularly, only 2-3% of the land is held by written title (Toulmin, 2008). This is one of the main reasons why ASGM is so easily able to operate - because mineral-rich lands are still administered by customary authorities and therefore, individuals do not need to purchase land or obtain permits to gain access (Nyame & Blocher, 2010). This, in addition to the low-capital start up, and the relatively low level of skill required for ASGM, makes it simple for individuals or groups to begin mining almost anywhere, and essentially means that while mineral rights remain vested in the state *de jure*; they are most often *de facto* controlled by customary authorities.

Customary authority to land is often considered a local, grassroots institution that ensures equitable and secure access to resources for the poor (Chimhowu & Woodhouse, 2006). There is also often a ‘royalty’ or rent paid by miners to customary authorities, as evidenced in Ghana, Senegal, Mali, and Burkina Faso, through observations by the author (unpublished) in the years leading up to this study. Customary land tenure systems in Africa are governed by local leaders - often village chiefs – who grant claims and regulate land transfers (Besley, 1995). In ASGM, customary authority over resources has evolved to meet specific local conditions. In Senegal and Mali, the *Tomboulouma* system, as described below, is the most direct manifestation of customary authority for ASGM (Teschner, 2014). Charged by the traditional village authority

with refereeing disputes, maintaining security, organizing, and collecting taxes on ASGM sites for the village, the *Tomboulouma* administer ASGM in the absence of government support for the sector. Just as customary authority has for millennia governed subsistence and small-holder agricultural in Sub-Saharan Africa; it does so today for ASGM via the *Tomboulouma* in Senegal.

ASGM today is often negatively associated with rural migration, with government officials and other development practitioners often pointing toward the fact that mobility amongst miners and the nature of so-called ‘rush sites’ make formalization and the associated improved practices highly complicated (unpublished field observations). Yet, this perceived chaotic migration is actually a derivative of traditional migration patterns in Sub-Saharan Africa, where customary land rights holders rent and sharecrop with strangers, often fueling the growth of land markets (Chimhowu & Woodhouse, 2006). This comparison is an important one, as it illustrates the similarities and connections between ASGM and traditional rural agrarian practices and livelihoods. Nyambe and Blocher (2010) argue, for example, that customary land tenure practices play an important role in the proliferation of ASGM activity in Ghana, and there is strong evidence of this also being the case in Senegal, Mali and various other contexts in both Sub-Saharan Africa and Latin America, as observed by the author through previous field work (unpublished).

While ASGM has been largely neglected as an economic sector in rural development policy discussions, its impact and significance are becoming increasingly recognized. A comprehensive understanding of the contributions of ASGM to rural populations, the economic relationships between ASGM and traditional agrarian practices, and the organizational role of customary land

title, are all important for the development of policies aimed at addressing improvements to the ASGM sector. This study intends to contribute to this small but growing body of literature in large part through building a methodology from which important baseline information about mercury use can be gathered, including information for the purposes of NAPs under the *Minamata Convention on Mercury*.

1.4.2 Estimating mercury use in ASGM

The Minamata Convention on Mercury requires governments of countries with significant ASGM sectors to develop National Action Plans for the sector which include, among other activities, carrying out baseline ASGM and mercury inventories (Minamata Convention on Mercury, 2013). The current global estimate for mercury use in ASGM utilizes estimates of mercury use at the national level that vary in degrees of certainty from $\pm 100\%$ to $\pm 30\%$ (AMAP/UNEP, 2013), with the more confident estimates being anchored in more than just anecdotal information. The national estimates come from a triangulation and extrapolation of the available data for a given country, including direct field evidence, official trade data, and a variety of secondary sources (Telmer & Veiga, 2009; AMAP/UNEP, 2013). Direct field data and various sources of independent evidence are the basis for good estimates that can be most confidently extrapolated, but as evidenced by this literature review, there is very little of this high quality information globally, and the high levels of informality in ASGM, as discussed above, create inherent limitations to any methodology that aims to quantify this sector. The following sections will provide an overview of global and national estimates and extrapolation methods, followed by an examination of field methods used to date.

Global estimates

One of the earliest global estimates for mercury use in ASGM was established by Lacerda (1997), in which he estimates approximately 460 tonnes/year released. Despite this and other documented reports of intensive mercury use in gold mining throughout the 1980s and 1990s (Lacerda 1997; Sznoppek & Goonan, 2000; Hylander & Meili, 2003), as well as a 1999 *International Labour Organization* report (1999) estimating some 13 million artisanal and small-scale miners globally, several global estimates for emissions of mercury from all anthropogenic sources for the years, 1988, 1995 and 2000 remarkably do not even consider ASGM mercury use specifically in their calculations (Nriagu & Pacyna, 1988; Pacyna & Pacyna, 2002; Pacyna et al., 2006). This highlights not only the uncertainty involved in mercury use estimates in ASGM, but also the lack of recognition of ASGM as a substantial sector and contributor to emissions in earlier times, just as it has not been recognized as a significant rural livelihood. Today, in part due to the increased awareness of ASGM that has been raised predominantly by NGOs through the negotiations of the Minamata Convention, information on ASGM has been increasing and improved global estimates have been made over the last ten years. Lacerda (2003) estimated approximately 450 tonnes/year of mercury used in ASGM globally. A 2005 estimate of global atmospheric emissions was made of 350 tonnes/year (UNEP, 2008). Then in 2009, an estimate was made of approximately 1000 tonnes/year of mercury use and release from ASGM (Telmer & Veiga, 2009). The most updated estimate of mercury use in ASGM comes from Telmer in *AMAP/UNEP* (2013) and *UNEP* (2013), and measures approximately 1600 tonnes of which about 45% is suggested to be directly emitted to the atmosphere, with the rest released to land and water. All of these estimates to date rely mainly on an extrapolation of varying degrees of

quantitative information, ranging from anecdotal to peer-reviewed research. The quality of information which informs these estimates is discussed below.

Rises in the price of gold typically increase the numbers of people involved in ASGM (Hylander & Meili, 2003), and inferentially the amount of mercury being used. The period between 1972 and 1987 when the price of gold rose from \$58.16 oz.tr to \$446.56 oz.tr is often referred to as the “second gold-rush” (Lacerda, 1997), with the first being the historic gold-rushes of the 19th century, as documented by Featherling (1997). From 1999 to 2011, the price of gold again rose substantially, which, alongside increasing rural poverty, has almost certainly led to the increase of artisanal and small-scale gold miners (UNEP, 2013). However, the substantial rise in global estimates of mercury use in ASGM is not attributed solely to increased ASGM activity, but is largely the result of improved reporting (AMAP/UNEP, 2013). For instance, in 2003 there were national estimates of mercury use in ASGM, with ranging levels of certainty, from 17 countries globally (Lacerda, 2003). In the global estimate by Telmer and Veiga (2009), 2 countries had relatively good information, 7 countries reasonable information, and 14 countries some but poor information³, for a total of 23 countries contributing to the estimate. The most recent global estimate includes good information from 10 countries, reasonable information from 16 countries, and some but poor information from 20 countries for a total of 46 countries with some level of information on mercury use in ASGM (AMAP/UNEP, 2013). Much of the strong information in the latter estimate came from countries that were, in earlier studies, only given conservative minimum mercury use based on a presence/absence test (0.3 tonnes/year, \pm 100% error). It can therefore be inferred that the rise in the reported mercury use, particularly in countries previously

³ In this context, good information means several direct field studies on the use of mercury in ASGM, reasonable means some quantitative estimates of mercury use in ASGM, and poor information means direct or indirect anecdotal evidence (Telmer & Veiga, 2009)

designated as having only ‘presence’, is strongly related to the increase in the amount of reliable data. The current study aims to contribute to this rise in reliable data, while also providing a methodology that can both increase the levels of confidence in the estimates, and be more broadly used to further increase the number of countries with reliable estimates.

Site specific estimates

In the latest estimate by Telmer in *AMAP/UNEP* (2013 p.98), it is stated that the following fundamental questions must be answered in order to make annual mercury use estimates on a specific ASGM site:

“Is mercury used? What are the practices in use? (Consider: whole ore amalgamation? Concentrate amalgamation? Mercury activation?); How much mercury is used per unit gold? – Grams of mercury lost per grams of gold produced? (Consider: do miners discard used mercury? Do the miners use retorts or recycle mercury?); How much gold do miners produce per year?; What is the total number of miners?”

Applying a mercury/gold (Hg:Au) ratio to gold production figures has been the main methodology utilized for estimating site specific mercury use in ASGM for the last 20 years, and can be seen in use as early as 1988 (Pfeiffer et al., 1989). This is largely because gold has a well-known monetary value that can be assessed, whereas mercury often represents an expense or is accessed for free and therefore the amount used by miners is often not recorded or considered. Determining the mercury/gold ratio involves using a scale to measure mercury before and after amalgamation, and then measuring the amalgam before and the sponge gold after it is burned,

providing the amount of mercury lost for the amount of gold produced (Velásquez-López, Veiga, & Hall, 2010; Cordy et al., 2011).

$$Hg:Au = (Hgt - Hge) \div Aus$$

Equation 1

In various studies on mercury in ASGM, average Hg:Au ratios have been applied to quantify mercury releases in ASGM operations that use the same production methods in similar geographic areas (e.g., Van Straaten, 2000; Telmer & Stapper, 2007; Telmer & Veiga, 2009; Cordy et al., 2011), however uncertainties still exist. Hg:Au ratios from whole-ore amalgamation⁴ have been known to vary between 3 and 50 parts mercury to 1 part gold, and concentrate amalgamation⁵ ratios are also known to vary based on a number of variables (Lacerda, 2003; Telmer & Veiga, 2009). For example if gold is very coarse (>mm sized grains) the Hg:Au ratio can be 0.5:1 rather than the typical 1.3:1 for concentrate amalgamation. Measuring and understanding different Hg:Au ratios is an important part of estimating mercury use in ASGM. However, application of Hg:Au ratios is only helpful if gold production data exists or can be confidently produced.

⁴ Whole-ore amalgamation is mercury intensive and means that mercury is brought into contact with 100% of the ore before it has gone through any type of concentration process.

⁵ Concentration amalgamation means that ore has already been concentrated, reducing the mass of material brought into contact with mercury is added and so is much less mercury intensive

Estimating gold production for ASGM

Understanding the governance systems, the composition of production groups, production methods, and the shape of the gold supply chain are all important pieces of information that contribute to determining gold production and miner populations. The latter – the number of miners – is key for scaling up gold production to single and multiple site levels, and ultimately to national level. Several informal sites in West Africa have been documented as having between five or six thousand people, but head counts are nearly impossible, particularly on new sites where new miners are coming and going (Persaud, 2013). Often simply asking how much gold an individual or a site is producing will result in inaccurate numbers (exaggerated or minimized), which is common in interview methods in rural settings (Chambers, 1994). Feige (1990), points out that such approaches to informal economy estimations often produce compromised data, as sensitive questions (such as the use of mercury or gold production) will often produce false or non-responses, which can be revealing about the level of trust or fear of miners, but require deeper analysis to make quantitative conclusions regarding mercury use. A method used by Telmer (AMAP/UNEP, 2013) in Burkina Faso was to measure the average composition of groups working mine shafts, determine the average production of these groups, and then determine the amount of mine shafts, in order to triangulate this data into a site specific gold production and miner population estimate. The most reliable way of determining the number of active mine shafts on a site is to carry out a physical count alongside a local key-informant.

Household and miner expenditure estimates and the cost of living on a mine site are independent lines of evidence to confirm and strengthen gold production estimates. Inquiries can be made into the cost of a basket of basic needs on a mine site, such as water, food, shelter, gasoline,

cigarettes, vehicles, appliances, and even the quality of someone's shelter (Crispin, 2003; Heemskerk, 2005). This allows a budget per person to be constructed that provides an estimate of the magnitude of the local economy. Dividing this number by a suitable divisor such as the average number of dependents per miner, allows an estimate of the amount of gold production needed to support the site. This can be compared to the direct estimate of gold production made from the number of miners and operations and the difference can then be reconciled through further dialogue and investigation with key informants and local experts to produce a reasonably robust estimate of gold production for a site. Combining this with measured Hg:Au ratios can result in robust site-specific mercury use estimates, and such estimates are further strengthened when they originate from at least two lines of independent evidence, such as gold production estimates, and local economy scale estimates, both of which are described below.

National level estimates

Scaling up estimates of Hg use to regional or national levels – which will be needed for National Action Plans under the Minamata Convention - requires an estimate of the magnitude of ASGM activity at those scales. This can be derived from government surveys or, as demonstrated in the present study, can be determined from a well-designed field survey that investigates a number of sites in detail and performs a rapid assessment of many others and then uses extrapolation to upscale. While some countries have organized administrative bodies specifically tasked to monitor ASGM activities and production (Lacerda, 2003), it is generally accepted today that the informality of the sector, as described in section 1.2.4, can make official statistics inaccurate. For a national estimate to be considered strong there needs to be enough direct evidence to give

confidence to extrapolations. This involves substantial field data, particularly when the sector is largely informal.

In place of often uncertain extrapolation methods, some experts have called for national wide censuses of ASGM (Hilson & Maponga, 2004). To date, there has been few, if any, reliable national level ASGM censuses carried out. Perhaps the closest was a study in 1998 in Papua New Guinea under an AusAid program where a country wide informal survey was implemented in most of the known mining areas of the country. The information that was gathered resulted in a tripling of the estimation of the miner population, from approximately 20,000 to some 60,000 people or more (Crispin, 2003). However, this information is now more than a decade old. More recently the Belgian *International Peace Information Service* collaborated with the Democratic Republic of Congo's *Mining Cadastre* to map more than 800 mine sites using GPS devices and questionnaires, revealing important information related to conflict minerals (Spittaels & Hilgert, 2013), but no information on mercury use. While the type of socio-economic information gathered from these kinds of studies may be valuable, it is not clear that national level censuses are the most practical or affordable method of estimating mercury use in ASGM. Surveys provide some statistical data, but they often lack the type of engagement and understanding of ASGM required to form a foundation upon which assistance to the sector can be built. Further, government mining or geological agencies in the developing countries where ASGM takes place often lack the resources and knowledge about effective approaches to actively engage the sector, particularly when there is a lack of security and/or infrastructure (Hilson, 2005), making estimating or monitoring difficult. Focused studies carried out by experts with knowledge of the sector, that are then extrapolated to the national level can often be done faster and cheaper than

national level censuses, and can provide a reasonable estimate of national mercury use. Knowledge of the sector and the processes in place help to build trust and understanding, enable clear and concise information to be shared. An example of this might be one car mechanic talking to another car mechanic, where problems can be talked through without falsifications or simplifications, and a common ground of knowledge exists.

A few researchers have attempted macro-level approaches to estimate or at least corroborate mercury use estimates in ASGM including analyses of trade data of mercury and gold. Both Lacerda (2003) and Cordy et al. (2011) used UN COMTRADE data to highlight the significant rise in mercury imports throughout the 1990's and the 2000's in countries in Latin America – corroborating their increased estimates of mercury use in ASGM derived from field studies. Telmer and Veiga (2009) also conducted a thorough analysis of mercury trade in COMTRADE databases in order to reveal the deficiencies in using such an approach. They found that 16 countries with known mercury-using ASGM activity do not report any mercury or gold transactions whatsoever, and 28 countries with known ASGM activity do not report any gold exports – including Indonesia and the Philippines which are considered to have two of the largest ASGM sectors (Veiga et al., 2006). Such macro-level studies reveal broad trends and illustrate weaknesses in what we know about mercury and gold trade, but due to the varying quality and frequency of reporting, such data has not yet provided specific information on a country by country basis.

Developments in the use of satellite imagery to confirm or further extrapolate field data from ASGM sites or regions can be used in some cases. This approach has been minimally used, but

shows promise as another independent methodological approach to increasing our understanding of spatial and temporal trends in ASGM (McLoughlin & Chirico, 2013; Lobo et al., 2014). Telmer et al. (2006) were able to quantify the magnitude of sediment and mercury mobilized by alluvial ASGM in the Tapajos basin of Brazil. Looking at ASGM regions in Indonesia and Brazil, Telmer and Stapper (2007) used remote sensing and GIS to “build a database that would span spatial scales and times greater than possible through field work alone” (2007, p.2). Specifically, they used aerial photography and satellite imagery to extrapolate site specific data they collected in the field to determine the scale and spread of ASGM in particular regions, and thereby make quantitative estimates of mercury use in the sector. A similar approach was taken by Asner et al. (2013) in order to measure the impact of ASGM in the Peruvian amazon. There, they used the Carnegie Landsat Analysis System-lite (CLASlite) to detect fine-scale disturbances in forest cover, allowing them to identify small-scale clandestine operations that are extremely difficult to access on the ground (Asner et al., 2013). These methods however, were applied to alluvial ASGM where vast areas of forest and floodplain are dramatically altered making the scars and magnitude of mining highly visible to aerial and satellite imagery. Primary hard rock mining, the majority of which is treated in the present research, presents much more difficult challenges for this approach as it is small in areal extent and deep quantities of materials are related to the depth and extent of invisible underground structures. However, there have been other efforts attempting to look at this type of hard-rock ASGM as well. In Mali for example, McLoughlin and Chirico (2013) utilized LandScan data along with field questionnaires in order to draw spatial relationships between populated areas and mine sites, creating an estimate of the mining population in the region. Imagery based approaches can be important tools for ASGM

inventory methodologies, but they should be accompanied by field-based work in order to provide a holistic understanding of the sector, as described throughout this thesis.

Although still imperfect, the methodologies to determine mercury use in artisanal and small-scale gold mining are improving, however, various assumptions still remain, and field methodologies that provide robust site-specific estimates of ASGM and its mercury use continue to be the most important sources of information for national and global extrapolation. One factor that may be driving improved estimates is that more attention is now being given to ASGM due to the clear recognition by the global community that it is the main source of anthropogenic mercury pollution; and that it is an important rural livelihood opportunity (UNEP, 2013). More information is beginning to become available as a result of a greater number of field studies (e.g., Telmer & Stapper, 2007; Velásquez-López et al., 2010; Cordy et al., 2011; Esquivel and Agredo, 2011). However, this type of work needs to further increase and methodologies at the site level need to be further improved to increase our understanding of the sector and its mercury emissions, and also to ensure that policy is informed by field knowledge.

In general, robust site specific estimates for mercury use in ASGM can only be completed and supported by direct observation alongside interviews or surveys by well trained personnel. An in-depth study of the ASGM sectors of Nicaragua and Honduras revealed that the majority of usable information contributing to estimates came from informal interviews (Esquivel & Agredo, 2011). Other experts have highlighted the importance of informal interviews or surveys that are carried out only after a trusting relationship has been built, as the key to gathering accurate information (e.g., Lahiri-dutt, 2004; Heemskerk, 2005; Hilson, 2005; AMAP/UNEP, 2013;

Persaud, 2013). This underlines the need for finding new ways of building trust with miners and perhaps involving them in the mapping process. In this context, effective information gathering can most easily be part of the implementation of improvement projects which have clear benefits to miners and communities and therefore establish a relationship through participatory activities where information flows in an easily understood quid pro quo relationship. Policies affect data gathering, and the perception of wrongdoing by any stakeholder is a major barrier to the sharing of information. Based on the paucity of existing data today, it is clear that the quality of surveys and the development of interview techniques for the ASGM sector remain underdeveloped, and more effort is required to improve techniques and build a larger and better database.

1.5 Methodology

The research took place over a three week period in May, 2014, during the second half of the mining season in Senegal (January to August), however there was significant prior contact, trust building and familiarity with the mining communities and region before this time, as explained in section 1.3.1. The primary data, including 80 structured interviews with miners, 120 household surveys, physical measurements and counts, observations, and various informal interviews with local experts and key informants, was gathered throughout this three-week period with the assistance of two research assistants. Other information obtained and observations that have contributed to this analysis were carried out by the researcher working directly with mining communities and local experts in Senegal over a period of two years leading up to this study.

The present study employs a mixed-methods methodology (Creswell & Plano Clark, 2007) with a rapid appraisal approach (Beebe, 1995) utilizing the tools of observation, informal and structured interviews, physical measurements, triangulation and secondary data analysis. Mixed-methods research combines qualitative and quantitative approaches in order to provide a better understanding of a research problem than a single approach alone (Creswell & Plano Clark, 2007; Johnson, Onwuegbuzie, & Turner, 2007). Traditional approaches to understanding ASGM and mercury use have largely been focused on the quantitative analysis of mercury use and exposure (e.g., Appleton et al., 1999; Lacerda, 2003; Limbong et al., 2003; Cordy et al., 2011). Such approaches provide little in the form of mercury use estimates, and there has been minimal innovation on other methods for carrying out national inventories of mercury use in ASGM. The statistical requirements of formal surveys are highly impractical in rural or informal conditions where the selection of samples is often limited or where there is often a lack of a sampling frame to begin with (Carruthers & Chambers, 1981). Without accounting for these conditions, survey data alone can result in a highly structured and superficial understanding of the context, particularly because little interaction is carried out with the local community (Theis & Grady, 1991). The present methodology aims to demonstrate that in addition to providing quantitative mercury estimates that can be utilized by countries developing baselines for the National Action Plans under the Minamata Convention, the methods utilized throughout the study provide both quantitative and qualitative environmental and socio-economic understandings of ASGM that can help contribute to more robust policy decisions and interventions in the sector.

The mixed-methods, rapid appraisal methodological approach is appropriate for providing a holistic understanding of the ASGM sector. Rather than relying strictly on statistical

replicability, the rapid appraisal achieves accuracy through a mix of sources, information and techniques (Theis and Grady, 1991), emphasizing the triangulation of mixed methods and data sources at various scales (Fitch, Rhodes, & Stimson, 2000). There is no prescribed list of methods for rapid appraisals precisely because of its flexible application and goal of improvisation to shed the most light possible with the least amount of resources in diverse research areas (Carruthers & Chambers, 1981). For this reason a rapid appraisal approach is highly appropriate for this study, which aims to demonstrate the usefulness of this methodological technique for low resource, developing country governments that require rapid information on the ASGM sector in order to develop action plans on ASGM and mercury use.

The rapid appraisal approach has often been labeled as “quick and dirty” research susceptible to bias, and ‘tourism research’ (Stocking, 1980). However, when executed with careful planning and a reasonable degree of critical reflexivity, it can be quite effective in producing reliable and rapid data for researchers and policy makers. Rapid appraisals have been used in exploratory research, which Manderson and Aaby (1992) assert have formed the basis for complete research reports. Several studies have also shown that when compared with structured, formal surveys, rapid appraisals often produce similar results (e.g., Collinson, 1981; Franzel & Crawford, 1987; Temu & Due, 2000). Further, and for the particular purposes of this study, there is little indication that quantitative and statistical precision is required for the formulation of policy related to mercury use in ASGM. For example, due to limited research and a paucity of data on the sector, Article 7, Annex C of the Minamata Convention was negotiated on the premise of a global estimate of mercury use in the ASGM sector put forward by Telmer in *AMAP/UNEP* (2013), which relied largely on an extrapolation of varying degrees of quality of information, but

which was sufficient for this purpose. This is because the estimate provided a new understanding of the approximate scale and impact of mercury use in ASGM, which allowed for the mobilization of resources to address the problem. Rapid appraisals gather both qualitative and quantitative data that contribute to building an understanding of a site, community or sector often for policy purposes, and therefore high variability and high standard deviation of responses are reasonable, and in fact there need not be an unnecessary and burdensome degree of accuracy (Chambers, 1981). Using a rapid appraisal approach, the primary researcher is directly involved in the data collection and is therefore able to build a more nuanced understanding and more effectively illustrate a picture of the context and issues.

In consideration of the rapid appraisal as a research approach for mercury inventories in ASGM, such a methodology should be part of a *global strategy* for understanding ASGM that over time, as resources become available, can be coupled with other data sets including census data and remote sensing data in order to further triangulate and refine quantitative estimates. This is a strategy proposed by the United Nation's Wye Group which describes a synthesis and integrated survey framework in order to answer important questions about rural agriculture (Wye Group, 2011), and which could easily be applied to ASGM with the right resources. More appropriately, perhaps ASGM could be incorporated into rural surveys and censuses regarding agriculture in order to better understand its scope, combining information gathering resources on these closely inter-related rural sectors. With adequate training, those carrying out such surveys could develop the necessary skills to engage the ASGM sector.

The following chapters provide a two-part study and analysis of ASGM in Senegal, divided into the socio-economic significance of ASGM in Chapter 2, addressing objective (i) – to analyze the socio-economic significance of ASGM and its potential for development in relation to other rural sectors in the developing world, and mercury use estimates for the sector in Chapter 3, addressing objective (ii) – to define and develop a replicable and widely applicable methodology for estimating mercury use in ASGM communities. The inter-related nature of the two will be illustrated throughout, as will the combined methods that are utilized. The methods for each study are detailed at the beginning of each of the two studies.

2 Chapter 2: the Socio-Economic Significance of ASGM

2.1 Introduction

This study aims to build knowledge and understanding of the socio-economic significance of ASGM to the Senegalese rural population, with particular attention to the ASGM sector's relationship with traditional agrarian livelihoods. Understanding the relationship between ASGM and agriculture is particularly important as it expands the ASGM policy conversation beyond the regulatory scope of mineral extraction, and brings it into a more comprehensive discussion concerning general rural development policy for developing countries. Past research into the relationship between artisanal mining and agriculture has focused studies and surveying on farming households (Maconachie, 2011). Such studies illustrate an important connection between small-holder farming and ASGM, but there remain many gaps in approaches to understanding this connection. A different approach has been taken here by focusing on artisanal mining as the primary data source, interviewing and surveying primarily miners and mining community households to understand their involvement in agriculture, not vice versa. Much of the data supporting the present study was derived from the direct field research and methodologies that were used to develop the mercury estimate detailed in the second study of this thesis, as well as household surveys conducted in one ASGM community. The findings detail the socio-economic significance of ASGM to rural populations in Senegal, demonstrating that ASGM enables diversified livelihood portfolios for rural and predominantly agricultural households, and increases incomes for an otherwise predominantly impoverished population. By making these connections, this chapter makes an important contribution to the literature on

international development studies, while also highlighting the importance of holistic, mixed-methods approaches to building a comprehensive understanding of the ASGM sector.

2.2 Research Design

2.2.1 Sampling strategy

This study utilized data gathered throughout the mercury inventory process in Chapter 3, including qualitative information on miners' reasons for being involved in the sector, and quantitative information on numbers of dependents and individual earnings. Additionally, it utilized information obtained through a household survey of 120 households in the community of Bantakho, Kedougou (Figure 3: Community of Bantakho). Using both structured interview results which provide qualitative and quantitative information on miners, along with household survey results which provide information on ASGM community household expenditures and assets, allow for two perspectives on the socio-economic conditions of an ASGM community to be drawn upon. Additionally the study involved an extensive comparative data analysis. Bantakho was chosen as an area of study because of its large size and high degree of organization by local ASGM authorities, which provides a typical example of the way that a community has evolved as a result of ASGM activities. Further, it was chosen because long lasting relations with the community as a result of work leading up to this research made the timely execution of the study more feasible.

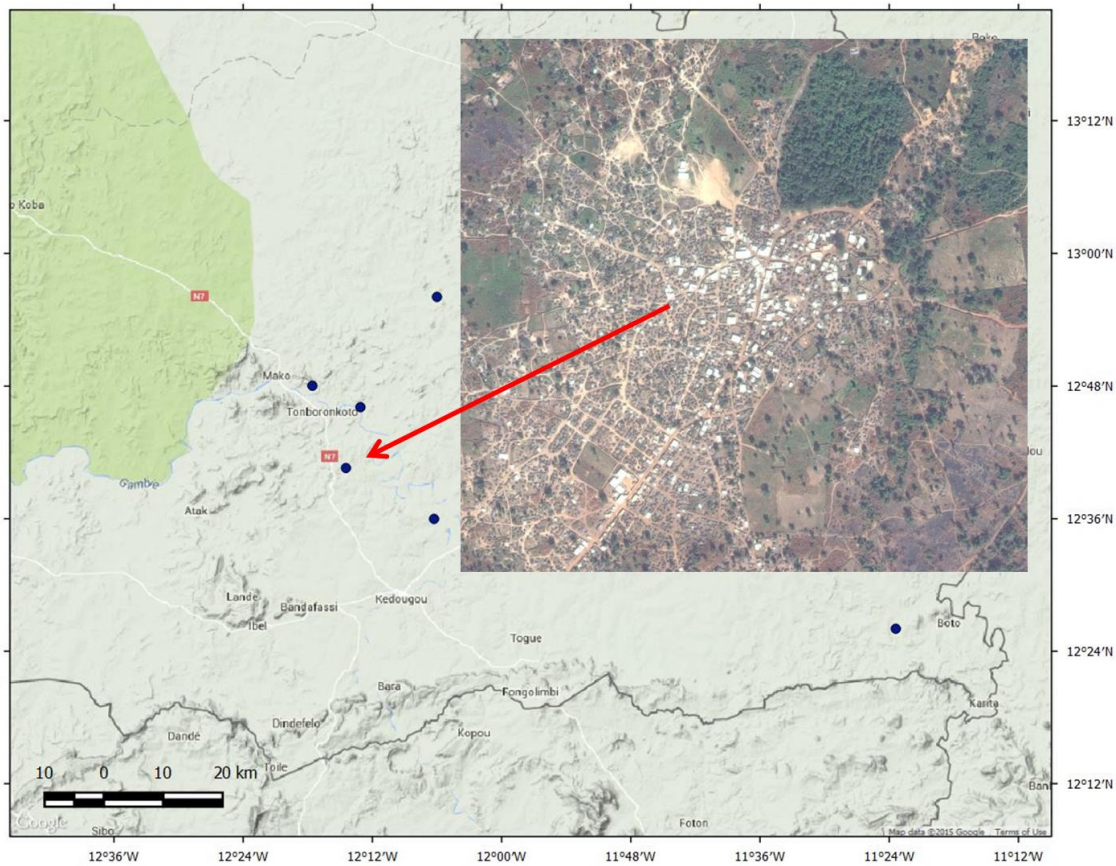


Figure 3: Community of Bantakho, Kedougou, Senegal

The population and size of Bantakho varies throughout the year, rising with the mining season (Nov-Jul) and declining with the rainy season (Aug-Oct). At the time of this study, the population was estimated to be approximately 35,000 people by local leaders. There are large parts of the village that are considered migrant settlements from Guinea, Mali, and Burkina Faso among others, and not a permanent part of the village, but fall within the boundaries of what might be referred to as ‘greater Bantakho’ and which are equally dense and not spatially distinct from the rest of the village. For this reason, the household survey was conducted within eight quadrats of the entire ‘greater Bantakho’ in order to gain the perspective of permanent villagers and migrant settlers alike. The quadrat approach was utilized in order to gain an equal

representation of responses around the entire village, reflecting all ethnic or other dividing enclaves that are typical of large ASGM communities. The entire greater Bantakho was circled on a motorbike with a village leader and key informant, mapping the perimeter as well as the roads and access points, without too much deviation from the perimeter. Using GPS coordinates to measure the area, it was found to be approximately 800,000 m², however accounting for the living areas that were not able to be included within the perimeter due to inaccessibility by motorbike, it was estimated that the village measured approximately 1,000,000 m². The village was then divided into eight approximately equal quadrats of 125,000 m² each, with some deviations from each in order to ensure that there were clear lines of quadrat divisions, namely roads, in order to assist in the survey exercise being carried out by the research team. In each quadrat, 15 household surveys were carried out randomly and opportunistically based on the availability and willingness of household heads to speak with the research team.

2.2.2 Datasets

This study utilized a structured survey method, carried out by the author and a two other researchers who were contracted from a local, community development not-for profit organization, over a three day period, as well as a dataset derived from informal and structured interviews with miners described in Chapter 3. Additionally a secondary data set derived from a desk-based study was used as a part of the discussion, described below.

Table 1: Datasets used in Chapter 2 study

Datasets Used	Origin
Structured household survey data	Household survey conducted as a part of this research in the community of Bantakho
Structured interview data	Structured and informal interviews conducted as a part of this research in the community of Bantakho, described in Chapter 3
Secondary data (discussion)	Desk-based review of relevant statistical and census data for the area of Kedougou and Senegal

The questions within the structured survey aimed to provide an understanding of the socio-economic characteristics of a typical ASGM community, including such factors as daily household expenditures, accumulation of assets, and household demographics. All results included here came from participants that were informed of the nature and purpose of the study, and consented to the use of their answers. The questions were designed specifically for this study and were not based on previous studies, but drew from literature on assessing incomes in ASGM communities and households (Booyesen, van der Berg, Burger, Maltitz, & Rand, 2008; Heemskerk, 2005; McKenzie, 2005). The questions were posed as follows:

- How many people live in this household?
- How many women, men, children (under 16)?
- Does anyone in this household have any cars, motorbikes, houses, cattle, jewelry, farming or mining equipment?
- How much money does this household spend in a typical day?
- How much of your income do you spend on food?

- What are the different types of work that people in this household are engaged in?

The questions that were utilized from the structured interview process included:

- Why do you mine?
- What other work are you involved in?
- How many dependents do you directly support?

These approaches were designed to elicit responses that together, provide insight into the socio-economic significance of ASGM households in the community of Bantakho and the region of Kedougou. Limitations to these questions and non-responses are discussed in section 2.3.

2.2.3 Data Analysis

Responses from the structured surveys were input into a database and analyzed using simple descriptive statistics. The results were cross-analyzed with the dataset derived from the structured interview results, as described in Chapter 3, in order to illustrate the socio-economic significance of ASGM and the connection between local households and ASGM. Further, a desk-based review of secondary data, including the most recent government mandated census and macroeconomic studies for the area by groups such as the World Bank, was carried out in order to provide relevant statistical and demographic data for triangulation and comparison, and to further validate and to extrapolate findings from the field research. This secondary data review allowed for the socio-economic findings resulting from the household surveys and the ASGM inventories to be compared to the wider rural economy, demonstrating its significance as a rural

sector particularly in Senegal. The secondary data analysis reviewed a large body of scholarly and grey literature related to rural livelihoods diversification, household demographics, rural development policy, ASGM, and informality.

2.3 Limitations

It was not the aim of this study or within the scope of the survey methods utilized to gather data statistically generalizable to the entire population of Senegal, but rather to begin to build a stronger qualitative and quantitative understanding of the socio-economic structures and characteristics of ASGM households in Senegal. It is common in rural and particularly informal settings to elicit non-responses to questions regarding income (Chambers, 1994; Heemskerk, 2005). In ASGM, this is further exacerbated by the fact that the majority of respondents are engaged in what is often believed to be an illegal activity. Further, income varies across seasons, sectors, and regions, and so cannot be reliably used without an adequate comprehension of the context. For this reason, an indirect approach to determining household well-being was taken, namely understanding the assets of households and determining their levels of spending.

Of the two separate questions regarding expenditures per household - total spending and food spending - almost all participants were only able to offer data on the daily amount of spending for food. In this context a household can mean several kinds of social arrangements. For example, Ellis (1998) defines a household as a social group that resides in the same place, shares meals, and makes joint decisions regarding resource allocation and income. Niehof (2004) considers a household as not just a living arrangement, but also a sharing of resources and daily

activities. In ASGM communities, such traditional definitions of household do not always apply. For example, several of the households were migrants who were gathered together in Bantakho for mining and do not necessarily represent a ‘family’ or the financial holdings of a ‘family’. One household composed of 6 women responded that each woman in the home owned a house (one each) back home in Guinea, but it would be unrepresentative to assign 6 homes as financial assets to this household. By examining the household therefore, we lose information on consumption of specific items by individual members of the household. This study was therefore limited to an understanding of money spent collectively by the “household” on a typical day on subsistence related items, primarily food, and the survey results do not reflect the daily expenditures of a typical earning miner.

2.4 Results

2.4.1 Household Survey

As anticipated, the results from the household surveys in the village of Bantakho had a high degree of variance between households, and there were several non-responses to certain questions, highlighting again the limitations of structured survey methods in informal rural settings.

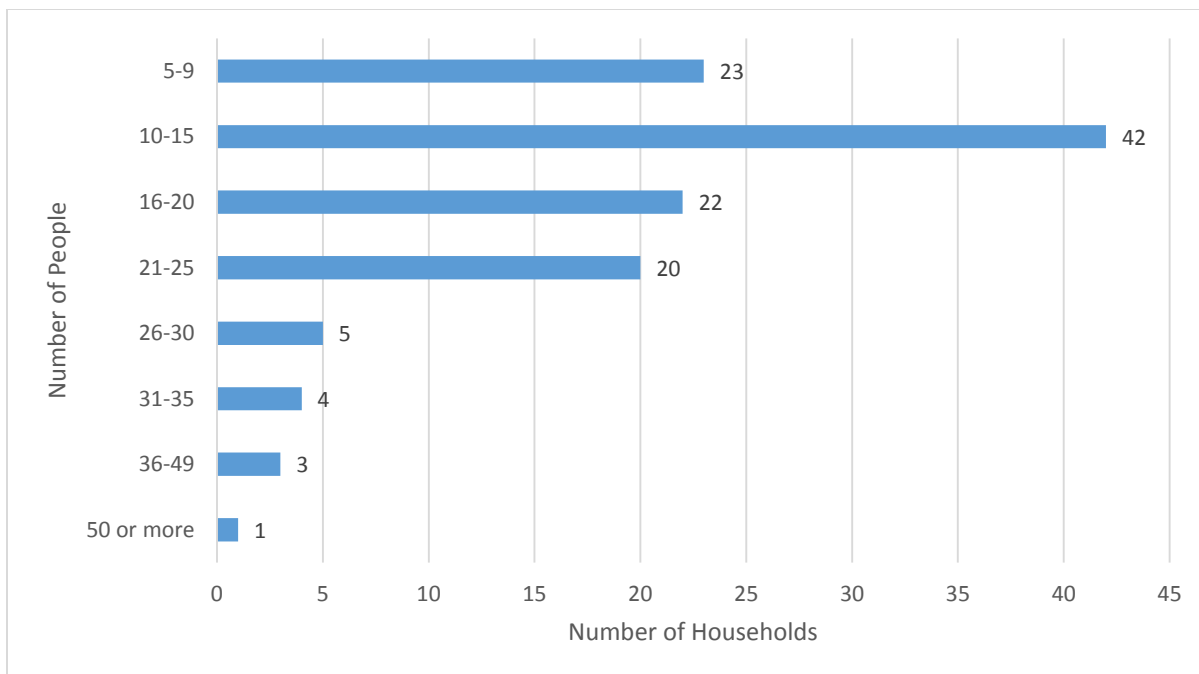


Figure 4: Number of People per Household

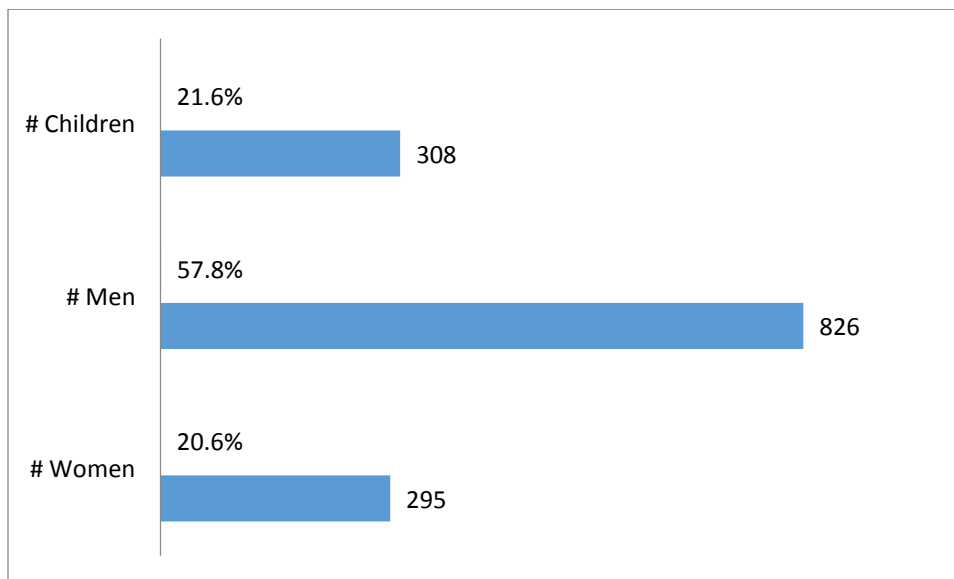


Figure 5: Total # of Men, Women, Children

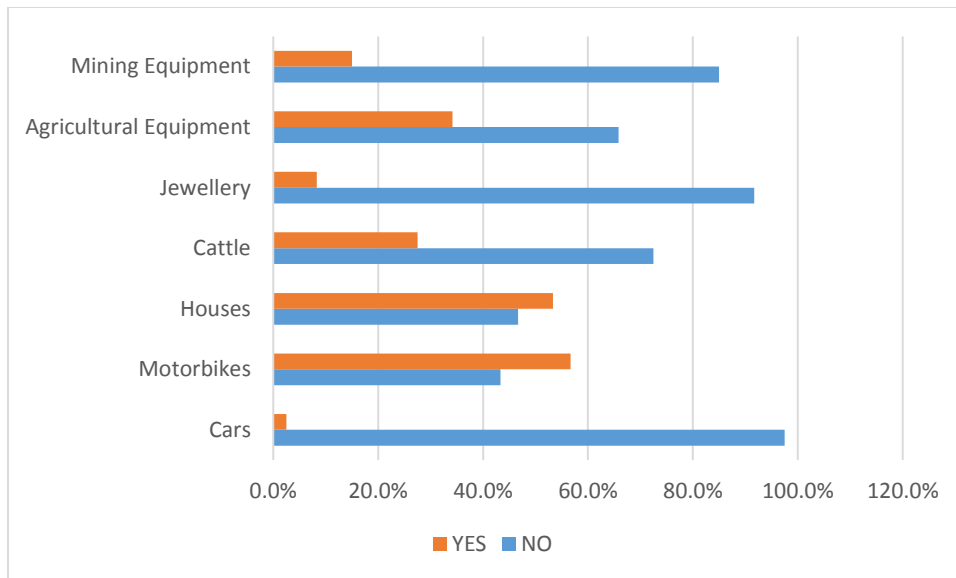


Figure 6: Household Assets

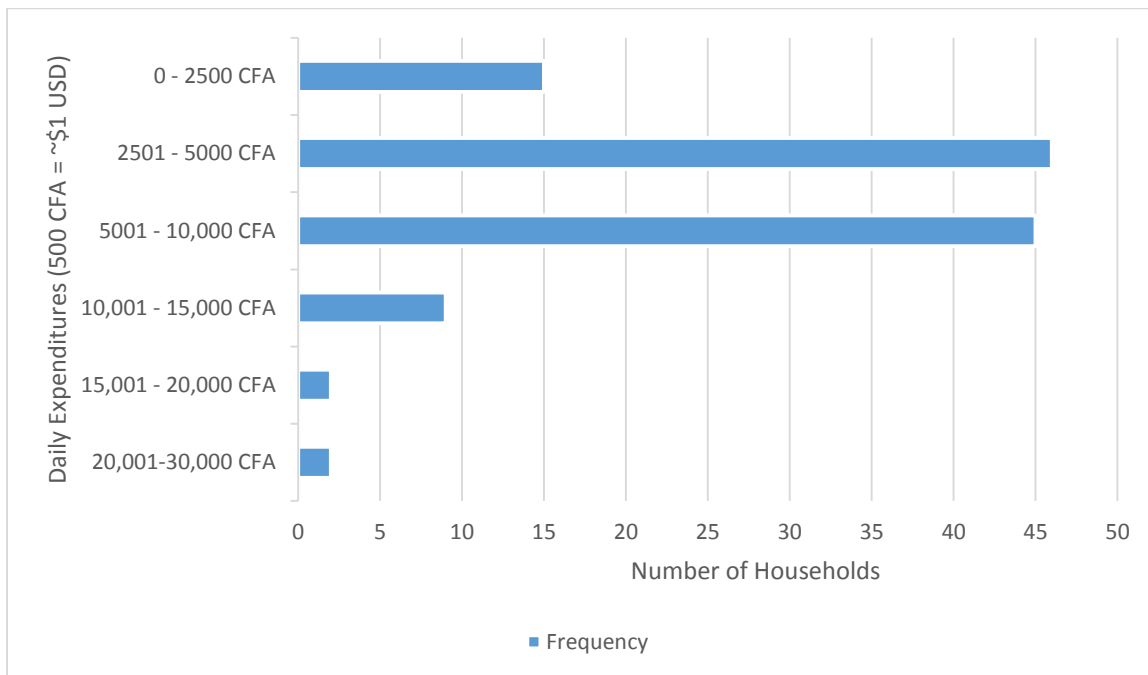


Figure 7: Daily Household Expenditures

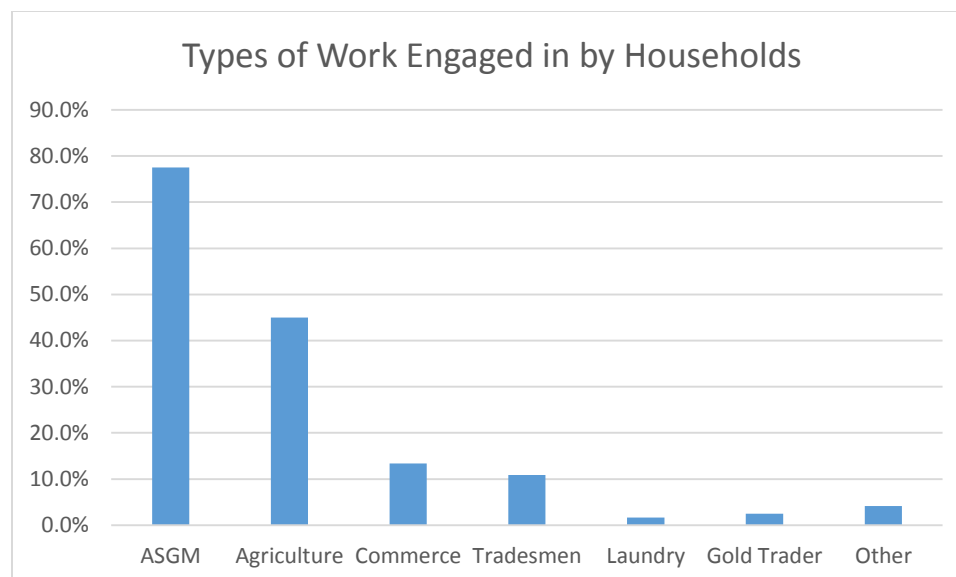


Figure 8: Types of Work Engaged in by Households

With regard to the first question about the number of people per household, among the 120 households surveyed, the average number of economically active members per household was 9 people, with a standard deviation of +/- 51%, and a non-response rate of 12% (Figure 4: Number of People per Household). All members above the age of 16 were considered economically active.

With regard to the question related to assets, although only 3% of respondents owned cars, 57% of households claimed to own at least one motorcycle. Additionally, 53% of respondents claimed to have houses, either in the village or somewhere else. Those that owned houses typically owned just 1 per household, while a few owned more than just one house in different locations outside of the village. Houses were explained to the respondents as being permanent structures of concrete or other material that are more permanent than grass huts. 28% of respondents owned cattle, 34% agricultural equipment, and 15% mining equipment (Figure 6: Household Assets.

Agricultural equipment was included as a “yes” response even for rudimentary, non-mechanized equipment, which was the case for all affirmative responses. Mining equipment was included only if it was mechanized or semi-mechanized equipment, such as a water pump, mill, crusher, detector, etc. Almost all households that included miners had rudimentary mining equipment such as hammers and ropes, but this was not included as affirmative for owning mining equipment. Mechanized mining equipment was an important positive indicator of savings and income, and it was therefore important to distinguish between the two classifications of equipment as there was a variance in responses, whereas, for agricultural equipment, no respondents owned mechanized equipment at all.

With regard to the question on household expenditures, the average daily household expenditure was approximately 6000 CFA, or \$12 USD (Figure 7: Daily Household Expenditures, with a standard deviation of 55% and a non-response rate of 2.5%. Given the average number of economically active members of the household, an average daily expenditure per person was calculated at approximately \$1.60 USD, with a standard deviation of +/- 66%.

In response to the question regarding the types of work engaged in by the household, 78% were involved in ASGM activities directly, 45% were involved in agricultural work, 13% in commerce of some type, and 11% in trades, with the rest in a variety of other jobs (Figure 8: Types of Work Engaged in by Households. Of the 45% of respondents that worked in agriculture, 99% of them (all but one respondent) also worked in ASGM.

2.4.2 Miner Interviews

The qualitative responses to the 80 structured interviews were carried out on 8 sites that were opportunistically selected and representative of small, medium, and large ASGM sites. These were carried out as a part of the mercury inventory process, and were designed to provide further information on the socio-economic significance of ASGM to miners and to rural economies. Across the 80 participants, when asked why they mine, 42% claimed that it was to make better money, 29% said it was due to a lack of other work, 15% said it was due to poverty, and the rest for other reasons including to support their families (Figure 9: Reasons for Mining).

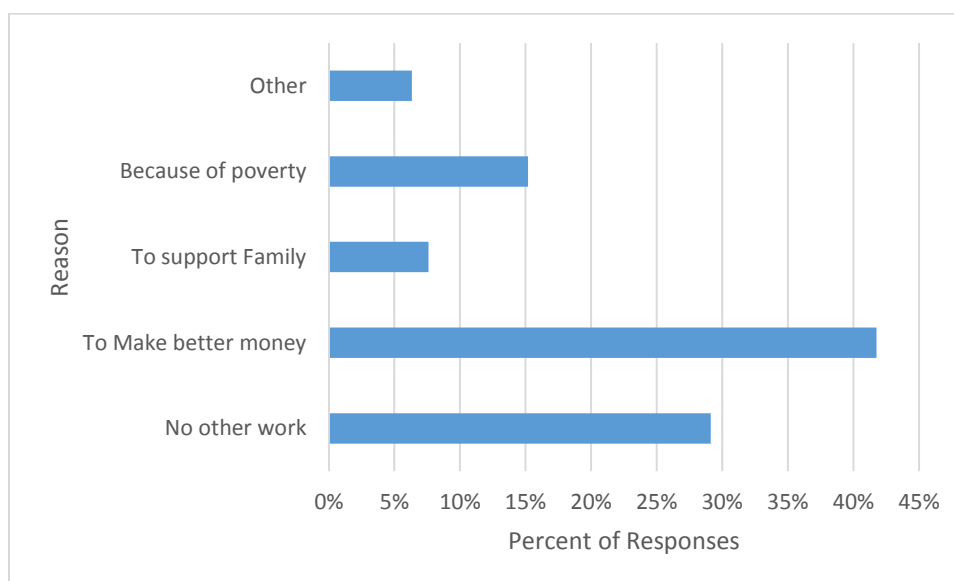


Figure 9: Reasons for Mining

When asked if they worked other jobs besides mining, 62% affirmed at least one other job, with 40% of all respondents saying that they work in agriculture in addition to ASGM (Figure 10: Secondary Work of Miners). When further probed about the earning potential of other work

compared to ASGM, essentially every respondent claimed that there is no other job that can pay as well as ASGM in the long run, despite the boom and bust nature of the income.

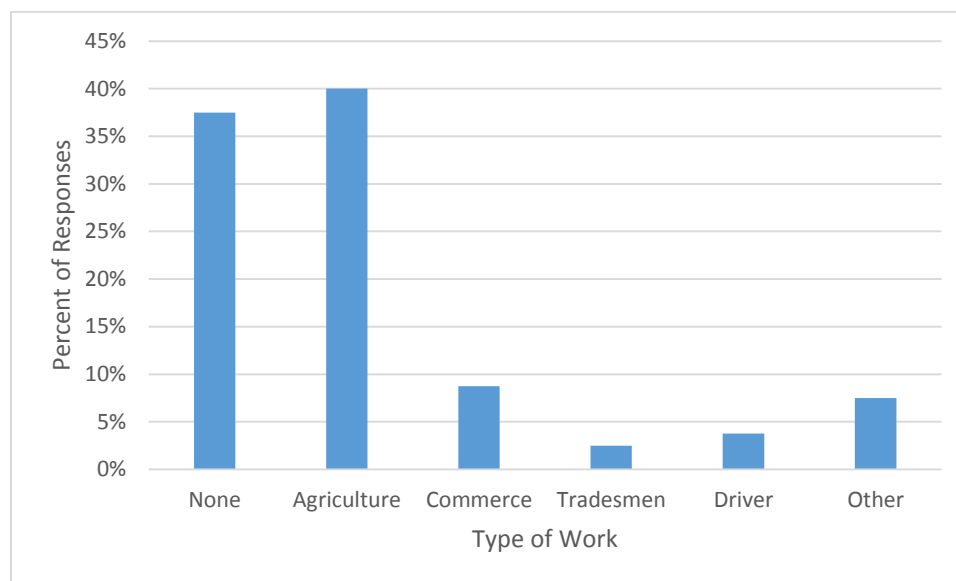


Figure 10: Secondary Work of Miners

When asked the number of dependents that they had, 31% claimed between 10-20 dependents, 23% between 5-10 dependents, and 20% less than 5 dependents. Across all 80 structured interviews, the average number of dependents that the miners supported was 11 people with a standard deviation of +/- 67% and a non-response rate of 6% (Figure 11: Number of miner's dependents). The majority of respondents clarified that this dependency was shared by at least 1 other family member, resulting in a dependency factor of approximately 5 people for every miner (+/- 67%), which supports the oft used multiplier of 5 for estimating the amount of people dependent on the ASGM sector – but for which little evidence has previously existed.

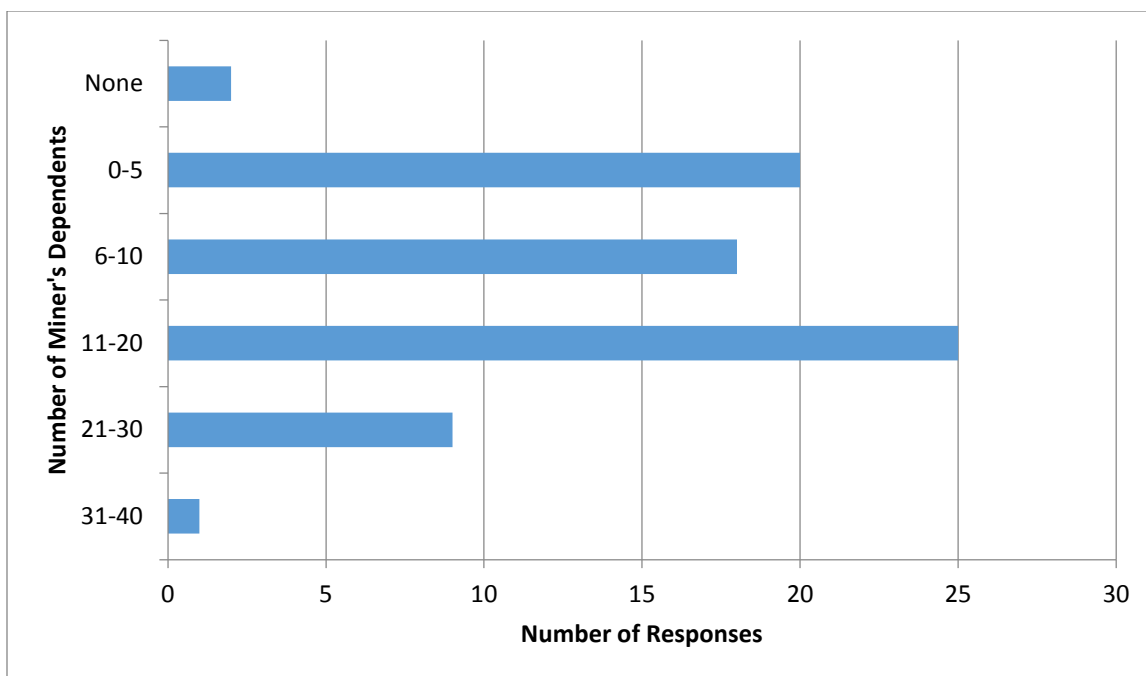


Figure 11: Number of miner's dependents

2.5 Discussion

2.5.1 ASGM and Diversified Economies

With the rise of ASGM over the last decade and a half, the sector has now become an integral part of the rural economy of the Kedougou area of Senegal. The population of Kedougou – the general area of study – is approximately 151,000 people (ANSD, 2013). Although a large proportion of the ASGM community of Senegal are migrants from surrounding countries (UNIDO, 2010), the estimated population of the sector within Senegal – as found by the current study and described in Chapter 3 - is approximately 67,000 people, amounting to the equivalent of 50% of the total recorded population of the region. This, among other points, demonstrates ASGM's employment magnitude and provision to a largely isolated and traditionally impoverished area of the country (Amnesty International, 2014).

The findings of this study demonstrate that the ASGM sector, as a complementary activity to the predominant agricultural sector, is a viable and perhaps preferable employment opportunity for those living in rural Senegal, and it does not necessarily detract from the agricultural sector. A 1995 rural income survey carried out by the Senegalese authority revealed that households further away from the capital, Dakar, especially those in more isolated regions, tended to have lower incomes, and the national average income per household was about double the average annual income of rural households (Kazybayeva, Otte, & Roland-Holst, 2006). The same is true for rural areas surrounding smaller Senegalese cities. In the same survey, for the Tambacounda/Kedougou area of Senegal, the average annual income per household was approximately 1,300,000 CFA or \$2300 USD, whereas the rural subsample of this group was only approximately \$1300 USD (Kazybayeva, Ott, & Roland-Holst, 2006). Such disparity can be generalized to further demonstrate the shortcomings of the traditional agrarian sector to provide sustainable livelihoods for rural populations. The severity of this disparity in the Kedougou region is likely also attributable to the high degree of isolation of villages and the corresponding lack of sufficient market access. The difference between market access for agriculture and gold is explained by the fact that gold traders are mobile and buy directly on the site of the producer, whereas agricultural producers need to transport products. On all sites visited throughout the present study, various gold buyers were available to purchase gold in the immediate vicinity of the processing areas.

In 2013 little seemed to have changed from 1995 in rural areas, and likely conditions had worsened considering inflation, as the national level GNI per household was \$1070, and the PPP

per household was \$1910 (World Bank, 2014). While conventional income surveys depict vast disparity between urban and rural incomes, such statistics might under-represent the diversity of rural income opportunities, including ASGM. Findings from the present study, for example, show individual miners earning between \$600 and \$1100 per year (see section Cross-Checking: Income Variances) once disaggregated to the miner or digger, an income which is also on par with the rural average for the Kedougou/Tambacounda region in 1995. However, households in this study were almost always engaged in more than one livelihood activity, usually including agriculture (Figure 8: Types of Work Engaged in by Households, and it is likely that most households are comprised of more than just one miner. Therefore, household incomes of those which include ASGM in their livelihood portfolios are likely much higher than the average GNI/PPP per household for Senegal, particularly per rural household. As discussed below in Chapter 4, this has significant implications for rural development policy in Senegal and surrounding countries, demonstrating the importance of ASGM to rural populations.

In 2012 the rural poverty percentage in Senegal was 57%, the percent of people living on less than \$2 a day was 60%, and those living on less than \$1.25/day was 34% (World Bank, 2014). In the Kedougou area, of which 71% of people are considered to be living in poverty (ANSD, 2013), the ASGM sector appears to perform better than others, with findings from the present study showing that the average income for miners that carry out no other activities is between \$4-\$7 dollars per day (+/-49%), placing many beyond the international poverty line of \$1.25 USD/day. Therefore, whether involved in other work or not, the findings of this study point toward many ASGM miners living well above the last 2011 official rural poverty line in Senegal of approximately \$1 USD/day, and also the capital (Dakar) poverty line of approximately

\$1.70/day (Republic of Senegal, 2014). Additionally, 62% of the miners interviewed were involved in at least one other job and could potentially earn even more, and have the opportunity to increase their savings potential through complementary subsistence activities. The increased savings potential of the majority of miners is of further relevance in that it illustrates the strength of the ASGM sector in creating economic rural development. This study found that the average daily household expenditure in ASGM communities was approximately 6000 CFA, or \$12 USD. Given the average household size of 9 economically active people (+/- 67%), this means daily spending per person of approximately \$1.65/day within the average household. Even when we consider additional costs incurred by miners, as discussed in Chapter 3, those miners earning between \$4-\$7/day have high potential for savings, particularly when pooling resources within a household. The savings potential of miners is also evidenced by the fact that 57% of the households surveyed in the present study owned at least one motorcycle, and 53% owned permanent structured housing of some kind (Figure 6: Household Assets). Such assets are positive indicators of the ability of a household to save, and point toward the economic importance of ASGM to the rural population of the Kedougou area (Booyesen et al., 2008; Heemskerk, 2005; McKenzie, 2005).

The positive economic relationship between ASGM, agriculture, and rural livelihood diversification is also further illustrated through the findings of this study. In the Kedougou area of Senegal ASGM has emerged as an important complementary livelihood for those involved in agriculture. 58% of Senegal's population lives in rural areas, and of this 60% work in agriculture (World Bank, 2013). The small-scale agricultural sector in Senegal, like surrounding countries in Sub-Saharan Africa, is largely affected by time and seasonality (Niehof, 2004), and this is highly

important with regard to the dynamic between agriculture and ASGM. Seasonality in agricultural work in Senegal does not make it an optimal sole source of income for households. For households engaged exclusively in agricultural work, seasonality further impacts those dependent on agricultural yields for subsistence. In the region of Kedougou, 81.6% of the rural households are primarily agricultural households, and 87.1% of all agricultural households work during the rainy season – in Kedougou there are essentially no irrigated crops, meaning inactivity in the dry season (ANSD, 2013). Just as agricultural work goes dormant during the dry season in Kedougou, conversely ASGM becomes inactive during the rainy season. As in most other countries in Sub-Saharan Africa (Maconachie & Hilson, 2011; Maconachie, 2011), the current study found that the mines are only active for approximately 8 months. It also countered any suggestions that most people will lay dormant throughout this time. It was found that 62% of miners interviewed were involved in at least one other job, with 40% involved in agriculture. Among those households surveyed, similarly 45% claimed to be involved in agriculture, and of these 99% were also involved in ASGM. Thus, rather than being considered an alternative activity that somehow detracts from agriculture, this study affirms the ability of the ASGM sector to complement small-scale agriculture by creating year round work for rural residents. In this sense, ASGM provides the incentives to keep rural populations from moving toward urban areas, which is a cornerstone of much rural development policy as it avoids urbanization and the associated development challenges (Wye Group, 2011).

In other studies in Africa, such as in Ethiopia for example, results point to desperation, rather than profit seeking, as the driving force behind livelihood diversification (Bezu, Barrett, & Holden, 2012), and this is likely the case for many other African countries. Survey results with

miners in the present study allude to this as well. The majority of miners interviewed responded to the question about why they mine with an affirmation of some type of “desperation”, whether it is poverty or the lack of sustainable employment options (Figure 9: Reasons for Mining). Although this does point toward the inadequacies of rural development policies, it also illustrates one of the main strengths of ASGM as a provider of an alternate income opportunity in areas traditionally dependent on agriculture, and as a provider of a livelihood diversification option for households that have little capital or education, and few other options. Such findings also provide a counter narrative to previous studies that point toward agricultural families with more assets and higher incomes as more likely to diversify their livelihood portfolios (Abdulai & CroleRees, 2001; Barrett et al., 2001). However, although the results demonstrate a lack of alternatives as the predominant reason for being involved in mining, this does not mean that mining is the last choice for those seeking economic diversification, or that participation in ASGM is a hardship. Throughout the period of this study and the time leading up to it, researcher observations and informal conversations with miners, illustrate a sense of freedom and pride in working in mining by many. For example, a female colluvial miner who was informally interviewed by the author declared that mining was in fact much less physically demanding than the agricultural work that she also carried out. Another miner explained how he felt free while working on the mine, in contrast to other types of work like agriculture which has been described in other ASGM studies by miners as “slave labour” (Cartier & Bürge, 2011). While ASGM offers an opportunity to those facing economic desperation, ASGM is not only a “desperation” activity, but also an avenue of financial strategy. As Niehoff (2004) points out, income diversification is not a strategy used by the poor alone, but rather by all socio-economic groups for various reasons. Thus, while ASGM offers an alternative source of income during times of distress, it also

provides an empowering alternative to traditionally marginalized populations for economic growth. Many people involved in the ASGM economy of Senegal are doing so as a clear business decision, with investments into small-scale mechanized equipment and other supplies a common practice. 15% of households surveyed, for example, owned at least one type of mechanized mining equipment, and essentially all those surveyed who were involved in agricultural work owned rudimentary agricultural equipment (Figure 6: Household Assets).

2.5.2 ASGM Organization and Structure

In the region of Kedougou, recent censuses show that 81.6% of rural households are involved in agriculture and, of those, 87% work on land close to their homes (between 0-5 km) (ANSD, 2013). Most households in the Kedougou region work in relative proximity to their homes, indicating the importance of land and resource use to local populations, and customary authorities play a vital role in these arrangements. According to Ostrom (1999), groups of people who can identify with one another are more likely than groups of strangers to develop norms that ensure sustainable resource use. This suggests an increased challenge for the development of norms or rules that ensure sustainable resource use, as ASGM sites often are composed of multiple ethnicities, tribes, genders, ages and professional backgrounds.

However, in ASGM, much of the common identification amongst miners, regardless of origin or background, can be characterized as a social network formed by a common mining culture. This social network in ASGM has been observed by the author and others across West Africa

(Jønsson & Fold, 2011), where common mining norms are established amongst a heterogeneous group of miners in order to effectively manage a mine site.

In Senegal, informal mine sites have been observed employing community dialogue structures, where representatives from different nationalities on the site speak on behalf of their national group during central meetings. Observations and informal interviews throughout the present study detailed ASGM sites operating under customary arrangements, with organizational processes that include the paying of informal taxes to local village chiefs and their designated mining administrators who are often known as the *Tomboulouma*. The *Tomboulouma* are the designated arbiters and overseers of the site, delegating shaft locations, resolving conflicts and ensuring security. The sophistication of this organizational approach is evidenced by several attributes on the site that are usually associated with formal operations. For example, the miners all finish the work day at the same time every day, and the *Tomboulouma* wear uniforms provided by the community. On other sites in Senegal, different nationalities were observed working side by side in the same mine shaft.

Traditional customary land arrangements are used to regulate both the agrarian and ASGM sectors. Such arrangements are further complicated by large-scale mining interests and their support from national governments. As discussed above, in 2003 it was estimated that up to 90% of land in Sub-Saharan Africa was held under communal or customary tenure (Chimhowu & Woodhouse, 2006), and much of this land in the Kedougou region of Senegal is rich in minerals. In the Kedougou region alone, there are an estimated 10 million ounces of gold reserves, and large scale mining has proliferated in the area over the last 10 years, with over five companies

holding exploration permits that cover a total area of approximately 6000 km² (Amnesty International, 2014). The direct administration and taxing of ASGM by local customary authorities in Senegal, such as the *Tomboulouma*, enables a form of direct control over underground resources that when recovered are directly injected into the local economy. The local and direct administration of ASGM creates a sense of purpose and meaning to rural villagers who are being pushed out of local agricultural work as it becomes less able to provide. In the case of the Kedougou area, where both agricultural land and ASGM workings are becoming susceptible to complete annexation by external large scale mining interests that bring little to the local economy, direct authorities provide collective and local representation. Further, because customary authority has traditionally governed agriculture arrangements, it acts as a strong foundation upon which ASGM and agriculture can co-exist and complement one another more effectively.

2.6 Conclusions

The objective of this chapter was to analyze and demonstrate the socio-economic significance of ASGM and its potential for development in relation to other rural sectors. The findings point toward ASGM as a relatively prosperous activity for rural inhabitants that can keep individuals well above the poverty line and provide them with the ability to save or acquire assets. They also show the complementarity between ASGM and agriculture, and the importance of this connection for households. This research could be improved through the use of a larger survey with a greater sample size, and through more inquiries into the earning/saving potential of miners versus agricultural workers. Further, this type of research could benefit from a more in-depth

assessment, of the role and significance of local governance structures including the *Tomboulouma*.

Broadly, the findings of this research emphasize the importance of ASGM to rural development in the Kedougou region of Senegal, and indicate the need to consider ASGM as inter-related and positively associated with traditional agrarian livelihoods and customary land tenure practices. Policies aimed toward reducing mercury use in the ASGM sector through improvement and formalization projects should consider these connections as important facets of sustainability in the sector, and ensure that any interventions support them. Finally, these findings also contribute to international development scholarship, adding to small body of literature that discusses the ASGM sector as a component of sustainable and alternative livelihood strategies, as a contributor to poverty alleviation, and as a complementary livelihood to agriculture in the developing world. Importantly, further research needs to be done to strengthen the current findings and to build yet a greater understanding of the socio-economic significance of ASGM to rural populations.

3 Chapter 3: A National Inventory of ASGM and Mercury Use in Senegal

3.1 Introduction

Policies aimed toward reducing and, where feasible, eliminating mercury use as required under the *Minamata Convention on Mercury* require baseline inventories of mercury use and associated data in order that improvements and support projects can be monitored and managed within a results-based framework. As discussed above, the methodologies for conducting such estimates are currently little understood, and robust estimates of the sector are limited. The following chapter addresses objective (ii): to define and develop a replicable and widely applicable methodology for estimating mercury use in ASGM communities. In doing so, it develops an estimate of mercury use and correlated socio-economic data for the ASGM sector of Senegal through a mixed-methods rapid-appraisal approach. A detailed discussion of the nature of mercury use in Senegal, and of the scope and structure of local ASGM economics provides an important starting point from which sound policy for the sector can be built.

3.2 Methods

The key findings of this study, including estimates of gold production, miner population, and mercury use in Senegal, were derived from a triangulation of information obtained from randomly selected, opportunistic structured interviews with individual miners, informal interviews with key informants and local experts, and through observation, physical measurements, and physical counting. Ten interviews were carried out on eight different mine

sites in an effort to capture the wide range of experiences of the sector, however non-responses were common and required elimination, and variance in responses were high. Mean estimations for the gold production and all associated variables such as mercury use and miner revenues were provided in standard deviations. Conservative minimums were used in all cases of uncertainty, meaning that actual production could be higher than the estimate presented in this study.

3.2.1 Site Visits

A total of 77 sites, as identified in a 2007 study on ASGM in Senegal through the PASMI program (SOW, 2014) study and then re-verified by local experts at the time of the study, are ASGM locations with varying degrees of activity and types of mining (primary, colluvial). The majority of the sites, according to local experts, were small and sparsely populated, and the greater part of the ASGM working population (approximately 68%) could be found on 7 major primary sites identified as Karakena, Diabougou, Sambrambougou, Tenkoto, Bantakho, Douta and Gondala.

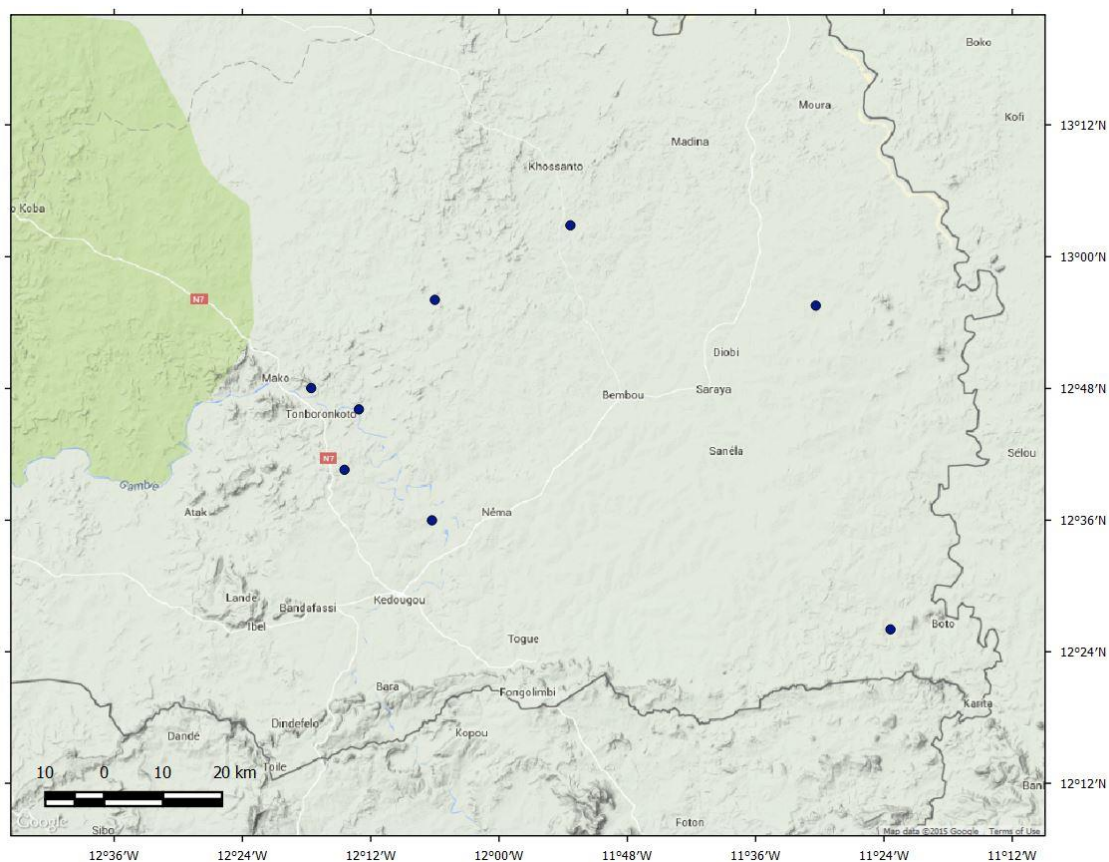


Figure 12: Sites Visited

Interviews and inventory methodologies were applied to a total of eight hard-rock sites as a part of this study representing five major sites, two medium sized sites and one small site, and accounting for 53% of the total estimated miner population in Senegal (Table 2: Sites Visited). These sites were selected opportunistically based on accessibility, and also because they were representative of the variety of site sizes that could be found in Senegal. An additional two small colluvial sites were visited and investigated using informal interviews and observation in order to verify local expert analyses and other anecdotal evidence regarding this type of site, the results of which are described below. Additionally various other hard-rock sites were visited and observed

but not included in the site-specific results, and rather considered as supporting observational evidence for the sector as a whole.

Table 2: Sites Visited

Site Name	Estimated Miner Population (range)	Date Visited	Coordinates
Ngari-Sékhoto (Woundoudou)	1100 – 1600	May 17, 2014	N 12°40.563', W 012°14.437'
Tomboronkoto	300 – 400	May 21, 2014	N 12°48.013', W 012°17.558'
Bantakho	6000 – 7500	May 11, 2014	N 12°46.074', W 012°13.089'
Tenkoto	3000 – 3500	May 20, 2014	N 12°56.060', W 012°05.975'
Douta	7000 – 8500	May 14, 2014	N 13°02.852', W 011°53.291'
Sambrambougou	5000 - 7000	May 13, 2014	N 12°55.535', W 011°30.404'
Guémedji (Kounteto)	700 - 900	May 18, 2014	N 12°25.993', W 011°23.412'
Samécouta	200 - 250	May 18, 2014	N 12° 35.951, W 012° 06.245'

3.2.2 Data Set

Interviews

On 8 mine sites representing an estimated 53% of the total miner population in Senegal, 10 structured interviews were carried out on each site, randomly and opportunistically, with individuals from different mining shaft groups that were willing to participate. The structured interview process was guided by a questionnaire that included questions related to the quantitative information required to make an estimate for mercury use, but also qualitative information that provided a more in-depth understanding of ASGM that is discussed throughout the various chapters of this thesis. In some cases, probing and deductive questioning were used to explore responses from participants and to clarify inconsistencies and obvious falsifications, as many topics were difficult to broach directly because of both the sensitivity of mercury use and gold production, and also because the miners are often limited by their situated knowledge of gold production and mercury. The structured interview was guided as follows:

- *Why are you involved in mining and for how long have you been so?*
- *How many people work on this shaft?*
- *How much mineral (sacks) do you collectively extract per day/week?*
- *How do you divide this material between the workers of this shaft?*
- *How much gold is typically found in one sack of mineral?*
- *How many days of the week and months of the year do you typically work?*
- *Do you do any other work besides mining?*

- *How many people do you support and where are they?*

The key information derived from these questions was triangulated with other datasets collected as a part of this study, including the Hg:Au ratio physical measurements and secondary data analyses, in order to develop the site specific mercury use estimates and the national mercury use estimate. Additionally, the responses to several of these questions supported the discussion of the socio-economic significance of ASGM to the rural population in Chapter 2. In addition to the 10 structured interviews with miners on each site visited, key informants and local experts were opportunistically and informally interviewed in order to gain a stronger understanding of the site context, and to verify observations and information coming from the miners and other sources. On at least one, but sometimes two of the interviews, non-answers or incomplete information was provided, and so these responses were eliminated from the data.

Population

On each visited site, a key informant guided the research team on a tour of the entire area in order to count the number of active shafts. Miner population numbers (Pm) were then calculated based on the number of physically counted active shafts (Ns) multiplied by the average shaft group size (Gz) as determined by the 10 or in some cases 8 or 9 interviews for that particular site.

$$Pm = Ns \times Gz$$

Equation 2

Due to uncertainty in these physical counts and also other factors that could limit or increase the amount of active shafts throughout the mining year (water in shafts, more miners moving in, etc.) a mean shaft number was used, and then a +/- % reflecting the standard deviation on the

interview responses for that site was given. In some cases the standard deviation is quite high, but the average is still deemed appropriate in order to account for the high variance that is typical of the sector, both across mine sites and even within mine sites.

On other sites that were not visited, population data was obtained from past studies (Sow, 2014) and verified with local experts and key informants that included local customary authority representatives and government sources, for up-to-date accuracy. In the absence of any data on some small and medium sized mines, population factors were applied, where small mines were given a 225 person mean population factor and medium mines a 675 mean population factor. These numbers reflect the author's observations on small and medium sized sites and were deemed as appropriate averages to apply by local experts. The last population estimate for the ASGM sector for example, was carried out in 2007 under a project called PASMI which estimated there to be 50,000 people working directly in ASGM (Sow, 2014). With the rise in the price of gold and increasing rural poverty since then, this number is likely to have grown – as the results of this study illustrate.

Gold Production

The quantifiable responses from the structured interviews that were used as variables for the gold production estimate include: shaft group size (S_z), sack extraction rate (Er), and ore grade/sack (G_s). Additionally the variable of eight months of active production, and a five day working week was used to calculate both the annual production rate per shaft and also the miner day rate pro-rated and non-disaggregated. Although the number of months worked per year varied in the interview responses, the 8 month work year (32 weeks, 160 days) was chosen to be applied across the sector, as it adequately represents major production delays and miner migration

throughout the rainy season as well as the time allocated to other livelihood activities of the miners such as agricultural work.

Shaft weekly production (Wp):

$$Wp = Gs \times Er$$

Equation 3

Shaft annual production (Ap):

$$Ap = Wp \times 32$$

Equation 4

Site annual production (Gp):

$$Gp = Ap \times Ns$$

Equation 5

Miner Revenue

To estimate daily miner revenue, the common site price of \$30 USD per gram was used for all sites (75% of spot price at the time of the study). This price was verified through conversations with various gold traders and miners on every site visited throughout the period of study. It represents the price paid for gold only, which in most of the Kedougou area of Senegal is considered to be approximately 22 karats, or 92% pure. This \$30 USD was multiplied by the annual estimated site production rate (Gp) and divided by the estimated site population (Sp) to produce the annual miner revenue (Ar), which was then divided by the number of estimated mining days (160) in order to produce the daily miner revenue (Dr). The daily miner revenue was calculated based on:

Annual miner revenue (Ar)

$$Ar = (30 \times Gp) \div Sp$$

Equation 6

Daily miner revenue (Dr)

$$Dr = Ar \div 160$$

Equation 7

The daily miner revenue represents an equal distribution of revenues across all members of the ASGM community, which as will be shown is not the case (see section 3.4.2). Thus, the daily miner revenue represents the mining revenue only, non-disaggregated, and not across 365 days per year, meaning actual incomes per miner vary significantly based on positions and when complementary livelihoods are occurring.

Mercury Use

To estimate mercury use, the common ratio of 1.3:1, which has been verified in other studies in West Africa (AMAP/UNEP, 2013) and through physical measurement in Senegal as a part of this study, was used against the gold production estimate. Physical measurements were carried out on three different mine sites, reflecting ranges between 1:1 and 1.6:1 conforming to the 1.3:1 average applied. For colluvial sites, a 50% reduction in mercury use was applied to reflect gold nugget processing which requires no mercury use. It is important to mention that this 50% reduction has been applied based solely on the author's observations and through information derived from anecdotal evidence by colluvial miners. Further studies are needed in order to

ascertain the use of mercury in colluvial sites in Senegal. Regardless, for the purpose of this study the 50% mercury use reduction has a minimal impact on the overall estimate because the colluvial sites represent a very small percentage of the total gold production and miner population (20% of estimated total national miner population and 20% of gold production).

Primary site mercury use (pHg)

$$pHg = Gp \times 1.3$$

Equation 8

Colluvial site mercury use (cHg)

$$cHg = Gp \times 1.3 \div 2$$

Equation 9

National Extrapolation

In order to extrapolate findings across all unvisited sites in Senegal a national average miner revenue (NmR) was created based on the site-specific average daily miner revenues (Dr) calculated from the visited sites, which was then applied to population estimates for all unvisited sites.

$$NmR = (Dr1 + Dr2 + Dr3 + Dr4 + Dr5 + Dr6 + Dr7 + Dr8) \div 8$$

Equation 10

This method of analysis was chosen as it is more representative of the high range of variability that is typical of the ASGM sector in general and that has been documented by many researchers

and experts (Heemskerk, 2005; Hilson, 2005). This method of analysis also allows for the accounting of large, high-grade finds by miners which do occur with frequency in the ASGM sector of Senegal. These differences per site are also reflected in the size of sites, where the larger sites are often known to have much richer deposits, thus inducing an influx of miners to exploit the supply. This has been confirmed many times over by the author throughout the present study and during the time leading up to this study, by key informants and miners who offer the information that a deposit is either rich or poor. In order to adequately present the range in production that exists in the sector, the final average annual miner revenue is independently given a min-max factor representative of the average standard deviation of the findings from each site, which is +/- 49%.

Example:

National miner revenue per day across all visited sites (NmR) = \$12.82

Mean Population

(225 miners) x (NmR) = \$2885/day

(\$2885)/ (\$30) = 96 grams/day

(96 grams) x (8 months x 4 weeks x 5 days) =15360 grams/year

3.3 Results

This section is organized into a narrative description of each of the eight surveyed sites, followed by a mercury use estimate utilizing the methods described above. Additionally a narrative

description of two non-surveyed sites is provided to illustrate the situation on smaller and alluvial mining sites. The results of three different physical measurements of the Hg:Au ratio are then provided, followed by a national extrapolation of the data to produce a national mercury use estimate for Senegal.

Table 3: Visited Sites Summary of Results

Site Name	Estimated Miner Population	Estimated Annual Gold Production (grams)	Estimated Daily Miner Revenue (\$ USD)
Bantakho	6575	636400	18 (+/- 34%)
Sambrambougou	6803	270463	7.5 (+/- 48%)
Douta	4134	80584	3.7 (+/- 47%)
Kharakéna	9688	464273	9 (+/- 40%)
Woudoudou	1300	69047	9.9 (+/- 52%)
Kounteto	973	102316	19.7 (+/- 60%)
Tenkoto	2700	70500	4.9 (+/- 51%)
Tomboronkoto	385	57173	28 (+/- 60%)

3.3.1 Gold production and daily revenues per site

Bantakho

Like the entire ASGM sector in Senegal, mining on this site takes place 5 days of the week, with approximately 10 hour days. Presence on the mine site on Monday or Friday is strictly prohibited, and these days are used to process collected ore in the village. Miners process their ore independently usually by way of milling using a milling service which employs inadequate grain mills, then washing on a sluice followed by mercury amalgamation. Some miners who only have small amounts of rocks will skip the sluicing process and simply mill the rocks and add mercury.

The deposit is rich on this site, and the miners tend to high-grade and target veins rather than excessively exploit the terrain, which results in very low extraction rates with high grades. The rich deposit is also evidenced by the fact that several large scale mining companies have long-held exploration permits in the area, and in fact most of the active ASGM mining areas fall within the exploration concession of an LSM company. The site and village is composed of many different nationalities, including Guineans, Gambians, Malians, and Burkinabe. These various national and ethnic groups tend to stick together on the site, as determined through personal observation and informal interviews, mining as groups and representing the interests of the groups through elected leaders. Also determined through informal interviews and observation is that there are women who work on the shafts as pullers, but none go into the shafts.

As a result of interviewing 10 participants, with one non-response, it was estimated that the average number of workers per shaft on this site was 30 (+/- 3.15 SD), the average number of sacks extracted per week was 4.8 (+/- 2.4 SD), and the average ore grade per sack was 18.5

grams (+/- 7.8 SD). This ore grade per sack was considered very high, however through further probing it was revealed that the miners were high-grading and being very selective, and that the area indeed was part of several rich veins, making it a popular mine site. The miner population on this site was estimated to be approximately 6600, with the number of active shafts at approximately 225. The grams per shaft per week were 88, while the annual production per shaft was estimated at 2828 grams. Extrapolating to the entire site resulted in an annual site production of approximately 636 kg of gold, the average annual miner revenue of \$2904 USD, and the daily miner revenue of \$18 USD (+/- 34% SD), with the standard deviation averaged from the three key variables.

Table 4: Bantakho Results

Variable	Estimate	Variable	Estimate
Number of Miners	6575	Total Production (Grams)	636400
Grams/shaft/week	88	Revenue/miner/year (\$ USD)	2904
Grams/shaft/year	2828	Miner Daily Revenue (\$ USD)	18 (+/-34% SD)

Sambrambougou

This is a primary (hard-rock) site where people from various nationalities including Senegal, Guinea, Mali, and Gambia work together on the same shafts, which make it somewhat of an anomaly in the Senegalese ASGM context, which is typified by ethnic and national segregation of labour groups. Women also work in shaft groups but do not go underground and mainly work as cord pullers and also food financiers. Some of the foreign workers on this site send their

money home with trusted people who take a 10% commission for delivery – as determined through informal interviews with miners and key informants.

The site is controlled by a group of *Tomboulouma* along with the site Chief and the village Chief. Each shaft has a *Tomboulouma* assigned to it who receives a portion of the production. There were no commercial vendors or restaurants on or near the site and everything was back in the village where there was more than 1000 different businesses including motorbike vendors. Because of the scattered nature of the shafts and the site, it was difficult to be accurate with the counting of shafts, however one rough count came up with approximately 150 active shafts, and one key informant verified between 150-200 active shafts. Most shafts, according to a local informant, are between 40 -80 meters deep. According to accounts by key informants and local experts, this site was much larger in past years but has been partially shut down by the military.

As a result of interviewing 10 participants, with two non-responses, it was estimated that the average number of workers per shaft on this site was 39 (+/- 5 SD), the average number of sacks extracted per week was 9 (+/- 10.2 SD), and the average ore grade per sack was 5.5 grams (+/- 3.5 SD). The miner population on this site was estimated to be approximately 6803, with the number of active shafts at approximately 175. The grams per shaft per week were 48, while the annual production per shaft was estimated at 1546 grams. Extrapolating to the entire site resulted in an annual site production of approximately 270 kg of gold, the average annual miner revenue of \$1190 USD, and the daily miner revenue of \$7.5 USD (+/- 48% SD).

Table 5: Sambrambougou Results

Variable	Estimate	Variable	Estimate
Number of Miners	6803	Total Production (Grams)	270463
Grams/shaft/week	48	Revenue/miner/year (\$ USD)	1193
Grams/shaft/year	1546	Miner Daily Revenue (\$ USD)	7.5 (+/- 48% SD)

Douta

This is a primary mining site with some colluvial workings being processed by women (who also work in the shaft groups as pullers). There were 25 *Tomboulouma* who control the site, each assigned to a certain number of shafts. The *Tomboulouma* make enough to thrive off of the mining without actually mining themselves, and they play an important role in refereeing disputes and organizing. There are only Senegalese and Guineans working on this site, and it is likely that the remittances to Guinea are likely high. Many of the gold buyers on the site were Guinean however it seems that the majority of the informal gold supply chain was heading across the Malian border.

As a result of interviewing 10 participants, with a non-response rate of two, it was estimated that the average number of workers per shaft on this site was 18 (+/- 5 SD), the average number of sacks extracted per week was 3.4 (+/- 1.8 SD), and the average ore grade per sack was 3.25 grams (+/- 2.05 SD). The miner population on this site was estimated to be approximately 4000, with the number of active shafts at approximately 225. The grams per shaft per week were 11, while the annual production per shaft was estimated at 358 grams. Extrapolating to the entire site

resulted in an annual site production of approximately 81 kg of gold, the average annual miner revenue of \$585 USD, and the daily miner revenue of \$3.7 USD (+/- 47% SD).

Table 6: Doua Results

Variable	Estimate	Variable	Estimate
Number of Miners	4134	Total Production (Grams)	80584
Grams/shaft/week	11	Revenue/miner/year (\$ USD)	585
Grams/shaft/year	358	Miner Daily Revenue (\$ USD)	3.7 (+/- 47% SD)

Kharakéna

This site, situated close to the border of Mali and along the main highway leading to the regions primary border crossing, is possibly the largest ASGM site in West Africa. The village chief along with a group of *Tomboulouma* claim that there are about 3000 active shafts, and observations verified a very high amount of active shafts, however a preliminary count led the research team to believe that the amount of actively producing shafts is likely closer to 1000. The numerous shafts on this site are only manageable because of the shaft groups being typically smaller here than in other areas of Senegal, with an average shaft group size of approximately 12 people. According to local key informants, there are also between 300-400 *Tomboulouma*, each responsible for anywhere between 5 and 40 mine shafts.

The mine site and village fall within the concession of AfriGold, and the Senegalese military has moved in to remove the miners in some parts of the land where the company wants to begin

exploiting. This has caused serious conflicts within the site and has led to the shutting down of many shafts and a large section of the mine. There is also a large area of the site where women process colluvial workings. There are all kinds of nationalities here, all working together on shafts, including Malians, Burkinabe, Ghanaians, Nigerians, Nigerans, Mauritians, Guineans and Guinea Bissauians.

As a result of interviewing 10 participants, with a non-response rate of 2, it was estimated that the average number of workers per shaft on this site was 13 (+/- 2 SD), the average number of sacks extracted per week was 2.2 (+/- 1.5 SD), and the average ore grade per sack was 8.4 grams (+/- 3.2 SD). The miner population on this site was estimated to be approximately 10,000, with the number of active shafts at approximately 775. The grams per shaft per week were 19, while the annual production per shaft was estimated at 599 grams. Extrapolating to the entire site resulted in an annual site production of approximately 464 kg of gold, the average annual miner revenue of \$1438 USD, and the daily miner revenue of \$9 USD (+/- 40% SD).

Table 7: Kharakéna Results

Variable	Estimate	Variable	Estimate
Number of Miners	9688	Total Production (Grams)	464273
Grams/shaft/week	19	Revenue/miner/year (\$ USD)	1438
Grams/shaft/year	599	Miner Daily Revenue (\$ USD)	9 (+/- 40% SD)

Woudoudou (Ngari-Tenkoto)

This is a medium-small primary mining site shared between three villages and only a few years old. There are 12 *Tomboulouma* and mostly Senegalese working the site. There are also women

working on shafts but never as diggers. Most of the workers on this site are here for the first time. It is claimed by the local authorities that there is an exploitation permit here that has been paid for by a Russian company that wants to make sure the land is held for them. The deal with the community is that they can continue with the artisanal mining until the Russians begin exploiting industrially, at which point the artisanal mining stops and the community receives one third of the profit. It is unclear how this deal was arranged and if the Economic Interest Group that represents the community will actually pass along the revenue.

As a result of interviewing 10 participants, with a non-response rate of 1, it was estimated that the average number of workers per shaft on this site was 22 (+/- 4.8 SD), the average number of sacks extracted per week was 6 (+/- 3.8 SD), and the average ore grade per sack was 6 grams (+/- 4 SD). The miner population on this site was estimated to be approximately 1300, with the number of active shafts at approximately 60. The grams per shaft per week were 36, while the annual production per shaft was estimated at 1150 grams. Extrapolating to the entire site resulted in an annual site production of approximately 69 kg of gold, the average annual miner revenue of \$1590 USD, and the daily miner revenue of \$10 USD (+/- 52%).

Table 8: Woudoudou Results

Variable	Estimate	Variable	Estimate
Number of Miners	1300	Total Production (Grams)	69047
Grams/shaft/week	36	Revenue/miner/year (\$ USD)	1593
Grams/shaft/year	1151	Miner Daily Revenue (\$ USD)	10 (+/- 52% SD)

Kounteto Site (Guémedjé village)

This site, very remote and near the Malian border, has been operating since 1998 and unlike many of the other sites in Senegal, most of the miners are local villagers that have been mining for many years. The ore grade here is very low but the extraction rate is high. Huge shafts are being dug out where several shaft groupings will work together digging in different directions. This is one of the few sites where workers (primarily diggers) are paid a salary of 40-50,000 CFA per month plus food rather than a share of the gold. This tells us that the shafts are actively producing in order to cover such costs. Also, the rope pulling is carried out mainly by women who take one 15 litre container of ore to process, of every 10 that they pull out of the shaft.

As a result of interviewing 10 participants, with a non-response rate of 2, it was estimated that the average number of workers per shaft on this site was 22 (+/- 7.8 SD), the average number of sacks extracted per week was 43 (+/- 24 SD), and the average ore grade per sack was 1.7 grams (+/- 1.5 SD). The miner population on this site was estimated to be approximately 1000, with the number of active shafts at approximately 45. The grams per shaft per week were 71, while the annual production per shaft was estimated at 2274 grams. Extrapolating to the entire site resulted in an annual site production of approximately 102 kg of gold, the average annual miner revenue of \$3150 USD, and the daily miner revenue of \$20 USD (+/- 60% SD).

Table 9: Kounteto Results

Variable	Estimate	Variable	Estimate
Number of Miners	973	Total Production (Grams)	102316
Grams/shaft/week	71	Revenue/miner/year (\$ USD)	3154
Grams/shaft/year	2274	Miner Daily Revenue (\$ USD)	19.7 (+/- 60% SD)

Tenkoto Village (Foukphoto and Gulf 1 and 2 sites)

The village of Tenkoto, and the three associated primary mining sites, are located about 35 km off of the main highway near Mako. It is a large village with much of the growth coming from artisanal mining. There are three separate sites that make up the gold mining areas around this village, and the miners here seem to move between them, often coming back and forth between shafts in one location or the other. For this reason we have considered the three sites as one overall Tenkoto site.

The majority of the miners here are Guineans, with some Malians and Senegalese as well. Women work on the site, and the organization and sharing of ore varies between shaft groups. About half of the work force stops mining for the rainy season, but some of the shafts claim to keep working for the greater part of the year if they are able. There are 12 *Tomboulouma* that oversee all three sites.

As a result of interviewing 10 participants, with a non-response rate of 2, it was estimated that the average number of workers per shaft on this site was 17 (+/- 5 SD), the average number of sacks extracted per week was 3 (+/- 2.4 SD), and the average ore grade per sack was 4.7 grams (+/- 4.3 SD). The miner population on this site was estimated to be approximately 2700, with the number of active shafts at approximately 160. The grams per shaft per week were 14, while the annual production per shaft was estimated at 441 grams. Extrapolating to the entire site resulted in an annual site production of approximately 71 kg of gold, the average annual miner revenue of \$783 USD, and the daily miner revenue of \$5 USD (+/- 51% SD).

Table 10: Tenkoto Results

Variable	Estimate	Variable	Estimate
Number of Miners	2700	Total Production (Grams)	70500
Grams/shaft/week	14	Revenue/miner/year (\$ USD)	783
Grams/shaft/year	441	Miner Daily Revenue (\$ USD)	4.9 (+/- 51% SD)

Tomboronkoto

This primary mine site along the main highway leading in to Kedougou is a small one that operates both like a traditional site with shafts and shaft groupings, but also concurrently with a small-scale open pit being exploited by several Malian and Burkinabe groups. There are apparently 6 of these foreign groups, numbering between 15- 42 people and the workers are paid in cash rather than by gold. They make between 30-50,000 CFA/month, while the owner is recovering approximately 10 grams of gold/day from between 3-4 truckloads of material. It is unclear how they are processing this material – they claim to just be using hammer mills and sluices which were observed by the research team, but the conditions seem to point toward the use of cyanide, although this was not observed anywhere.

Each hammer mill that operates pays the community 10,000 CFA/month, which amounts to approximately 400,000 CFA/month as a community tax, administered by the customary authorities. There are women working the shafts as pullers but not entering the shafts. Many of the local villagers work in agriculture as well as mining, and they work year round as miners and farmers weather permitting.

As a result of interviewing 10 participants, with a non-response rate of 2, it was estimated that the average number of workers per shaft on this site was 10 (+/- 3 SD), the average number of sacks extracted per week was 7 (+/- 5 SD), and the average ore grade per sack was 6.2 grams (+/- 4.8 SD). The miner population on this site was estimated to be approximately 385, with the number of active shafts at approximately 40. The grams per shaft per week were 45, while the annual production per shaft was estimated at 1429 grams. Extrapolating to the entire site resulted in an annual site production of approximately 57 kg of gold, the average annual miner revenue of \$4455 USD, and the daily miner revenue of \$28 USD (+/- 60% SD).

Table 11: Tomboronkoto Results

Variable	Estimate	Variable	Estimate
Number of Miners	385	Total Production (Grams)	57173
Grams/shaft/week	45	Revenue/miner/year (\$ USD)	4455
Grams/shaft/year	1429	Miner Daily Revenue (\$ USD)	28 (+/- 60% SD)

Non-Structured Interview Sites

These sites were visited in order to provide observational and informal interview evidence of other types of sites including colluvial and mixed-mining. They did not contribute to the data upon which the national mercury estimate was made, but do provide other important information on the sector such as incomes of colluvial miners, small-site population numbers, and mercury use in colluvial settings.

Tomboron Niadji/Khossanto

This is a small colluvial site deep in the bush near Khossanto where women pan alluvial workings, without using any mercury to process. We counted 51 women and spoke to 3 of them who all claimed to make between 5-10 grams of gold per month, which they sell at the price of 16250-17000/gram. It is hard work for the women, as they have to walk a long way every day and they have to pay for water (200 CFA for a 30 litre container) in order to pan. During the one hour that we spent talking to these women, two of them found small nuggets of gold weighing likely between 1/8 to 1/4 grams. There are many small sites like this around Senegal, perhaps more than 40 according to several local experts and conversations with key informants in 2014. It is not clear how many of these sites are producing mercury free gold, but it is clear that it is contributing to local economic development, and of particular importance to the economic empowerment of women.

Samécouta

This is a small village site that is comprised mostly of villagers from Samécouta and Lamine. There are approximately 50 women panning shallow colluvial deposits and making between 5-10 grams per month, based on conversations with 3 of them, and there are approximately 200 men using gold detectors and finding large gold nuggets, also averaging around the same 5-10 gram per month production. Much of the gold is produced mercury free, however some of it is crushed into powder and then extracted with mercury - this depends on the composition of the nugget.

3.3.2 Mercury Use

Physical measurements were carried out on three of the structured-interview sites in order to verify a suitable Hg:Au ratio to apply to the gold production estimates. The lowest Hg:Au ratio

measured at 1:1 and the highest at 1.6:1. Given these results, the standard ratio of 1.3:1 was applied as an average across all primary sites, conforming to other studies that place the average ratio for concentrated amalgamation in West Africa at 1.3:1 (AMAP/UNEP, 2013; Persaud, 2013). For all colluvial sites, a 50% reduction in mercury use was applied to reflect the cases of mercury free processing on such sites, verified through personal observation and conversations with local experts. Further research is required on colluvial sites to refine this number, however its application to the total mercury use estimate is minimal as colluvial sites are estimated to represent only 20% of total gold production.

Table 12: Physical Measurement #1

Step	Measurement
Amount of mercury added to concentrate	10.45 grams
Amount of mercury leftover after squeezing	5.38 grams
Amount of Hg:Au amalgam	7.11 grams
Amount of sponge gold after burning	3.08 grams
$Hg:Au = (10.45 - 5.38) \div 3.08$	
Hg:Au ratio	1.6:1

Table 13: Physical Measurement #2

Step	Measurement
Amount of mercury added to concentrate	3.66 grams
Amount of mercury leftover after squeezing	2.37 grams
Amount of Hg:Au amalgam	2.56 grams

Amount of sponge gold after burning	1.27 grams
$Hg:Au = (3.66 - 2.37) \div 1.27$	
Hg:Au ratio	1.5:1

Table 14: Physical Measurement #3

Step	Measurement
Amount of mercury added to concentrate	0.43 grams
Amount of mercury leftover after squeezing	0.16 grams
Amount of Hg:Au amalgam	0.56 grams
Amount of sponge gold after burning	0.26 grams
$Hg:Au = (0.43 - 0.16) \div 0.26$	
Hg:Au ratio	1:1

3.3.3 National Estimate

The national estimate for mercury use in the ASGM sector of Senegal determined by the present study is based on an extrapolation of data derived mainly from the structured interviews, using an average national miner revenue and estimated miner populations on each site across the country (see methods).

$$NmR = (Dr1 + Dr2 + Dr3 + Dr4 + Dr5 + Dr6 + Dr7 + Dr8) \div 8$$

Equation 11

Using the methods described above, the results of this study produce an estimated miner population of Senegal (comprised of various nationalities) of approximately 67,000 people, producing 4.5 tonnes of gold per year, with a contribution to the local economy of approximately \$134 million USD at the time of the study, and using approximately 5.2 tonnes of mercury per year. Once extrapolated nationally, the data illustrates the national annual miner revenue of approximately \$2000 USD, and the national daily miner revenue (*NmR*) of approximately \$13 USD based on an 8 month work year. The 8 month work year is reflective of the mining/dry season and was confirmed as an appropriate amount of working days by local experts and miners. A +/- 49% range is provided to account for the overall standard deviation of findings, however as discussed below further support is provided to strengthen the reliability of the mean estimate.

Table 15: National Estimates

	Min	Mean	Max
Miner Population	34000	67000	99000
Gold Production	2.3 tonnes	4.5 tonnes	6.7 tonnes
Mercury Use	2.6 tonnes	5.2 tonnes	7.7 tonnes
Local Economy	\$68 million USD	\$134 million USD	\$200 million USD
Miner Annual Revenue	\$1000 USD	\$2000 USD	\$3000 USD
Miner Day Rate	\$6 USD	\$13 USD	\$19 USD

3.4 Discussion

3.4.1 Limitations

As previously discussed, there are many common limitations to any research and analysis of largely informal ASGM sectors, and such limitations are exacerbated when attempting to quantify and extrapolate particular environmental and economic indicators such as mercury use and gold production. These limitations should be taken into consideration by policy makers, future researchers and other groups aiming to build a monitoring system for ASGM, with the understanding that statistical exactitudes in ASGM are currently a complex pursuit until a hypothetical future period when the majority of the sector has formalized. Thus, while this work does not aim for statistical exactitudes, it should be understood that with accurate and timely information directly obtained from field work with miners, practical and useful policies can be made.

In Senegal, and in ASGM elsewhere, production rates by miners can be highly variable and sporadic often depending on a combination of geological knowledge, technical capacity, and in many cases simply the gold endowment of that specific site. While this variance of production does occur within one mine site, it is much more variable between different mine sites, where factors such as organization and particularly mineral deposits play a key role. Therefore, a high standard deviation on rates of gold production, and all associated variables for estimating national mercury use is reasonable and likely in most studies of the sector. Even if a resource intensive national census of ASGM were to be carried out, it is likely that the variance in production would remain high and the standard deviations similar. Rather than statistical

relevance, this study aimed to provide reasonable estimates through a triangulation of independent lines of evidence. Using triangulation alongside expert opinion and analysis can provide a high level of confidence in the mean estimates. The best mercury use estimates of the ASGM sector to date are considered by peer-reviewers and experts to be accurate and reliable enough to have been used in the negotiation of the Minamata Convention, without any statistical analysis and often little quantitative support provided.

Other limitations include the fluctuating price of gold throughout the year, which is often reflected in the field price that the miners obtain for their gold. Although the rate of fluctuation compared to the global markets is delayed in the field, this can result in some imprecision when extrapolating gold production to annual miner revenues. Also, the location of the ASGM sector in the Kedougou region of Senegal, surrounded by the porous borders of Guinea and Mali, means that it is highly migratory, with miners coming and going from mine sites throughout the year, making miner population estimates approximate, as they are fluid. The remote and isolated setting of the Kedougou area, some 700 km away from the capital Dakar, and the lack of simple access to many sites further complicates research of the ASGM sector.

A three person team was required to visit all of the sample sites and conduct all of the interviews, and any inventory could be strengthened through a coordinated effort and increased funding. As well, this work was formed upon the back of an extensive project of two years duration, highlighting the need for significant prior information and experience in the region for a study of this type. Regardless of such limitations, the nature of ASGM in Senegal, based on the researcher's extensive experience in the region, is one of relative homogeneity in terms of

processes and labour practices, including the rates of production, prices, incomes and other variables, between mine shaft groups and even between mine sites. External validity and transferability are therefore possible with this type of research, even if this type of rapid-appraisal sample is relatively small and fast. The mercury use estimate simply cannot be perfect in an informal setting – and this work serves no greater purpose than testing a method for forming a reasonable estimate. The observable trends, details, socio-economic, and cultural understandings of the sector that are possible with this type of study are what make it essential for governments who require information that will inform their rural development policies.

3.4.2 Cross-Checking: Income Variances

The findings of the present study are consistent with previous understandings of ASGM in Senegal and surrounding countries (eg. UNIDO, 2010; Sow, 2014; Teschner, 2014), and provide important information and reliable evidence upon which governments and other actors can formulate National Action Plans for the sector. The findings indicate a gold production of approximately 4.5 tonnes per year (+/-49%), which when extrapolated across the entire miner population evenly amounts to approximately \$13 per day per miner (+/-49%), based on an 8 month, 160 day, work year. Approximately 50% of this revenue is going to mine shaft leaders – as determined through the structured interviews, and there are clearly variances in this revenue based on positions and other variables. However, an analysis of different independent lines of evidence, including cost of living and secondary economy analyses, suggest this is a reliable estimate.

Although the extrapolation method used in this study produces an average miner revenue per visited site, which combined are then used to create a national average, there are various other factors that contribute to variance of miner incomes, including the working position of the miner within a shaft group (digger, puller, etc.), the level of informal taxes paid by the miner, the grade of the ore, and simply chance of finding a large deposit. Additionally, it is important to distinguish between the revenue of a miner and the income of a miner, as various inputs into the activity such as the purchase of mercury or the renting of a milling service can be costly. The findings show average revenues across different sites to range from as low as \$4/day to as high as \$28/day. These revenues vary temporally and geographically, and so an average revenue of \$13 is plausible if extrapolated across the entire population, and although not exact with regard to the actual take home pay of the miners, is a strong indication and reliable variable to use in the gold production estimate at the national level. However, by breaking the average miner revenue down into an estimated take home income per miner, a more clear understanding of the purchasing power of miners in the local economy can be gained, which when compared to the estimated cost of living on a mine site provides further support of the present findings.

The socio-economic structures of almost all mine sites in Senegal include relatively homogenous rates of pay based on one's position within a mine shaft group. Based on interview data and observations from across all of the sites visited, the general composition and division of earnings of most shaft groups are well understood. Under the current system in Senegal, on almost every site (with the exception of the *Kounteto* site identified within this study), miners are working together in shaft groupings and dividing the gold-bearing ore according to the locally agreed upon sharing agreement – typically the same across the sector with a few small variances across

sites. With a shaft group of 10 people the shaft leader gets 50% of the revenue, the diggers 30%, the rope pullers 10%, security 5%, and a local tax of 5% (Figure 13: Typical Shaft Ore Sharing Arrangement. Whereas, the population division is almost inversed, as the shaft owner only represents 10% of the shaft group, and the diggers 50% (Figure 14: Typical Shaft Group Population Division.

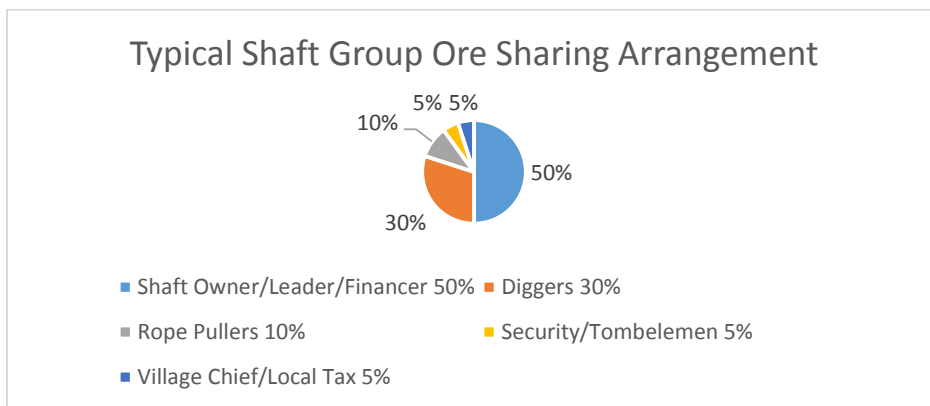


Figure 13: Typical Shaft Ore Sharing Arrangement

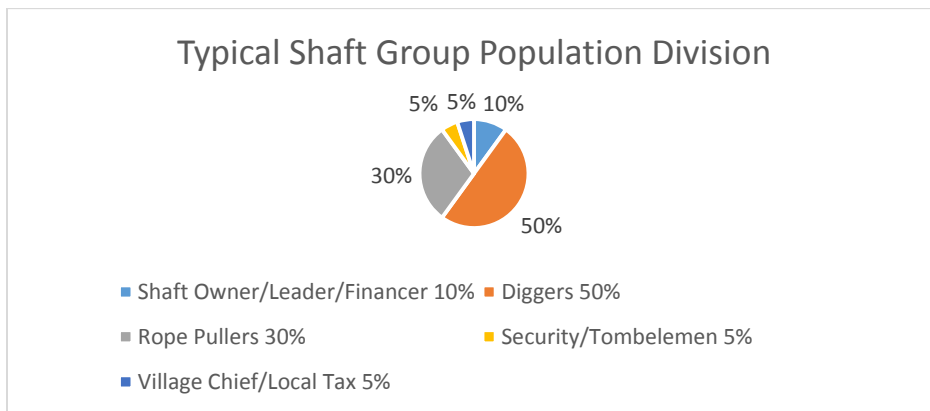


Figure 14: Typical Shaft Group Population Division

Utilizing the estimated gold production of the ASGM sector in Senegal of approximately \$134 million USD per annum, we can estimate that approximately 50% of this is going to the shaft leaders who represent 10% of population. Importantly, it is the shaft leaders who provide essentially all inputs into the mining activity, including equipment, food and shelter, which according to various informal conversations on mine sites with shaft leaders and key informants, typically amounts to approximately half of their revenue, or 25% of total extraction. Once subtracting the additional 10% for security and taxes, 40% of the revenue or \$53.6 million USD is left for approximately 80% of the population, or 53,600 people. It can therefore be estimated that the actual income for everyday diggers is approximately \$6.6 (75% x \$53.6 million/33,500 people) per day and for rope pullers approximately \$4.15 (25% x \$53.6 million/20,100 people) per day based on the 160 day work year (Figure 15: Typical Daily Income Distribution).

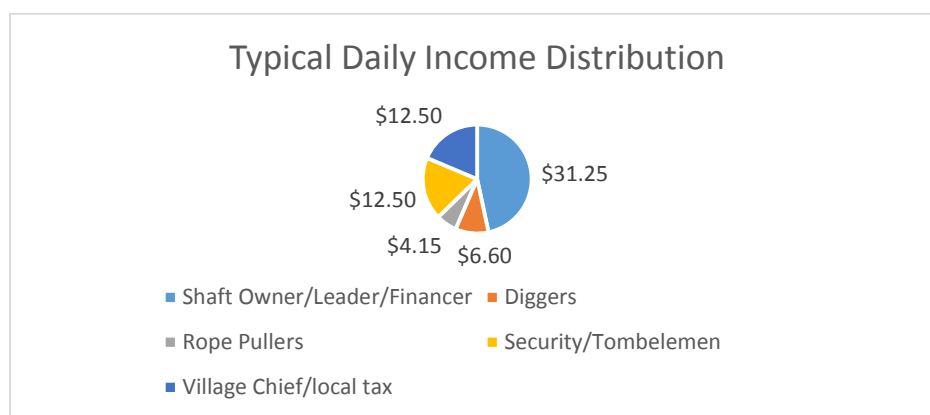


Figure 15: Typical Daily Income Distribution

The socio-economic structures and mining processes are essentially homogenous across the ASGM sector in Senegal, with the exception of two different mine sites where workers are paid in wages rather than the typical commission type arrangement where miners are paid in ore. On

these two sites the miners were earning between 40,000-45,000 CFA per month, which amounts to approximately \$720 over an 8 month work year, or \$4.5 USD per day. Informal interviews with these miners revealed that although the possibility existed for them to gain more from mining under the traditional commission arrangement, they were content knowing that they had a consistent income. Although not conclusive evidence, the fact that wage labour on surrounding ASGM sites conforms to the more typical commission based incomes that are estimated through the findings of the present study indicate the overall reliability of the gold production estimate.

3.4.3 Cross Checking: Cost of Living and the Secondary Economy

Researcher observation and data derived from the household surveys in this study also strengthen the reliability of the estimated national gold production of 4.5 tonnes per year. In almost all mining communities visited, thriving local markets were observed, with evidence of all kinds of trades and services, from car washes to hair stylists, fruits to motorcycle merchants, money was being made and spent locally. Additionally, as further discussed below, miners seem to have the ability to save money and purchase assets. In fact, 57% of the households surveyed in the present study owned at least one motorcycle, and 53% owned permanent structured housing of some kind (Figure 6: Household Assets. Additionally, many of the interview respondents throughout the structured interview process claimed to have numerous dependents (on average 13 dependents relying on 2 people; Figure 11: Number of miner's dependents), and several claimed to send money home via trusted courier, highlighting further the saving power of miners beyond their daily cost of living. Given the daily variances in returns from mining, the average daily cost of living of a miner is difficult to estimate. The household surveys resulted in average daily

household expenditures of approximately \$12 USD, or \$1.60/day for each economically active aged member of the household (Figure 7: Daily Household Expenditures. This expenditure, however, reflected mainly subsistence costs for collective meals, and did not capture the money spent by individual miners throughout the day, nor their savings nor “disposable income”.

Determining the daily costs for miners can be accomplished by considering the common expenditures on a mine site and then dividing them to a daily cost and adding them together.

Common expenditures include:

- Mercury, approximately \$4 USD/~10 grams, which lasts on average approximately 1 month, so over 20 working days, approximately \$0.20/day
- Cost to use a mill is approximately \$5 USD/~15 kg of ore, most miners will stockpile ore until they believe that they have a sufficient amount to make milling worthwhile, or otherwise pay a manual crusher for smaller amounts. Mill use is, likely approximately once per month, averaging over 20 working days to a daily cost of approximately \$0.25. Manual crushing is approximately the same daily cost.
- Cost of gasoline is 1000 CFA for a small bottle, which is needed on average twice per week for motorcycles, so approximately \$1/day
- Other costs include cigarettes, \$0.10/day; beer or soda, \$1/day; water, \$0.20/day; tea, \$0.20/day

Using these estimates alongside a conservative daily household expenditure of \$1.00 per economically active person, we can estimate a minimum cost of living of approximately \$3.85/day. If the minimal daily cost of living on a mine site in Senegal is approximately

\$3.85/day, then a \$4-\$8/day income for miners seems a reliable estimate when considering savings and capital flight in the form of remittances, further confirming the reliability of the national ASGM production estimate, and the correlated mercury use estimate.

Another method of cross-checking the gold production estimate through an independent line of evidence is to estimate the size of the local economy using information obtained from a specific mine site. For the purposes of this study, the village of Bantakho was rapidly appraised to produce an approximate estimate of the size of the local economy. Within the community of approximately 35,000 people of which approximately 28,000 are believed to be of an economically active age, 179 commercial vendors were counted, 102 restaurants, 176 active mills, and a variety of other services and activities that contribute to the local economy. Through a series of informal interviews, physical counting and observation over several days, it was estimated that individual vendors were selling on average approximately \$200 worth/day for a total of \$35,800/day, restaurants \$80/day for a total of \$8000/day, mills \$24 per day for a total of \$4200/day, and all other services including mechanics, trades, laundry, entertainment, specialized vendors and transport among others combined to approximately \$50,000/day. The amount totaled equals a daily approximate local economy of \$98,000 USD.

To further examine the relationship between the local economy and the gold production estimate a comparison between the two can be made. \$98,000 USD is spent per day in Bantakho on goods and services representing the secondary economy. Using the total population of Bantakho of 35,000 people, and the estimated miner population of approximately 7000 people, we estimate a secondary economy that is roughly four times larger than the primary gold production and

therefore the gold production value needed to sustain the local economy is roughly \$35,000,000 USD divided by four, which equals \$8,750,000 USD. This is approximately \$10,000,000 USD lower than the estimated \$19,000,000 USD gold production estimate. This makes sense as 50% of the gold is collected by shaft owners to run the mine and take profits. Most of this is not spent in the immediate local village and so the local economy estimated here should be roughly four times half the gold, which equals 38,000,000. This is only 7.9% different than the estimate based on gold and so illustrates an approach to estimating the size of the secondary economy that can be used inversely to estimate gold production (and related mercury use) independently.

More detailed data on the local economy including the cost of living, savings, and remittances would further strengthen the independent lines of evidence, and further research is required. However, these independent lines of evidence conform to one another and provide a starting point for the building of supporting data sets to strengthen the reliability of the gold production and correlated mercury use estimate.

3.4.4 Origin and Availability of Mercury in Senegal

By all accounts and observations, mercury is highly available, easily purchased, and very low cost for miners in Senegal. On every site visited, the cost of mercury for a 10 gram plastic bag was between 1500 - 2000 CFA, or approximately \$3-\$4 USD. When compared with the average price received by miners in the field for 1 gram of gold (\$30 USD), and when factoring in a mercury amalgamation ratio of 1.3 Hg: 1 Au, the purchasing ratio of mercury used to gold produced makes it highly economical for the miners to use mercury as a processing tool.

Essentially for every \$30 that the miners make, they need to spend approximately 50 cents on mercury – a purchasing power ratio of 60:1.

There is no explicit law against mercury use in the ASGM sector in Senegal, and it is not mentioned in the national mining code, however it is considered *de facto* illegal by miners and local Kedougou authorities. This state of illegality is the result of article L44 of the *Environmental Code* which says that noxious and dangerous chemicals that present or may present a danger to humans or the environment, are subject to the control and supervision of relevant departments, and by way of national government edict n° 2010-1281, which prohibits the importation, collection, transportation, recycling, storage, manipulation, treatment or elimination of mercury without Ministerial approval (Sow, 2014). It is certain that no person or group involved in the ASGM sector has received such approval, and the last recorded importation of mercury was in 2010 and was of the amount of 372 kilograms (“Mercury Watch,” 2010). Therefore mercury is likely entering Senegal through clandestine supply chains, typically by gold buyers entering mainly from Mali, with whom it is believed that the majority of gold is exiting.

3.4.5 Understanding Mercury Use in Senegal

The present study demonstrates that the ASGM sector of Senegal used approximately 5.2 tonnes of mercury in the 2013-2014 mining year. This information provides an important starting point and baseline for evaluating mercury reduction initiatives in the sector.

Mercury use in ASGM in Senegal is essentially homogenous across the sector. In virtually all sites where mercury is used, the miners are substantially pre-concentrating the ore before applying mercury to form an amalgam. While this type of processing is much less mercury-intensive than whole-ore amalgamation, it also encourages individual processing, making it in some senses more difficult to eliminate as the use of mercury is much more decentralized and dispersed (Figure 16: Artisanal Mining and Processing Flow Chart. It also likely indicates that emissions and exposures are highly dispersed; potentially impacting a greater number of people and creating more contaminated sites/structures.

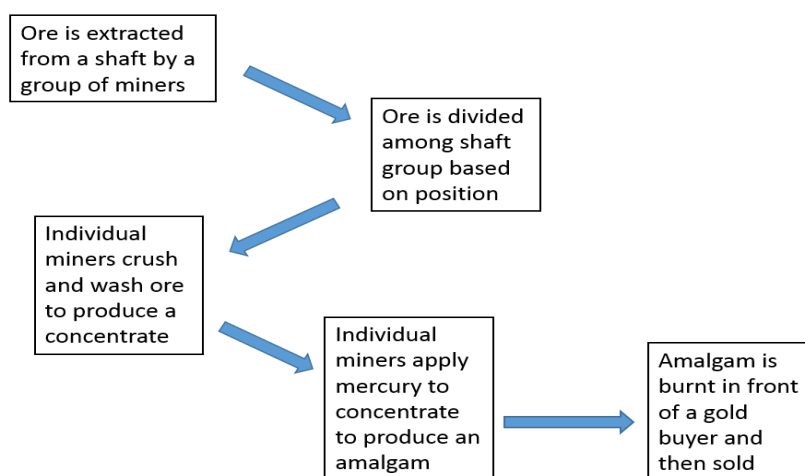


Figure 16: Artisanal Mining and Processing Flow Chart

Although the independent processing of concentrated material by miners contributes to a diverse mineral processing economy, it is also one of the greatest obstacles to mercury reduction and elimination. Under the current socio-economic system in Senegal, miners are able to take their own ore to be crushed, milled, sluiced and then amalgamated, all of which are available as services on the mine site by independent operators. However, this system also reinforces

mercury use as it leaves little options except for amalgamation for those low-earning shaft workers and other service providers who process small batches of concentrate in order to be paid on a regular basis. As such, one first step in reducing mercury use in the ASGM sector of Senegal would be for shaft groups to pool their ore and process it in batches, with the entire group paid in cash or gold as opposed to ore. This is the system that is in place on one of the largest sites studied in Senegal, Kharakhéna, where the decision was made by local authorities to mandate groups to process ore together in order to avoid disputes about the division of raw ore. This decision inadvertently also created a more centralized processing system that can more easily be targeted by technical initiatives, such as the introduction of mercury free processing systems. Centralized processing can be incentivized through increased gold recoveries brought by improved technologies, without disrupting the decentralized nature of the shaft groups.

Mercury use is not only homogenous across most of the ASGM sector of Senegal, but also across most of West Africa, thus the same problems identified through this research are generalizable to other countries, as are the same solutions applicable. The use of approximately 5.2 tonnes of mercury in the Senegalese ASGM sector – a ratio of mercury used to gold produced of just under 1.3:1 - is representative of the common practice of concentrate amalgamation, and the same ratios have been measured on numerous occasions by the author in places like Mali and Burkina Faso (Field Observations, 2013). Thus, per miner, mercury use is similar to other West African nations, and importantly ASGM remains Senegal's largest source of mercury pollution. On a global scale, because Senegal does not practice whole ore amalgamation and has a moderately sized ASGM sector, its ASGM mercury use and release represents only 0.5 % of global releases. Nonetheless, interventions that lead to reductions in Senegal are highly relevant and transferable to much of the rest world, and since most interventions are pilot in nature, Senegal remains an excellent place to carry out interventions and improve methodologies. In fact, as the Senegalese government prepares to ratify the Minamata convention and likely solicit resources to develop

a National Action Plan on mercury in ASGM, it will be required to declare that it has an ASGM sector that “is more than insignificant” (Annex 7 “Minamata Convention on Mercury,” 2015, p. 17). Having a mercury use estimate upon which such a statement can be justified and consequently used as a baseline for reductions in mercury use in the ASGM sector of Senegal, is one of the cornerstone results of this research.

3.4.6 Reducing Mercury Use

Technical support to miners and mining communities is essential to reducing mercury use and exposure, and such initiatives must be carefully planned to be pragmatic, feasible and respectful of the socio-economic and communitarian structures in place. Past initiatives in the Kedougou region of Senegal have attempted to reduce mercury use and exposure, but largely failed. Through a joint Blacksmith/Africa Clean project more than 100 retorts were distributed in eleven communities in the hope that the devices would be used to capture mercury emissions and reuse mercury throughout the amalgamation process. Throughout the present study no retorts were observed being used and informal interviews with key informants and miners on almost every mine site visited suggest that essentially no one in the sector is using these retorts, illustrating the failure of the project. Another program that expired in 2013 called Wulanaafa, funded by USAID, was originally meant to be an agricultural and natural resources management program, but began assisting ASGM communities. The project provided mercury awareness and health training, and donated two mills to two different communities, neither of which are currently in operation. Finally, a 2008 program called PASMI carried out a baseline ASGM study, spearheaded the creation of ASGM legal cooperatives (Economic Interest Groups (GIEs), and also provided some technical support in the form of community mills. At the time of the present

study, all but two of the GIE's created under PASMI were expired, and the mills provided were fully decommissioned, with one in the community of *Tomboronkoto* apparently having operated for no longer than twenty four hours.

The failure to respect and build upon existing socio-economic structures and to listen to the needs of miners is one of the main reasons that past initiatives in Senegal have produced few positive results. Working directly with miners to understand what solutions will work for them is a key component of sustainability, and the introduction of practical, low-cost and intuitive technology is essential for this low-capital, poorly educated sector. Mercury use and exposure can be reduced, and in some cases eliminated, and better practices utilized, when the right type of information about the sector is collected and adequately communicated to all stakeholders involved. An essential step to reducing mercury use in the Senegalese ASGM sector is to build off of the example observed in *Sambrambougou* as discussed above, where miners process their ore collectively and then divide profits in cash. Gentle nudging of mine shaft groups, and eventually entire sites, toward more centralized forms of processing will allow for the first major reductions in mercury use by avoiding the dispersed, independent mercury processing that is currently occurring. Such reforms of the ASGM sector are a part of a process however, and external impositions of centralized processing systems that the miners are not accustomed to are destined to fail. Working within customary structures, as recommended in Chapter 4, and building upon recognized practices by ASGM groups is a necessary part of the solution.

3.5 Conclusions

The objective of this chapter was to define and develop a replicable and widely applicable methodology for estimating mercury use in ASGM communities. The key findings (Table 15: National Estimates, indicate annual gold production by the ASGM sector of Senegal of 4.5 tonnes (+/- 49%), and mercury use of 5.2 tonnes (+/- 49%), with a miner population of approximately 67,000 people, and a local economy of approximately \$134 million USD (+/- 49%). The findings also show that once disaggregated based on miners working positions and taxes paid, the actual income of miners is between \$4-7 USD, with approximately 50% of all gold production revenues going to shaft group leaders.

By using Senegal as a case study it has been shown that a mixed-methods, rapid-appraisal that uses structured interviews, direct observations and counts, physical measurements, informal interviews and expert opinion can provide a reliable site level and national level estimate for mercury use and the correlated factors such as gold production and miner population numbers. It has further been shown that this type of study could be strengthened through an analysis of independent lines of evidence including understandings of the size of the secondary economy, or the cost of living on a mine site. Importantly, the socio-economic data that was derived from this study and described in Chapter 2, illustrate the importance of field-based holistic understandings of the ASGM sector, and show that mercury use estimates are an important research tool for informing sound policy for the sector.

4 Chapter 4: Policy Discussion

4.1 Regional Coordination

The two studies comprising this thesis provide timely and relevant quantitative and qualitative information that can assist the Senegalese government and other stakeholders in developing sound development policies for the ASGM sector and the Kedougou region. Although the findings are aimed to be specific to Senegal, many parallels can be drawn with the ASGM sectors of surrounding countries. Both Mali and Guinea, which border Kedougou and share the same greenstone belt that makes gold mining popular in the area, are known to have thriving ASGM sectors that function very much under the same socio-economic structures and technical processes that define the ASGM sector of Senegal. Mali, for example, utilizes the *Tomboulouma* system much in the same way as the Senegalese, and there is significant anecdotal evidence of a strong gold and mercury trade connection between the two countries. Other nearby countries that are known to have very similar ASGM sectors includes Sierra Leone, Liberia, Ivory Coast, Burkina Faso, and Ghana. All of these countries are signatories to the Minamata Convention and will be aiming, like Senegal, to develop practical National Action Plans for their ASGM sectors. As such, the findings and discussions presented throughout this research, and that which follows, can be valuable for a much wider audience than Senegal alone, including particularly policy makers in surrounding countries and at regional and global levels, all of whom are in need of developing solutions for ASGM.

Considering the migratory nature of workers involved in ASGM, countries in West Africa need to work together to find solutions that satisfy miners who often see no borders with regard to their work. According to a 2008 study, 61% of ASGM miners in Senegal are Senegalese, 28% Guinean, and 13% Malian (UNIDO, 2010). The Economic Community of West African States works to create regional economic integration, and in 2009 this included the creation of a *Directive on the Harmonisation of Guiding Principles and Policies in the Mining Sector*. While the document currently makes no mention of ASGM, it could provide a valuable forum for discussions and integrated policy surrounding ASGM, which may be beneficial for countries like Senegal and Mali and Guinea, whose ASGM populations and hot-spots are situated along a porous border zone.

4.2 Rural Development

Although agriculture plays a vital role in rural development policy (Hilson & Garforth, 2012; Okoh & Hilson, 2011), the activities that complement it and in fact strengthen it should also be addressed and supported. In fact, the United Nation's Wye Group (2011) asserts that in a territorial approach to rural development, a focus on strategic investments in new sectors as opposed to subsidizing declining sectors is desirable. In other words, the government of Senegal should aim to transition away from a sectorial approach to rural development, which distinguishes between farm and non-farm activities, and instead consider the connection between the two based on territorial contexts. With the impoverished region of Kedougou, situated some 700 km from the Capital Dakar, and heavily influenced by seasonality, migrant workers, and importantly, ASGM, a territorial approach in this case may even mean subsidizing the ASGM

sector first before other rural sectors of Kedougou. A rural development focus on non-farm incomes can actually help the agricultural sector by reducing farmer's vulnerability to adverse shocks, by providing income-generating opportunities for the landless poor, and improve well-being in a way that farming cannot (Wye Group, 2011). ASGM, as this research has demonstrated, has the ability to provide substantial benefits to the rural agrarian populations in Kedougou, Senegal, and the government should capitalize and support this opportunity.

4.3 Large Scale Mining and ASGM

Throughout the 1990s the liberalization of most of Africa's mining codes occurred, opening up opportunities for foreign large-scale mining (LSM) to gain contracts and concessions (Jønsson & Fold, 2011). This has largely been the case in the Kedougou region of Senegal, with large scale mining proliferating over the last 10 years, with over five companies holding exploration permits that cover a total area of approximately 6000 km² (Amnesty International, 2014). Official gold production in Senegal has been limited to the Sabodala gold project in Kedougou operated by Teranga Gold, which is producing approximately 5 tonnes of gold per year (Soto-Viruet, 2012). There is no doubt that the LSM sector will bring some benefits to the Senegalese government, particularly in the form of eventual taxes, royalties, and infrastructural development, but the degree to which this will benefit the rural inhabitants of the Kedougou region is less certain. Typically, large scale gold mining employment represents a fraction of the estimated employment provided by ASGM, because it is much more technical and has no need for a large physical labour force, and those nationals that are employed tend to be well-educated and often from urban centres. For example, Teranga Gold in 2014 employed 585 people, 90% of which

were nationals, and 28% of which were local to the Sabadola area (Teranga Gold, 2014). Of the 525 nationals employed by Teranga, this represents less than 1% of the amount of people employed in the ASGM sector of Senegal, or assuming conservatively that 50% of the Senegalese sector is foreign; it still only represents 1.5% of the employment magnitude and less at the local level.

With this research estimating gold production at 4.5 tonnes per year by the ASGM sector, it is producing nearly the same amount of gold as the LSM sector, and its socio-economic benefits are far reaching. For example, according to Teranga Gold, the Sabodala gold project in 2013 contributed \$22.7 million USD to the Senegalese government, \$4.3 million to local payroll, and \$0.8 million to CSR initiatives (Teranga Gold, 2014). Even by considering that the amount being transferred to the government will somehow be reinvested in the Kedougou area, this maximum amount potentially being left in the Kedougou area by Teranga Gold amounts to approximately 19% of that which the ASGM sector leaves in the local economy directly. If several of the various other exploration companies in Senegal become operational the economic benefits of the LSM sector will grow, but as Clausen et al. (2011) point out, an economic efficiency test in various country-specific contexts might find that a wider distribution of wealth within a society, as allowed by ASGM, is in fact preferable to larger economic growth within fewer hands, as is common with LSM. The value of the current study is that it provides a detailed understanding of the socio-economic importance of ASGM to the area of Kedougou, while also creating a baseline for improvements. This information may allow the Senegalese government to consider the importance of developing and supporting the ASGM sector alongside the LSM sector.

4.4 Formalization of ASGM

The Senegal ASGM sector is one that has grown quickly over the last several years, with the sector now comprised of approximately 67,000 people producing approximately 4.5 tonnes of gold per year, which seems to conform to the growth in neighboring countries such as Mali (Diallo, 2014). This growth in numbers and production in the ASGM sector have contributed to the rise in mercury use in Senegal, which is now estimated to be at approximately 5.2 tonnes per year. The government of Senegal has been struggling to administer this growing sector, with various formalization approaches attempted over the last five years. Among such approaches have been the establishment of Economic Interest Groups (GIEs) which are able to obtain Artisanal Exploitation Authorizations (AEAs); miner registration card systems; and most recently the strong-handed closure of most ASGM sites and the implementation of a mining *couloir* system. The GIE/AEA approach was a failure from its inception, with an annual 3% production tax, a \$3000 USD registration fee that expired after two years, and a series of paper filings in the capital 12 hours away by car. To address these issues, in 2009 the government allowed GIE's to obtain the AEA with the commitment to pay the registration fee at the end of the two year period. Regardless, by 2014 there were no GIE's with registered permits, and almost all had defaulted on their payments. This was not because they were unable to afford the payments, but rather because the government created little incentive and numerous obstacles for them to transfer their pre-existing negotiated customary arrangements to ones with the government.

Most recently, the Senegalese government has followed the example of many other countries in the implementation of the mining *couloir* system, which pushes ASGM miners into designated areas that do not overlap with large-scale mining interests. Interviews and observations throughout the present study made it clear that such arrangements will not suffice for miners who already have active agreements with customary authorities. Current agreements allow for thriving local economies and provide for direct local economic development mechanisms, such as through the *Tomboulouma* system as described above, where mining royalties are often re-directed into community development initiatives. These are socio-economic arrangements that rural inhabitants are accustomed to and that have governed other traditional livelihoods for millennia. These arrangements do not create any unnecessary burden on the ASGM sector, such as annual registration fees, complicated bureaucratic steps, and excessive paperwork. It is therefore highly unlikely that a government program aimed toward moving miners into designated areas will be a success.

The evidence from other areas where governments have designated special mining zones referred to as *couloirs* or mining corridors shows the shortcomings of such a system. In Africa, this has primarily been tried in Tanzania, Ghana, Zambia, Zimbabwe, Mozambique, DRC, Mali, and now most recently Senegal. Policies to institute *couloirs* have largely failed because the amount of space provided to miners has been inadequate and the gold deposits of the areas designated have been poor (Jønsson & Fold, 2011). In Mozambique for example, 48 *couloirs* had been established by 2006, but were largely unused and did little to control the ASGM sector (Dondeyne & Ndunguru, 2014). In Ghana the *couloir* system has also rarely worked and has met resistance from miners, customary land owners, and communities (Nyame & Blocher, 2010).

The *couloir* system essentially creates open access situations by disrupting customary governance structures, and by doing so there is little enforcement of who can mine, how they mine, and where they mine within the *couloir* (unpublished field observations, June 2013). This creates a mining situation of increased disorganization, conflict, and environmental degradation, and as Bugnosen (2003) aptly points out, discourages small-scale mining entrepreneurs and the development of a local mining-business culture. It also further contributes to the individual mining processing structures that are discussed above that are conducive to pervasive and dispersed mercury use. Without the development of an organized business culture and sense of ownership and empowerment by locals of their mining situations, it is likely that the sustainability of efforts to reduce or eliminate mercury use in ASGM is weakened. Technical support projects linked to the ASGM sector to assist in the reduction and elimination of mercury need to support formalized entities that have the ability to invest in, grow and professionalize their operations. In those cases where the *couloir* system is unavoidable due to tenure rights issues, the Senegalese government could take pragmatic steps to at least ensure improved practices. For example, the government could recognize the locally registered *Tomboulouma* and provide support and training to them for improved mining and resource management practices to better enable the miners to meet accepted health and safety and environmental standards. Improved practices in ASGM, including mercury-free technologies and techniques, are vital aspects to sustainability in ASGM and should be considered an important goal.

Finally, the government could eliminate unnecessary annual fees and direct production taxes, instead seeking out a percentage of the customary royalty as a part of the official registration process, or not seek any rent from the ASGM sector at all. A large majority of the gold being

produced in the ASGM sector of Senegal is being sold through clandestine channels into Mali and in some cases Guinea. Were taxes and royalties to be eliminated on the ASGM sector, miners would be more apt to formalize operations and sell gold through transparent, legal supply chains. Although a small revenue stream would be lost to the government, it would be outweighed by at least two benefits: a) large amounts of Senegalese gold could be purchased by the government at a competitive price, increasing the national gold reserve; and b) the illicit gold trade routes would be slowed, thereby slowing the flow of mercury and perhaps other contraband into Senegal and inadvertently pushing miners toward alternative practices. By understanding and recognizing the importance of ASGM to the region of Kedougou, the government of Senegal can begin to regard the sector as more than just another form of mineral exploitation, and rather as a vital component to rural economic development.

4.5 Recommendations

Addressing mercury use in the sector as a part the government's National Action Plan on mercury and ASGM for the Minamata Convention requires a holistic approach to the sector, beyond simply compartmentalizing ASGM into *couloirs* or instituting top-down formalization measures that do not recognize the needs, requirements, and existing functioning arrangements of ASGM communities. In 2010 the government of Senegal, through financing from the United Nations Industrial Development Organization, created a National Strategic Action Plan on ASGM which included eight objectives covering the period from 2011-2015. These objectives ranged from baseline data gathering to formalization and training measures, but as of January 2014 none of these goals had been met (Sow, 2014). The first objective of this NSAP is of

particular importance to the present study, as it aimed to evaluate the state of pollution and the impacts on health of mercury use in ASGM, with a designated budget for this action of approximately \$50,000 USD (UNIDO, 2010). Such a study was never implemented, but in 2013 the Senegalese government became a signatory to the *Minamata Convention on Mercury*, meaning that a new NSAP on ASGM will be required, or in Minamata Convention language, a National Action Plan (NAP).

Although some of the previous objectives of the 2010 NSAP should be included, specific targets (currently unspecified) and actions to be included within a renewed Senegalese NAP on ASGM for the Minamata Convention ultimately will require deliberation and approval by the Senegalese administration and should be developed in collaboration with the various stakeholders including members of the ASGM community, local NGOs, the LSM sector, and representatives from local agricultural associations, as a part of a national consultation process. The following general policy recommendations, which have been formulated from the findings of the present study, aim to inform this process by providing a summarized analysis of the requirements to bring about mercury use reduction and sustainability in the ASGM sector of Senegal. Importantly, the present study also provides a baseline assessment for the sector on which an NAP can be built.

Policy recommendations for the Senegalese ASGM sector include:

- Increased regional coordination on ASGM, particularly amongst the ECOWAS (Economic Community of West African States) countries, in some cases bilaterally such as with the Guinean government

- Incorporation of ASGM into a territorial approach to rural development that recognizes the importance of ASGM as a complementary activity to traditional agrarian livelihoods in the Kedougou region
- The development of stronger rights and recognition for ASGM operations respecting the value of ASGM as a complementary activity to LSM
- A streamlined formalization process that is cheap, efficient, locally administrated and provides options for foreign workers who can prove they are members of a shaft group and working under the authority of a *Tomboulouma*
- Direct collaboration with customary authorities and the *Tomboulouma* in order to ensure best practices on the *couloirs*
- The elimination of production taxes and royalties on ASM gold
- The elimination of importation taxes on chemical-free ASGM machinery and supplies
- The establishment of mercury burning zones and training on the efficacy and value of centralized, communal processing by shaft groups
- Training of local NGOs on mercury inventory methodologies and the elaboration of a bi-annual inventory of the sector
- Annual mercury reduction targets that are supported by technical interventions that respect the socio-economic structures that exist currently on ASGM mine sites.

5 Chapter 5: General Conclusion

The Senegalese government, as a signatory and eventual ratifying party of the *Minamata Convention on Mercury* will be obligated to develop a National Action Plan on mercury use in ASGM, which includes a mercury inventory for the ASGM sector of Senegal. The objectives of this research have been to: (i) analyze the socio-economic significance of ASGM and its potential for development in relation to other rural sectors in the developing world, and; (ii) define and develop a replicable and widely applicable methodology for estimating mercury use in ASGM communities. Using a mixed-methods, rapid-appraisal approach, this research provided the first detailed mercury inventory and methodology for estimating mercury use in the ASGM sector of Senegal, as well as an analysis and overview of the socio-economic significance of ASGM to the area of Kedougou and more generally for Senegalese rural development. This detailed inventory of the ASGM sector of Senegal provides for the first time baseline information upon which the Senegalese government can recalibrate old and formulate new policies that are more responsive to field realities and that help it to meet the requirements of the Minamata Convention.

The relevance and fit of these two studies to one another is a natural one, the collection and analysis of socio-economic information of ASGM plays an important role in the estimation of mercury use in the sector, while also providing the required information on which mercury reduction and ASGM improvement projects can be built. The findings demonstrate a thriving ASGM sector composed of approximately 67,000 people, producing 4.5 tonnes of gold per year while releasing 5.2 tonnes of mercury into the environment. The findings also evidence an

ASGM sector strongly connected to customary tenure and complementary to traditional agricultural practices, and one that is important to rural development in the Kedougou region of Senegal. As such, this research has made an important contribution to the literature on international development studies, building upon previous studies on alternative and sustainable livelihoods, and non-farm income diversification. Ultimately, this research provides a global overview and analysis of the ASGM sector that can lead to its improvement as a livelihood for not only the thousands that rely on it in Senegal, but the millions that rely on it in Sub-Saharan Africa and beyond.

There are many inherent challenges in research on the informal sector, and these are exacerbated in rural developing country settings. This work could be improved through increased funding for longer research periods and larger research teams, enabling a larger body of sample sites and sample groups to contribute to the datasets. Further, complementary studies that provide independent lines of evidence, such as those described in Chapter 3, need be further developed and strengthened. One effective way of improving information on the ASGM sector would be to include ASGM related questions in rural censuses that take place in known ASGM regions such as Kedougou, Senegal. Regardless of the challenges, by utilizing the present methodology toward improving information on the ASGM sector, the Senegalese and other governments can develop a baseline as a starting point for building a more robust monitoring system for the sector, and importantly for building practical and sustainable improvement projects for ASGM.

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Appendix I – How do ASGM mines operate and what is their legal status?

There is relative homogeneity in terms of the way that mines operate across the ASGM sector of Senegal, and also many similarities between the ASGM sectors of other West African countries. The majority of mines are primary hard-rock, where groups of miners come together, often under the leadership of a financier or ‘shaft leader’, to begin the exploitation of a shaft, or several shafts, within a mining community. The mining community is typically administered by a customary authority who grants permission for that group to begin working a shaft in exchange for an informal tax or royalty which is often paid in the form of ore. These mining groups will work the shaft on a commission basis, being paid in ore rather than a wage, by the shaft leader. When the shaft is not producing ore - for example during the preliminary digging phase, or when excess water cannot be adequately removed from a shaft - the miners are incentivized to continue working by having their food and shelter provided by the shaft leader, and with the expectation that they will eventually strike a good deposit.

Once gold bearing ore is removed from the shaft, it is distributed between the shaft leader, the various miners of the shaft group, and the customary authorities (see section 3.4.2). Individual miners will take their ore and process it independently or through the purchase of crushing, milling, and sluicing services which are provided on all sites. Once a gold concentrate is produced, the miners then add mercury which forms an amalgam with the gold, allowing them to easily extract and burn it to produce sponge gold. It is this sponge gold that is then sold to a gold buyer within the community. The gold buyers are also typically the merchants of mercury,

selling or even giving the mercury to miners with the expectation that they will sell their gold to them.

The life of a mine shaft or mining community can vary based on a variety of factors, including particularly the gold endowment of that site, but also the sentiment of the miners on the potential for gold on that site in comparison to others. Some mining communities will be completely abandoned for a year, when all of the miners leave for a more promising site, only to spring up again the following year. Based on the information provided throughout the various informal interviews within this study, some ASGM mining communities in Senegal have been in existence for more than 25 years. This longevity of an ASGM site is common, despite the tenuous legality of such mines throughout their existence.

Today in Senegal, like most other countries, minerals are the property of the state, regardless of land rights and private or customary land ownership (Clausen et al., 2011). Governments allocate access to these resources, creating *de jure* mineral rights for approved mining activity which, when granted, constitute *de facto* private property claims. Currently, few ASGM miners have such *de jure* mineral rights - 90% of artisanal miners operate informally in Sub-Saharan Africa (Clausen et al., 2011), and almost all in are therefore illegal. Current mining law and practice in most developing countries today create unfavourable conditions and bureaucratic hurdles for most ASGM operators, and make the acquisition of mineral and property rights out of reach for most (Hilson, 2013). When property rights are granted to ASGM groups, they are often tenuous and can be withdrawn by the state at any time, particularly to accommodate the interests of large-scale mining (see Bugnosen, 2003; Tschakert and Singha,

2007; Jønsson and Fold, 2011; Hiron, 2011). As such, ASGM has largely developed outside of formal institutions, in a condition of informality that is governed by extralegal rules and customary authorities (see section 2.5.2). Despite this informality being a well-functioning, organized and efficient system that complements existing customary land uses, in many senses it is simply still an ‘illegal’ activity. This illegality acts as a major hurdle for any type of intervention aimed toward improving the sector, as an impediment toward investment in the sector, and also serves to stigmatize miners socially, imposing upon them a ‘status’ that they must live with every day.

Appendix II - Photographs



Photo 1: The uniformed Tomboulouma in Bantakho – arbiters and customary authority on the mine site



Photo 2: A miner pans some concentrate after applying mercury



Photo 3: A long line of covered mine shafts in Bantakho



Photo 4: Two pullers wait for the next batch of ore to come up



Photo 5: Female colluvial miners pan for gold on a small site