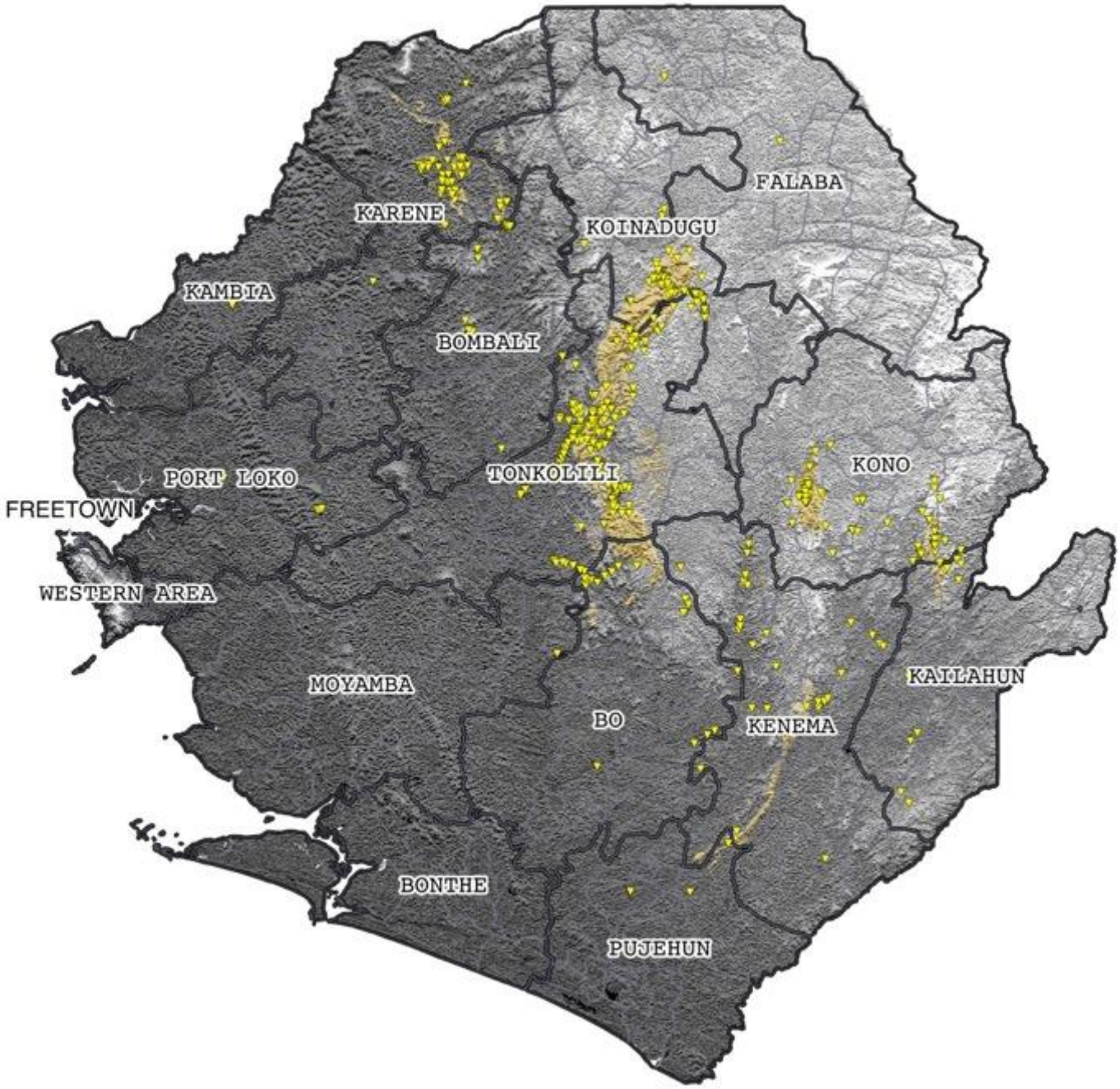
THE ASGM OVERVIEW OF SIERRA LEONE

DRAFT 1.5



ENVIRONMENT PROTECTION AGENCY
FREETOWN, SIERRA LEONE

APRIL 12, 2018

This document is part of The Global Environment Facility (GEF) funded project, implemented by UN Environment, where The Environmental Protection Agency of Sierra Leone (EPA-SL) and United Nations Institute of Training and Research (UNITAR) serve as the executing partners.

This report is based on the field research carried out by Juha Ronkainen (Consultant, EPA-SL), Jorden De Haan (Consultant, UNITAR), Dr. Kelvin Anderson (Consultant, EPA-SL) and Mohamed Abdulai Kamara (Senior Environmental Officer, EPA-SL). This report has been prepared for the Environment Protection Agency of Sierra Leone by Juha Ronkainen (editor, chapters 1-3, 4.1-4.4, 4.7-4.9, 4.13-4.15, 5), co-authored with Jorden De Haan (chapters 4.5-4.7, 4.9, 4.10-4.12, 4.14, 4.15, 5). Dr. Kelvin Anderson authored the attached Countrywide Geological Report (Annex 4) and his input was substantial in chapters 4.4 and 4.8. Mohamed Abdulai Kamara provided significant input in chapters 3 and 4.5. All photos and illustrations are from Juha Ronkainen until otherwise noted.

The views expressed do not necessarily represent the views of affiliates organizations.

Glossary

[To be extended]

ASGM: *Artisanal and small-scale gold mining*

ASM: *Artisanal and small-scale mining*

Artisanal and small-scale gold mining *means gold mining conducted by individual miners or small enterprises with limited capital investment and production;*[1]

Artisanal mining operations *means mining operations that does not exceed a depth of ten metres;*[2]

Formalization of the ASGM sector can be understood as
a process that ensures that ASGM stakeholders are legalized and organized in legitimate entities which represent their needs; policies are implemented, monitored, and enforced; and that ASGM stakeholders receive technical, administrative, and financial support that enables them to adhere to standards.[3]

Small-scale mining *means the intentional winning of minerals in mechanised operations not exceeding twenty metres in depth or involving the sinking of shafts, driving of adits, or other various underground openings;*[4]

[1] (Minamata Convention: Article 2).
[2] (Mines and Minerals Act, 2009: Section 1)
[3] UN Environment Global Mercury Partnership, forthcoming. Formalizing Artisanal and Small-scale Gold Mining: A Practical Toolkit for Countries Preparing National Action Plans.
[4] Ibid.

1 Table of Contents

GLOSSARY 3

1 BACKGROUND 6

2 RESEARCH TOPICS 7

THE MINAMATA CONVENTION AND ASGM 8

3 METHODOLOGY 9

3.1 Research Methodologies 10
3.2 Selection of the visited ASGM communities 11
3.3 Limitations 12

4 RESEARCH FINDINGS 14

4.1 Previous experiences in addressing ASGM 14
4.2 Demographic, social and economic information 15
4.3 The size of the ASGM sector 22
4.4 Geographical distribution of ASGM 25
4.5 Legal and regulatory status 29
4.6 Leadership and organization of ASGM at national and local levels 30
4.7 Gold Trade 34
4.8 Mining and processing information 39
4.9 Mercury use and trade 50
4.10 Impacts on local development 54
4.11 Women in ASGM 60
4.12 Youth and Children 65
4.13 Environmental information 68
4.14 Health information 76
4.15 Access to financial and technical assistance and formalization 81

5 CONCLUSIONS 84

5.1 Importance of the ASGM sector 84
5.2 Challenges 84
5.3 Solutions 85

6 BIBLIOGRAPHY 87

7 ANNEX 1: DESK REVIEW AND ANALYSIS OF THE RESEARCH TOPICS 1

8 ANNEX 2: STRATEGY FOR THE MINING COMMUNITY SURVEYS 1

8.1 Background 1

8.2 COMMUNITIES WHERE MERCURY IS USED 1
8.3 COMMUNITIES WHERE MERCURY IS NOT USED 2
8.4 TRAVEL PLAN 3

9 ANNEX 3: ON RESEARCH METHODOLOGIES 1

9.1 QUANTITATIVE METHODS 1
9.2 QUALITATIVE METHODS 2
9.3 GEOSPATIAL METHODS 3

10 ANNEX 4: COUNTRYWIDE GEOLOGICAL REPORT I

1. INTRODUCTION 1

2. METHODOLOGY 1

3. SUMMARY GEOLOGY OF GOLD IN SIERRA LEONE 1

4. MINING COMMUNITIES VISITED 3

4.1. SELLA LIMBA CHIEFDOM, KARENE DISTRICT 3
4.2. SANDA LOKO CHIEFDOM, KARENE DISTRICT 4
4.3. DIANG CHIEFDOM, KOINADUGU DISTRICT 6
4.4. SIMIRIA CHIEFDOM, TONKOLILI DISTRICT 10
4.5. KUNIKE BARINA CHIEFDOM, TONKOLILI DISTRICT 15
4.6. YELE CHIEFDOM, TONKOLILI DISTRICT 15
4.7 VALUNIA CHIEFDOM, BO DISTRICT 17
4.8 BAOMA CHIEFDOM, BO DISTRICT 20
4.9 NIMIKORO CHIEFDOM, KONO DISTRICT 20
4.10 SANDOR CHIEFDOM, KONO DISTRICT 25

5. CONCLUSIONS 26

11. ANNEX 5: CALCULATION SHEETS 1

1 Background

According to the Global Mercury Assessment,[5] Artisanal and Small-scale Gold Mining (ASGM) constitutes 37% of the global anthropogenic atmospheric mercury emissions to environment. According to this study, an estimated total of 727t (estimates range from 410-1040t) of mercury is released to atmosphere by actions of mercury amalgamation used to liberate gold from gangue minerals.

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. The Convention was adopted on 10 October 2013 at a Diplomatic Conference held in Kumamoto, Japan, and entered into force on 16 August 2017. The first conference of parties was subsequently held in Geneva on 24-29 September 2017.

Sierra Leone signed the Convention on 12 August 2014 and ratified it on 1 November 2016. To facilitate early implementation of the Convention, the Environmental Protection Agency is executing the Global Environment Facility (GEF) funded project *Development of the Minamata Initial Assessment (MIA) and the National Action Plan (NAP) for Artisanal and Small-scale Gold Mining (ASGM) in Sierra Leone*. The project is co-executed by the United Nations Institute for Training and Research (UNITAR).

The objective of the NAP is to reduce (and eliminate if possible) the use of mercury and emissions and releases. However, because the ASGM is a source of livelihood for millions of people worldwide, any transition to more environmentally-friendly methods should be based on a comprehensive understanding of the sector.[6] For this reason, NAP executing countries should strive to prepare a *national overview of the ASGM sector*.[7]

This document is an overview of the ASGM sector in Sierra Leone for decision makers. Chapter 2 outlines the specific research topics for this study, and chapter 3 presents the methodology used for its implementation. Chapter 4, thematically organised, then presents the overall research findings. Conclusions based on the research findings are presented in chapter 5. To increase general readability of this overview, much of the technical information can be found in footnotes and annexes.

[5] UNEP Chemicals Branch, 2013.

[6] And more generally, the NAP is an opportunity to make the ASGM sector more sustainable and promote the sector's contributions to socio-economic development.

[7] (UNEP, 2015)

2 Research Topics

According to UNEP guidance, "the formulation of the NAP should be based on Convention obligations and current technical and scientific understanding of the ASGM sector, the use of mercury and processing of gold amalgam, including its health and environmental effects, as well as social and economic analysis of the ASGM sector."[8]

More concretely, the four main research themes referred to above include:

- **Policy, regulatory, and institutional framework**, covering the national legal and policy frameworks that pertain to the regulation of extractive industries, including ASGM sector;
- **Health aspects**, examining the impact of ASGM on the health of miners, the broader mining community and surrounding populations;
- **Socio-economic aspects**, such as the importance of ASGM from the perspective of the populations engaging in it, including from a gender and age perspective;
- **Technical and environmental aspects**, covering the overall scale of ASGM, the techniques applied and the environmental impacts.

Figure 1: Themes of the ASGM overview. (Illustration: Malgorzata Stylo from (UNITAR, 2017b). Used with permission.)

As illustrated in Figure 1, these four topics have important interlinkages and are all relevant for creating an evidence-base for a comprehensive and context-specific National Action Plan. The objective of this report is to provide the Government of Sierra Leone with tools and in-depth knowledge of the ASGM sector, in order for them to manage and develop the ASGM sector in compliance with the requirements set in the Minamata Convention. Further to that, this document also examines ways in which the ASGM sector could be better aligned with the strategic priorities set for minerals sector in the Agenda for Prosperity[9,10].

For the purpose of this study, the four research themes have been broken down into the following 15 research topics:

1. Previous experiences in addressing ASGM;
2. Demographic, social and economic information;
3. The size of the ASGM sector;
4. Geographical distribution of ASGM;

[8] UNEP, 2015.

[9] Sierra Leone's Third Generation Poverty Reduction Strategy Paper (2013 – 2018). Available at http://www.sierra-leone.org/Agenda%204%20Prosperity.pdf, accessed 4 April 2018.

[10] According to the Agenda for Prosperity, the two main strategic priorities of the Mineral Sector are to:

- *Ensure that Sierra Leone's mineral wealth supports national economic and social development in a sustainable manner.*
- *Ensure that the mining sector becomes transparent and accountable and promotes good investment.*

In order to achieve these priorities, the document also presents ten actions points for government.

5. Legal and regulatory status;
6. Leadership and organization of ASGM at national and local level;
7. Gold trade;
8. Mining and processing information;
9. Mercury use and trade;
10. Impacts on local development;
11. Women in ASGM;
12. Youth and children
13. Environmental information;
14. Health information;
15. Access to financial and technical assistance and formalization.

THE MINAMATA CONVENTION AND ASGM

Minamata Convention postulates the obligation of countries with 'more than insignificant ASGM activity' to develop and implement a National Action Plan (NAP), with the following objective:

> *Each Party that has artisanal and small-scale gold mining and processing subject to this Article within its territory shall take steps to reduce, and where feasible eliminate, the use of mercury and mercury compounds in, and the emissions and releases to the environment of mercury from, such mining and processing,* (Article 7.)

More specifically, according to the convention the NAP should include:

a) *National objectives and reduction targets;*
b) *Actions to eliminate:*
  (i) *Whole ore amalgamation;*
  (ii) *Open burning of amalgam or processed amalgam;*
  (iii) *Burning of amalgam in residential areas; and*
  (iv) *Cyanide leaching in sediment, ore or tailings to which mercury has been added without first removing the mercury;*
c) *Steps to facilitate the formalization or regulation of the artisanal and small-scale gold mining sector;*
d) *Baseline estimates of the quantities of mercury used and the practices employed in artisanal and small-scale gold mining and processing within its territory;*
e) *Strategies for promoting the reduction of emissions and releases of, and exposure to, mercury in artisanal and small-scale gold mining and processing, including mercury-free methods;*
f) *Strategies for managing trade and preventing the diversion of mercury and mercury compounds from both foreign and domestic sources to use in artisanal and small-scale gold mining and processing;*
g) *Strategies for involving stakeholders in the implementation and continuing development of the national action plan;*
h) *A public health strategy on the exposure of artisanal and small-scale gold miners and their communities to mercury. Such a strategy should include, inter alia, the gathering of health data, training for health-care workers and awareness-raising through health facilities;*
i) *Strategies to prevent the exposure of vulnerable populations, particularly children and women of child-bearing age, especially pregnant women, to mercury used in artisanal and small-scale gold mining;*
j) *Strategies for providing information to artisanal and small-scale gold miners and affected communities; and*
k) *A schedule for the implementation of the national action plan.* (Annex C.)

3 Methodology

This study employed a mixed methods approach, combining quantitative, qualitative and geospatial data collected from both secondary and primary sources. The study was carried out in four phases:

- First, the **existing literature** was reviewed according to the research themes, and data gaps were highlighted. Secondary sources provided important information on various research topics, and the findings are discussed in chapter 4 along with the findings from the field. The summary of this literature review can also be found in Annex 1.
- Second, **key-informant interviews** were conducted by the EPA[11] both in provinces and in Freetown in January 2018. During this phase, all main mining hubs in Sierra Leone were visited to combine information on existing ASGM activities. The results of this work can be found in Annex 2.
- Third, **mining communities to be surveyed** were selected on the basis of the information gathered during phase two, and in consultation with NMA. Mining community surveys were conducted between 22 January and 17 February by the research team consisting of national and international experts.[12] The detailed field mission schedule can be found in Annex 2.
- Fourth, information on the environmental impact and the scale of ASGM operations was collected using **satellite imagery**.

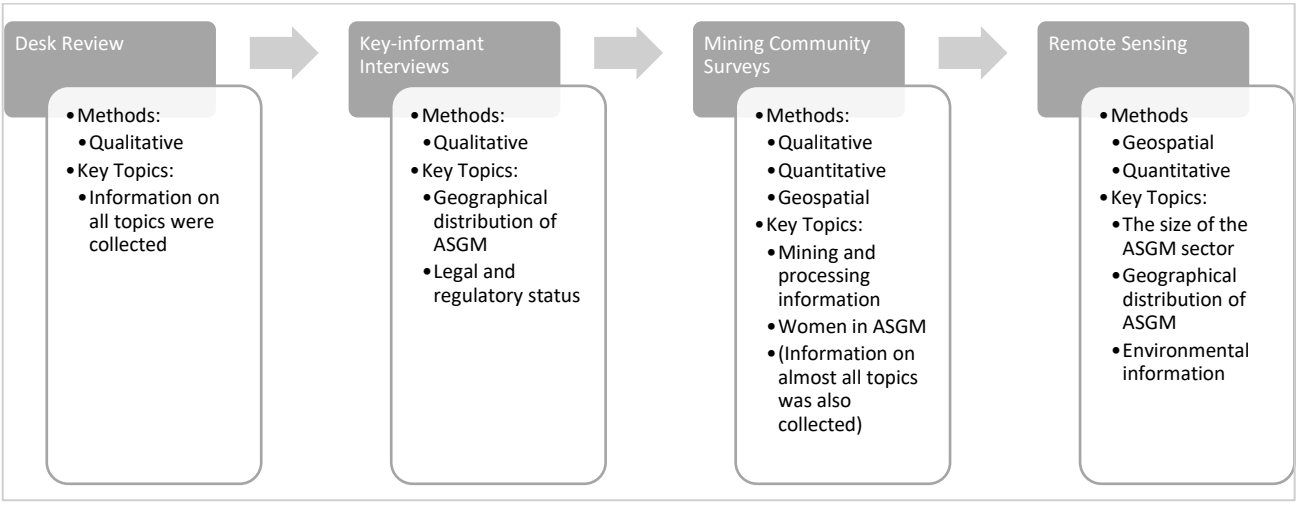


Figure 3: Phases, applied methods and research topics[13]

[11] This was mainly carried out by Mohamed Abdulai Kamara (Senior Environmental Officer, EPA). Juha Ronkainen (Consultant, EPA) and Jorden De Haan (Consultant, UNITAR) accompanied Mr. Kamara in interviews taking place in Freetown.

[12] The research team included Juha Ronkainen (Consultant, EPA), Jorden De Haan (Consultant, UNITAR), Dr. Kelvin Anderson (Consultant, EPA) and Mohamed Abdulai Kamara (Senior Environmental Officer, EPA).

[13] Remote sensing was not originally planned to be that important, but it emerged as crucial methodology to better understand the scale of the scattered ASGM sector in Sierra Leone.

3.1 Research Methodologies

In order to answer to the long list of research topics introduced in chapter 2, three main methodological approaches were utilized in this study, i.e. qualitative, quantitative and geospatial. As most of the questions are qualitative in nature, it was natural to adopt the UNITAR Methodology for the Socio-economic ASGM study, as a fundamental methodological guidance for this study.[14] In technical qualitative questions, the UNITAR methodology was complemented by the toolkit developed by the Artisanal Gold Council (AGC).[15]

In quantitative questions, the main inspiration came from the AGC toolkit, as well as from the handbook developed by Levin Sources[16]. The approach developed by AGC, served as a basis for estimating the size of the ASGM sector, including amount of gold produced or mercury used. The handbook from Levin Sources provided useful insight into tracking and understanding illicit financial flows in ASGM.[17]

To better understand the scale of ASGM operations in Sierra Leone, a bespoke geospatial methodology was developed for this study, to make use of the large spatial datasets made available for this research by NMA, and to utilize satellite imagery information in the context of this study. The geospatial

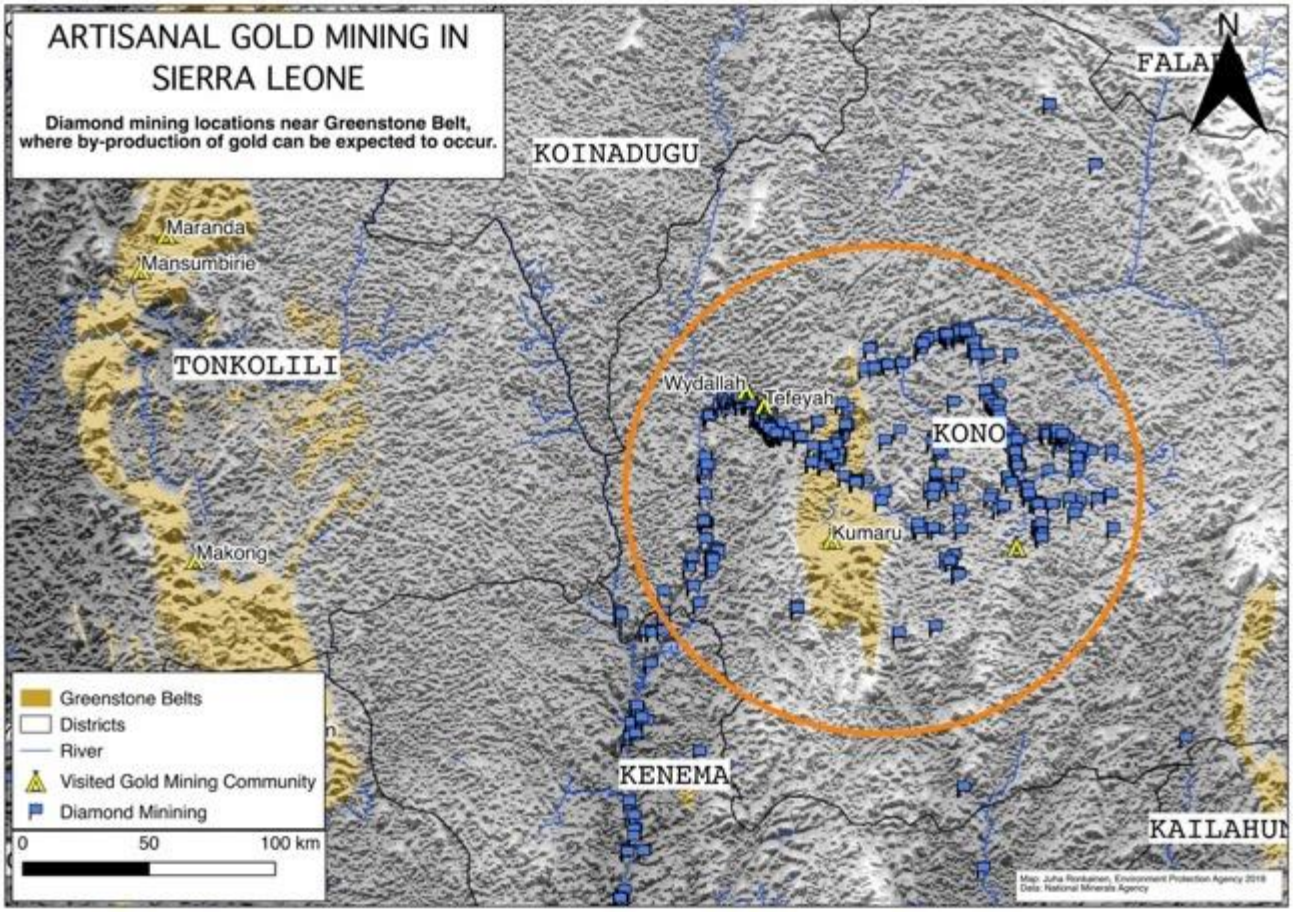


Figure 4: Illustration of the geospatial method used to estimate by-production of gold

[14] (UNITAR, 2017b)
[15] (O'Neill & Telmer, 2017)
[16] (Hunter M. S.-N., 2017)
[17] (Hunter M. S.-N., 2017)

methodology is explained in detail in Annex 3, where also quantitative and qualitative methodologies are further elaborated.

3.2 Selection of the visited ASGM communities

The field research was conducted in four weeks on 22 January – 17 February. The selection of the sites was based on the preliminary data collection carried out by EPA, while NMA was also consulted to make sure no important communities had been neglected. As establishing baseline estimates on mercury use is a direct requirement of the Minamata Convention, two groups were formed when selecting the communities to be visited.

a) Mining communities where mercury was supposed to be used: Laminaya, Kampala, Masumbirie, Maranda and Baomahun
b) Mining communities where mercury was not supposed to be used: Kathanta, Kassasie, Makonie, Dalakuru, Yele, Makong, Kumaru (Komao), Wydallah, Tefeyah.

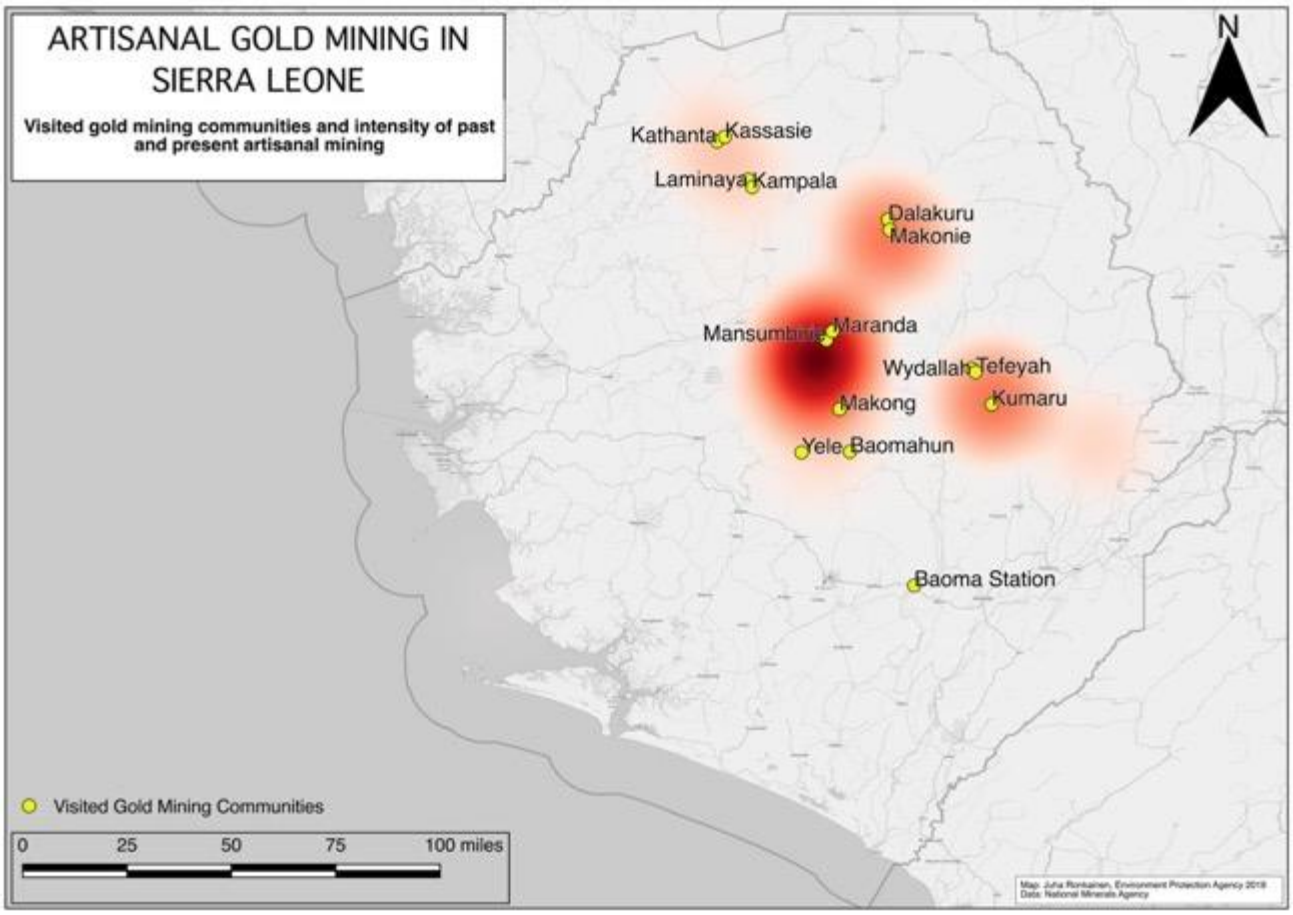


Figure 6: Visited gold mining communities

The entire list contains the main known gold mining areas in Sierra Leone, and is representative in terms of size, organizational structure and extraction type. The list also contains the only operating licensed small-scale gold mine in Sierra Leone located in Makonie. The list is long and extensive, but it allowed the research team effectively to validate the claimed limited mercury use[18]. During the research, one another location was added to the list, namely Baoma Station, in Bo district.

[18] None of the requirements for ASGM set in the Minamata Convention are not applicable to ASGM without mercury use. (Minamata Convention: Article 7.1).

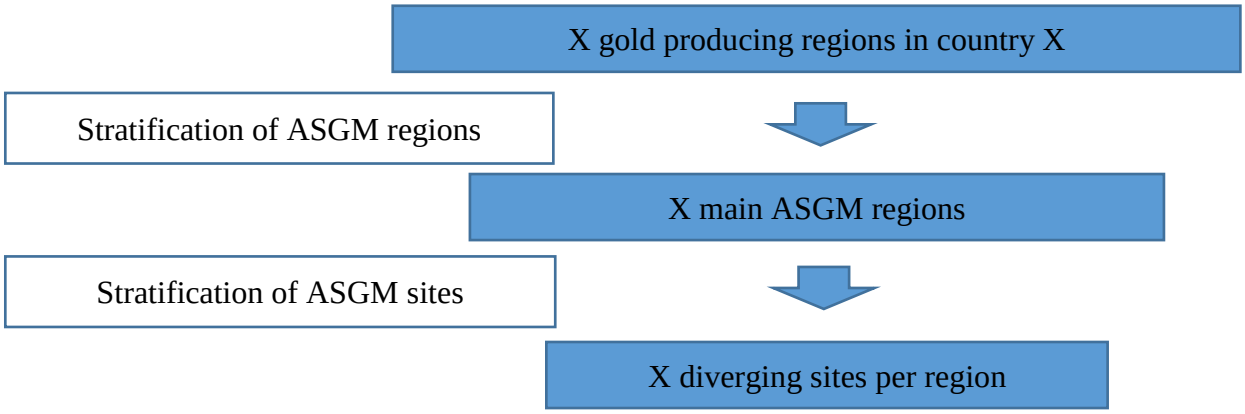


Figure 7: Selection of ASGM communities. (Illustration from (UNITAR, 2017b). Used with permission.)

3.3 Limitations

> *We can be blind to the obvious, and we are also blind to our blindness.*[19]

The greatest limitation of this study is set by the fact that it is an overview, where generalizations on a wide range of topics are made based on entirely different research methods. Moreover, the following specific remarks can be made on the applied methods:

Producing reliable estimates on ASGM population, gold production and mercury use is difficult. The study at hand, is the first known study, where these estimates are based on something else than mere opinions. However, the quantitative methods applied are explanatory in nature, and thus contain significant uncertainties which entire scale is almost impossible to estimate.[20] The main problem stems from the fact that the sampling of ASGM sites and respondents is not statistically representative due to the fact that there was too little information available on the population at the time of research: Simply speaking, it is difficult to take a representative subset of the population which you know very little about (e.g. population size).[21]

Regarding the geospatial methodology used, the following remarks can be made: The manual demarcation of ASGM sites neglects all areas where there is no visible change in land cover (deforestation) and it fails to detect any active artisanal mining happening in areas, where deposits are rich enough to cater mining for several years[22]. The manual demarcation struggles also when trying to

[19] Noble Prize winner Daniel Kahneman, in his book *Thinking Fast and Slow (p.24),* where he examines the limitations of human mind on judgement and decision making.

[20] Similar problem is present for example in (UNEP Chemicals Branch, 2013), and occupy almost all known mercury inventories prepared using the UNEP Toolkit for quantification and identification of mercury emissions and releases.

[21] For anyone interested in statistical complexities included, there is a lively and lengthy discussion available at ResearchGate https://www.researchgate.net/post/How_can_we_determine_the_sample_size_from_an_unknown_population.

[22] Baomahun mining community is an example of a place, where alluvial mining has been conducted for several consecutive years in the same areas.

detect mining which happens under the thick canopy and therefore is not visible via satellite imagery[23]. Therefore, it serves only as an absolute minimum estimate for the land occupied by artisanal miners in 2017.[24] The algorithmic demarcation relies solely on present and historical records without validating whether there is actual mining happening in the demarked area or not. Thus, it is prone to overestimation in abandoned areas, where mining has already ceased.

The main problem with both demarcation approaches is that they fail to detect active areas which have not been recorded by NMA. Such areas are not difficult to find: Even though the algorithmic approach detects the actual cleared mining area relatively well by overestimating only by 15 per cent (Figure 8A), it entirely fails to detect 2.7 hectares of cleared area just below it. However, it is worth mentioning that this underestimation is balanced by a hefty overestimation of 3.7 by the river, where mining has apparently ceased or might never took place in the first place[25] (Figure 8B).

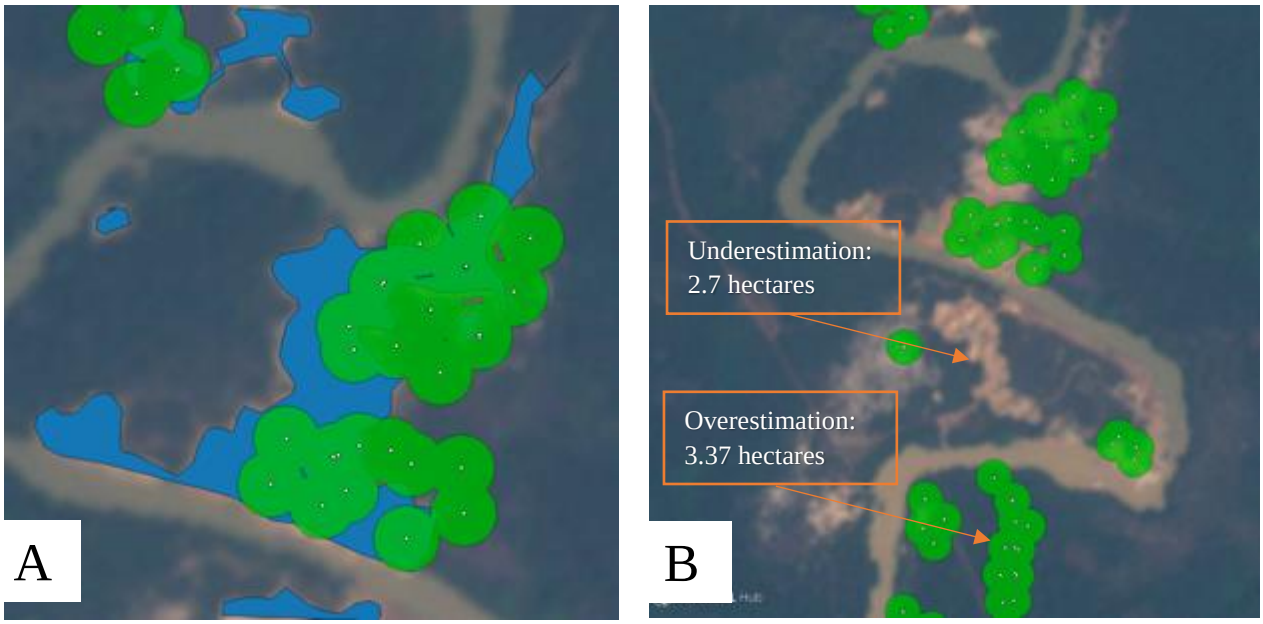


Figure 8: Limitations of algorithmic ASGM area detection. Blue is the actual cleared area. Green is what is detected algorithmically. Scale: Diameter of a circle is 80 meters.

Despite its obvious limitations, these two demarcation approaches (manual and algorithmic) turned out to be fruitful in estimating gold production and work force, and even beyond: Analysis carried out using satellite imagery and spatial records also provided answers to many other interesting questions, especially on environmental impact (chapter 4.13), access to health care (chapter 4.14) and access to education (4.2.4).

As the research team visited almost entirely prominent mining sites, the results are naturally biased towards more established ASGM operations. Indeed, as the primary mission of the research was to establish a baseline for mercury use in ASGM, the research was focused on main mining sites, where its use might be expected. Finally, there is inescapable cultural bias in this study caused by the fact that

[23] E.g. scattered hard-rock mining in Masumbirie and Maranda.

[24] It can be used as an indication of the annual rate of deforestation and land degradation caused by artisanal miners (Chapter 4.13).

[25] The NMA records indicate application fees and some income tax payments from year 2013.

some of the researchers come from entirely different cultural background and none of the researchers themselves are from the ASGM communities.

4 Research Findings

4.1 Previous experiences in addressing ASGM

As Sierra Leone's artisanal mining sector has been dominated by diamonds, much of the past attempts to address artisanal mining has been focused on artisanal diamond mining. Some of this attention has been arguably driven by the fact that diamonds played important role in the civil war. Over the years, both EPA and NMA have been working with ASGM workers, but based on the interviews, these interventions have focused on legal aspects of mining, ensuring artisanal miners are complying with the law. However, attempts to address ASGM in practical level, taking into consideration its importance as a livelihood option as well as its sector-specific technical challenges, are not known.

However, important steps have been taken recently: Strategic environmental assessment of the artisanal mining sector in Sierra Leone (SEA)[26], was undertaken jointly by EPA and NMA, and the final report was published in December 2016. The objective of this assessment was to "assess and evaluate likely significant environmental and health effects as well as the economic implication of artisanal mining on other viable sectors."[27] The report draws upon extensive consultations with the key stakeholders, field research and it has been validated at the national level. As such, its importance and relevance must be stated and its role as an important building block of the National Action Plan adopted.

[26] (EPA & NMA, 2016)

[27] (EPA & NMA, 2016), p.9

4.2 Demographic, social and economic information

Figure 9: Miners returning home after a work day in Dalakuru

4.2.1 Main economic sectors

Figure 10: Timber logging in Sella Limba chiefdom

On a global level, Sierra Leone remains among the world's poorest countries, ranking 180th out of 188 countries in the Human Development Index in 2013. Decades of economic decline, 11 years of armed conflict and the more recent Ebola crisis have had dramatic consequences on the economy. Poverty remains widespread with more than 60% of the population living on less than $1.25 a day and unemployment and illiteracy levels remain high. [28] This is particularly so among youth, with approximately 70% of youth unemployed or underemployed.[29] This remain an important challenge, especially when considering that Sierra Leone has a youthful population, with 63% of the population below the age of 25 years, and especially so in rural areas which have limited infrastructure.

In the areas visited, agriculture and mining remain the main economic sectors. In the North and North-Western regions, agriculture is principally conducted on a subsistence basis, while some farmers sell

[28] UNDP, 2016. Human Development Report 2016. Human Development for Everyone. URL: http://hdr.undp.org/sites/default/files/HDR2016_EN_Overview_Web.pdf

[29] UNDP's web page of Sierra Leone. Accessed on 23/03/2018. URL: http://www.sl.undp.org/content/sierraleone/en/home/countryinfo/

their excess production locally. In these regions, farmers mainly produce rice, but also corn, cassava, grannots and pepper. In the Eastern and Southern regions, farming is equally principally conducted on a subsistence basis, but besides this, there are also farmers growing crops for commercial purposes, such as cacao and coffee. In terms of mining, diamond and gold are the minerals mostly mined, while in recent years, many diamond miners have started mining gold in response to a decline in diamond deposits and rapid increase in the international gold price. This also resonates with other studies recently conducted in the sector. However, in the Northern region, there are also miners who have shifted from gold to coltan mining as this mineral has recently been detected in several gold deposits in this region. Finally, a transition from other livelihoods to timber logging has also been identified by respondents in the field study, which was also reflected in large piles of freshly cut trees that were observed by the researchers aside the roads (Figure 10).

4.2.2 Earnings and cost of living

Most of the gold mining in Sierra Leone is alluvial in nature, and thus miners typically work six days a week for the period of dry season (7 months).[30] Based on the data collected during the field visits, it is estimated that an average miner earns approximately 28,000 Le a day.[31] This daily range varies between as low as 10,000 Le earned by panners working in rivers, who are mostly women, up to 50,000 Le a day, which is possible in well-established mining sites located in gold-rich greenstone belt areas. It must be stated that even though some of the daily costs have been deducted from the above-mentioned figures, it is highly likely that in many cases they still need to pay relatively big costs included in mining, for example transportation costs (15,000 Le).

It is important to notice that while some miners claim to continue working during the wet season, the conditions become very challenging with filled-up and flooding rivers, as many of the mines are located in close proximity to rivers and wetlands. Raining also increases the cost of mining, as pumping water out of the pits is one of the main costs of artisanal mining. Therefore, most of the miners simply move away from mining into farming or timber logging during the wet season. The seasonality of artisanal mining in Sierra Leone, as well as agriculture's complementing role, are well established in research literature.[32]

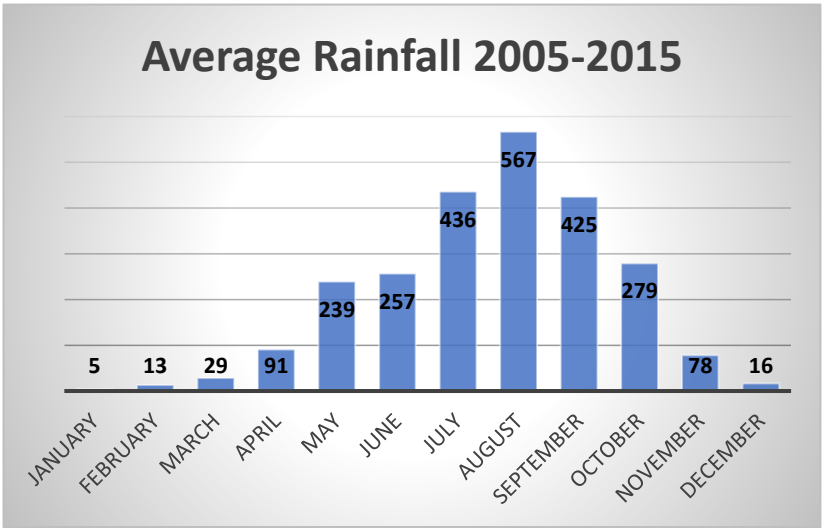


Figure 11: Average Rainfall 2005-2015

[30] Miners are assumed to work from the middle of October to the middle of May. See Figure 11 (Data: http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisCCode=SLE, accessed 12 April 2018.)

[31] This is a weighted average

[32] (Cartier & Bürge, 2011) provides an excellent account on these aspects, also summarizing key findings of past research, and is thus highly recommended reading.

The motivations of miners to engage in gold mining are covered chapter 4.10 in this document, but it is interesting to look at the daily earning of artisanal miners and compare it to other economic sectors and to the expected daily costs of living in rural Sierra Leone. Assuming there is a household with two adults and four children (four units), where one adult is earning 28,000 Le a day and another one 15,000 Le, we can calculate that this household is having 9214 Le (1.23 USD) a day per unit. [33,34] While these modest earnings are not enough to raise the household members from *absolute poverty*[35], even this modest level of income maintained for the period of dry season projects this household just beyond the national poverty line (1,866,128 Le a year per unit)[36], as they would be having as much as 1,956,500Le per unit. This clearly demonstrates that ASGM has clearly the potential of raising people from poverty in Sierra Leone, especially as we consider that the current techniques applied in mining are rudimentary[37] and could be relatively easily improved.

As the national poverty line defines the minimum what a person needs to have for food and non-food (shelter, clothes) needs, it is interesting to see how much extra this example mining family might have in a year. The theoretical calculation reveals that they would be able to save 105,000 Le per month, improving their resilience and giving means to send their children to school. Indeed, despite the law providing each Sierra Leonean a free primary education, in practice the lack of approved schools and approved teachers mean that parents need to pay informal school fees even at primary level in order to keep their children at school.

As these collected school fees are informal, it is difficult to say anything specific, but according to the information collected the school fee for a primary school can be as high as 250,000 Le per year and 500,000 Le for a secondary school. In comparison, tuition fees in the University of Makeni are between 1,000,000-4,000,000Le per annum. In the light of this, it is not a surprise that one of the most often mentioned reason to engage in gold mining is to be able to pay the school fees. In the example, the family had 1,260,000 Le more than the bare minimum needed at their disposal on a yearly basis. Therefore, it can be imagined that they should be able to offer primary education for all of their children and maybe some of them could even finish a secondary school, considering that senior secondary schools are typically located in bigger population hubs, and some money must be reserved for basic daily needs beyond school fees as well.

[33] According to the Sierra Leone Demographic and Health Survey, the average household size in Sierra Leone is 5.9 people, while 46% percent of the population is under 15. (Statistics Sierra Leone, 2013)

[34] Children are counted as 0.5 as in (Statistics Sierra Leone/World Bank, 2013), and parents are assumed to work 6 days a week. (((43000x6)/7)/4=9124

[35] International standard set by the World Bank: 1.90 USD/d/person

[36] It must be noted that the given figure is "the total poverty line, defined as the line below which individuals cannot meet their food and non-food minimum needs." This includes the extreme poverty line, defined as "the line below which individuals' total food and non-food consumption falls below the minimum food requirements." (Statistics Sierra Leone/World Bank, 2013).
According to the national poverty line, the bare minimum the household of 6 people would need is 20,451Le/d. This is in line with the research findings, where interviewed people estimated that a household needs between 15,000-50,000Le a day.

[37] See chapter 4.8.

In addition to that, the following table contains prices of some basic items, as they were quoted during the field research.

Table 1: Prices of some basic items

Item	Price (Le)
a cigarette	250/piece
a meal (A portion of Kassava leaves in Kumaru)	5000/portion
fuel	7000/litre
transporting a sack of ore (80kg) for a short distance (1km)	15,000/one way
renting a small water pump typically used in mining	30,000/day
a shovel	45,000-50,000/piece
mercury	100,000/Oz (28.35g)
surface rent (Kunige Barina chiefdom)	200,000/0.5 hectare
renting an excavator	1000,000/h
crusher (A jaw crusher needed for better gold recovery)	22,000,000/piece

4.2.3 Population characteristics

Sierra Leone has a young and fertile population, where almost half of the population is under 15 years old.[38] According to the Housing and Population Census conducted in 2015, Sierra Leone has a total population of 7,092,113, which – according to UN - is projected to double by the end of this century.[39,40] According to the census, 59 per cent of the population live in rural areas, and 57,9 per cent of the total households are engaged in agriculture. Agriculture - including forestry and fishing, crop farming, and animal production - is the largest industrial sector, employing 59.2 percent of the employed population. Considering the above-mentioned facts, it might not be too much to say if we assume that almost all households in rural areas are engaged in agriculture, while service industry probably dominates the urban areas.

4.2.3.1 ASGM Population

As mining is exclusively conducted in rural areas, all general facts on rural population still hold when we zoom into households engaged in gold mining. However, there are few interesting characteristics worth pointing out, while keeping in mind that these generalizations mainly apply to the biggest group of ASGM workers, i.e. the manual labour force.[41]

ASGM is often complemented by agriculture, strongly weaving it into the local economy.[42] This is only natural, as the most common mining type - alluvial mining - cannot be easily conducted during the wet season. ASGM attracts specifically two groups of people: young unemployed men, often

[38] (Statistics Sierra Leone, 2013)

[39] 2015 Housing and Population Census – Final Results, https://www.statistics.sl/wp-content/uploads/2017/01/final-results_-2015_population_and_housing_census.pdf, accessed 29 March 2018.

[40] https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf, accessed 29 March 2018

[41] The ASGM sector hosts a variety of different stakeholders ranging from labourers to gang leader and gold traders, as well as wider stakeholders that are indirectly involved in the sector. These actors are further analysed in chapter 4.6.

[42] (Cartier & Bürge, 2011)

dominating the more established mining sites, such as the ones visited by the research team, and women, engaged in gold panning and washing by the countless rivers. Women are also often found at the end of the concentration cycle, liberating the gold from black sands by panning.

The ASGM population is mobile. Shallow alluvial deposits can be exhausted in months or in few years. Word of mouth is quick, and young work force is swift to relocate in the hope of better earnings. This is one of the key challenges in developing the sector towards more formal economy, as cultivating methods and creating sustainable structures require time. Therefore, ASGM was described sometimes as a 'hand to mouth' activity, which is in line with the fact that generally ASGM in Sierra Leone consist of countless smaller informal operations, and there is not a single ASGM site with formal organizational structures in place, as can be easily found in DRC or in Uganda, in comparison.

While there are also those who prefer to stay put, the extreme migration of miners from Baomahun to Kumaru is illustrative: The research team was able to visit Baomahun mining community in March 2017, when it was full of people and bustling. When the community was visited again in February 2018, it felt almost deserted, and it was told by the town chief that almost half of the population had fled to Kumaru. This influx of miners was clearly seen in Kumaru, as in only a year approximately 100 hectares of land had been cleared and an entire mining camp with hundreds of houses had been constructed.

Figure 12: Part of the rapidly constructed mining camp in Kumaru

4.2.4 Education

Extensive information has already been collected by Statistics Sierra Leone on education: It is known that the literacy rate among population 10 or older is 51.4 per cent, and illiteracy is likely to be found in rural areas: 32.7% of the people aged 3 and above living in rural areas, have never attended a school. These are important characteristics of the population of Sierra Leone, including the ASGM population, and must be taken into account when strategies to develop the ASGM sector are considered.

There was a primary school in the vicinity of almost all visited mining communities. This impression is backed by the spatial analysis conducted using a dataset made available by USAID (Figure 13):[43] There is a total of 2969 primary of junior secondary schools, within an average 3 km radius from the demarcated ASGM activity.[44] Sometimes children had to travel to the neighbouring village, as was the case in Kassasie village in Karene district, but sometimes they even had a junior secondary school in the village. When mining sites are far from habited areas, specific mining camps are constructed. Such a camp, Yamfara 2, exists three kilometres from Dalakuru town, and it was told that the children in Yamfara 2 were able to go to school in Dalakuru. In only one place, in a remote corner of lake Sonfon, the research team met a settlement where children categorically didn't have access to education at all.

Basic literacy skills are needed in order to develop the mining sector in the future, but access to and interaction with higher education institutes, such as Fourah Bay College, would also be desirable, in order to drive the sector towards higher recovery and more environmentally sustainable mining methods. In some countries, such as Uganda, mining sector also employs formally educated people as mine managers, but such interaction with higher education institutes was not encountered in Sierra Leone.

[43] As a part of their Steward program, USDAID made conducted an analysis of education facilities in Sierra Leone, which is available at https://data.humdata.org. Apparently, the dataset contains gaps in Karene and Bombali districts, but it serves the purpose to illustrate the fact that the school network is relatively extensive, at least when it comes to primary education.
[44] The method of algorithmically demarcate ASGM activities is explained in chapter 3.

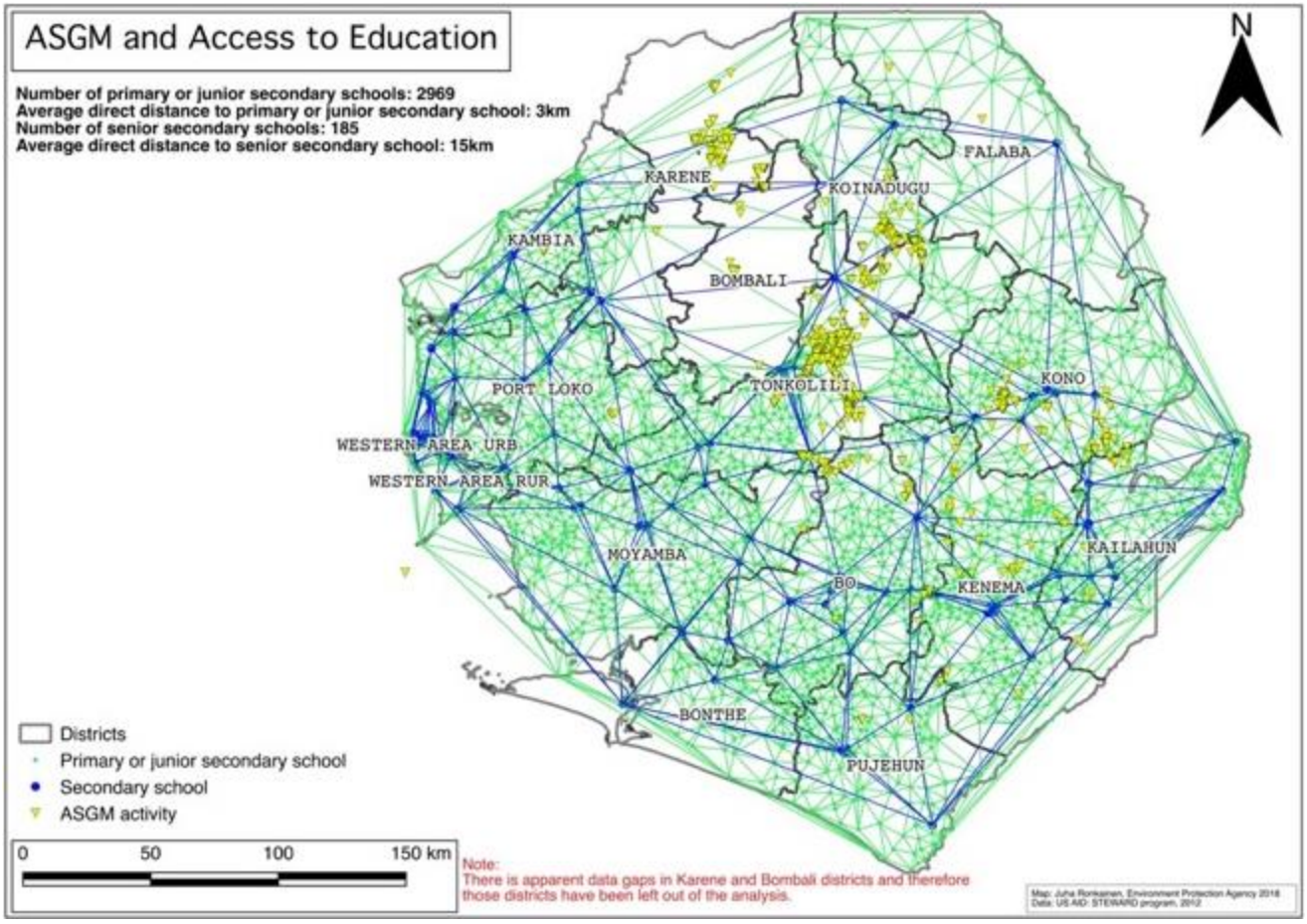


Figure 13: ASGM activities and locations of schools

4.3 The size of the ASGM sector

Figure 14: Abandoned pits around Laminaya in North-West region

One of the greatest challenges in his study was to come up with quantitative estimates on mining population and gold production, which are key figures in understanding the sector. There was no reliable information on the size of the population which could help one to extrapolated findings on community-level to the entire population: It was not known how many ASGM workers are there in Sierra Leone or where exactly are they working. To overcome this problem, a unique geospatial method was developed for this study, as described in chapter 3.

4.3.1 Legalized sector

The starting point for the analysis was to use the information received from NMA[45]: 127.79kg kilogram of gold was officially exported from Sierra Leone in 2017[46] of value 37,859,317,369.28 Le (5,047,909 USD)[47]. Furthermore, it was told that 154 artisanal gold mining licenses were issued in 2016, and 130 in 2017, meaning that in average there has been 142 active licenses throughout the year in 2017. As according to the regulations, there cannot be more than 50 miners working under each license, it can be concluded that officially there was approximately no more than 7100 miners producing no more than 127.79kg of gold in 2017 operating within a minimum area of 71 hectares[48]. This is naturally not the entire picture, but it can be stated that these are indicative figures of the *legalized* ASGM sector in Sierra Leone, and thus worth noting.

4.3.2 The Big Picture

A bespoke methodology to extrapolate site-level estimates into country-wide estimates was developed as described in Annex 3. In short, up-to-date satellite imagery was combined with the spatial records received from NMA to extrapolate site level estimates into a country-level estimates of the size of the ASGM sector. The main results are presented in Table 2.

[45] Personal communication (Ronkainen-NMA, 28 February 2018)
[46] 2015: 98.10kg, 2016: 171.08kg
[47] Conversion rate: 1USD=7,500 Le
[48] According to the Mines and Minerals Act 2009, artisanal mining licenses can be a maximum of half-an-hectare.

Table 2: Summary of ASGM statistics in Sierra Leone

Type	Area		Gold (24K) production		Workforce		Daily earnings (Le)	
	min	max	min	max	min	max	min	max
AM	343.21	687.4	384.46	770.03	12606.45	25248.90	33088.03	
AMGB	168.8	384.2	918.80	2091.26	11708.04	26648.28	50178.59	
HR	7.26	10.98	24.61	37.22	132.06	199.72	49085.59	
HRBG	31.26	64.55	105.96	218.80	568.61	1174.16	49085.59	
Mixed	46.09	46.09	336.31	336.31	4013.30	4013.30	42582.76	
SmallScale	n/a	n/a	185.26	185.26	15.00	15.00		
By-production	56.37	56.37			3909.85	3909.85		
Panning and diving	n/a	n/a	332.01	332.01	33168.00	33168.00	15000.00	
Average (column)	652.99	1249.59	2287.41	3970.88	66121.32	94377.22	25822.63 (weighted)	30817.45 (weighted)
Average (min/max)	951.29		3129.15		80249.27		28320.04	

It can be stated that in average, **950 hectares of land is occupied** by **roughly 80,000 ASGM labourers**, **producing 3.1 tons of gold annually**. When using a spot gold price of 42.7 USD/g, the **export value of mined gold is approximately 130 million USD**.[49] It is important to say that the estimation of workforce is on manual labourers, who are present in mining sites on a daily basis.

It is interesting to compare the results with some known estimates on ASGM population. Recent Strategic Environmental Assessment report[50], mentions that illicit ASM operations might employ between 100,000 and 300,000 individual miners, not making any difference between minerals being mined. Recent World Bank study[51] gives a range of 200,000-400,000 ASGM workers. At the other end of the spectrum, there is an academic estimate that there can be as many as 437,000 ASGM miners producing as much as 3.5 tonnes of gold annually[52]. However, none of the mentioned reports provide any further reasoning for their estimates, which is also understandable: SEA document has a special emphasis on environmental impact, World Bank report only lightly touches Sierra Leone and the academic article focuses on estimating gold ASGM workforce in comparison with known gold production.[53]

[49] Spot gold price on 11 February 2018

[50] (EPA & NMA, 2016)

[51] (World Bank/COWI, 2016)

[52] (Seccatore, Veiga, Origliasso, Marin, & Tomi, 2014)

[53] However, the last study provides insight into one limitation of this study, i.e. its bias towards more established mining locations. If indeed 437,000 workers were to produce as little as 3.5 tons of gold annually, that would mean that in average a typical worker would produce as little as 0.04g a day, when working 26 days a month for the 7 months of the dry season. As typically only half of the produced gold is shared between workers, that would literally mean that an average worker would earn as little as 0.02g a day, gaining only 5000 Le a day. In our visits we never met anyone earning that little, but that doesn't mean the estimation could not be true: It is highly possible, that the research entirely neglected large numbers of miners working outside of known established mining sites. Furthermore, it is highly possible that there are a large number of miners, who actually work only a small period of time during the year. This would explain the low given average production rate. It is also possible that as mining has become more and more difficult due to the

While keeping in mind the limitations of these estimates, it is interesting to put the figures into a context: According to Kimberley Process statistics, in 2017, Sierra Leone exported rough diamonds worth 158,872,778.13 USD.[54] This means is that even though diamond mining might have dominated the discourse on artisanal mining in Sierra Leone almost entirely, the ASGM sector is almost equally important, at least when looking purely the export value. It is also interesting to compare ASGM with some large-scale mining presently occurring in Sierra Leone: In 2014 Sierra Rutile Limited (now subsidiary of Iluka), exported rutile worth 81 million USD, while at the same time employing approximately 1500 Sierra Leoneans. [55] The estimated area occupied by artisanal gold miners (950 hectares) can be further compared to that of Sierra Rutile's workings in Imprerri chiefdom, where their open pit mines directly occupy a total area of approximately 1200 hectares (Figure 15).

Figure 15: Sierra Rutile open pit workings near Imprerri chiefdom

depleting surface deposits, it has become more centralized and has already began its transformation into small-scale mining, which typically occupies way less miners than purely non-mechanized artisanal mining.

[54] https://www.kimberleyprocess.com/en/sierra-leone, accessed 28 March 2018.

[55] (Statistics Sierra Leone, 2015)

4.4 Geographical distribution of ASGM

4.4.1 Known ASGM locations

Simply speaking, in Sierra Leone, ASGM takes place either directly on the greenstone belt[56] areas, where hard rock or alluvial[57] deposits can be mined, or along the rivers flowing from the greenstone belts, where mining is only alluvial. While most of the time diamond and gold mining doesn't occur at the same time, there are few locations in Kono districts, where by-production of gold is happening along with alluvial diamond mining. The different mining styles are addressed in detail in chapter 4.8. Figure 16 illustrates the situation[58].

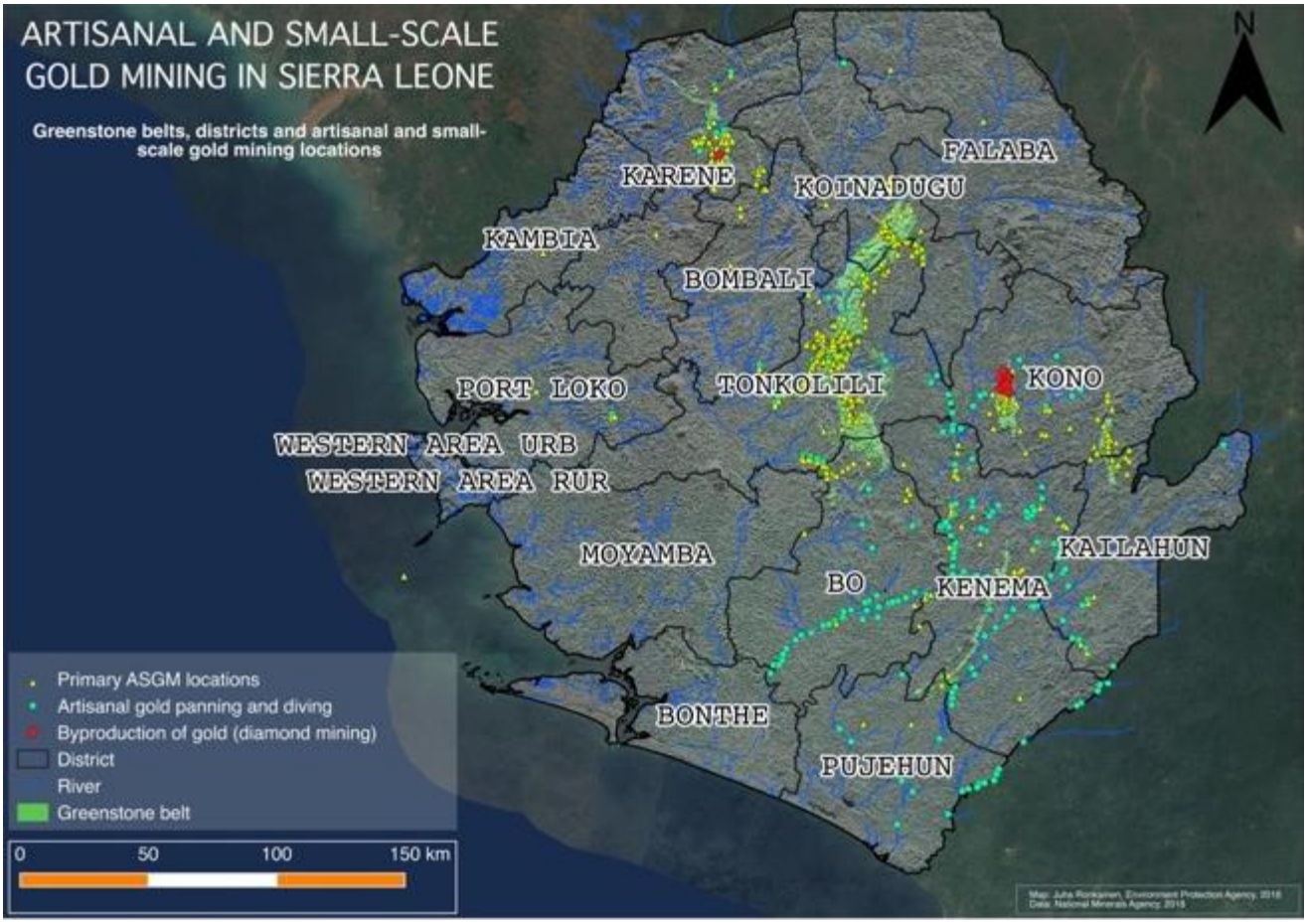


Figure 16: ASGM types and locations in Sierra Leone

[56] The main hosts of gold in Sierra Leone are the greenstone belts. These are mafic and ultramafic volcanic, intrusive and associated volcanosedimentary rocks, metamorphosed to greenschist or amphibolite facies. These facies contain green minerals including amphiboles, chlorite, epidote and serpentine. The following greenstone belts are known to contain gold; Gori Hills, Kambui Hills, Kangari Hills, Loko Hills, Nimini Hills and the Sula Mountains.

[57] Please note that the term 'alluvial' has been used as a synonym to soft-rock mining, following the terminology as in (O'Neill & Telmer, 2017). The more general term 'placer' would probably be more accurate, as not all soft-rock deposits are alluvial: The term alluvial directly refers to water, and free gold particles can also be disseminated by wind and land movements.

[58] The method of defining the locations has been explained in chapter on Methodology, and in Annex 3.

From the figure above, it is already clear that out of 16 districts, Tonkolili is the heart of ASGM in Sierra Leone. This is only natural, as the district hosts the largest proportion of greenstone belt areas within its territory. Other prominent ASGM districts are Koinadugu, Karene, Kenema and Bo. Kono is known to be the most active diamond mining district in the country, but it also has the single most active artisanal gold mine[59], and the unique occasions where gold mining occurs along with diamond mining. When we zoom into chiefdom level, we realize that most of the ASGM operations are exactly in those chiefdoms locating on greenstone belts.

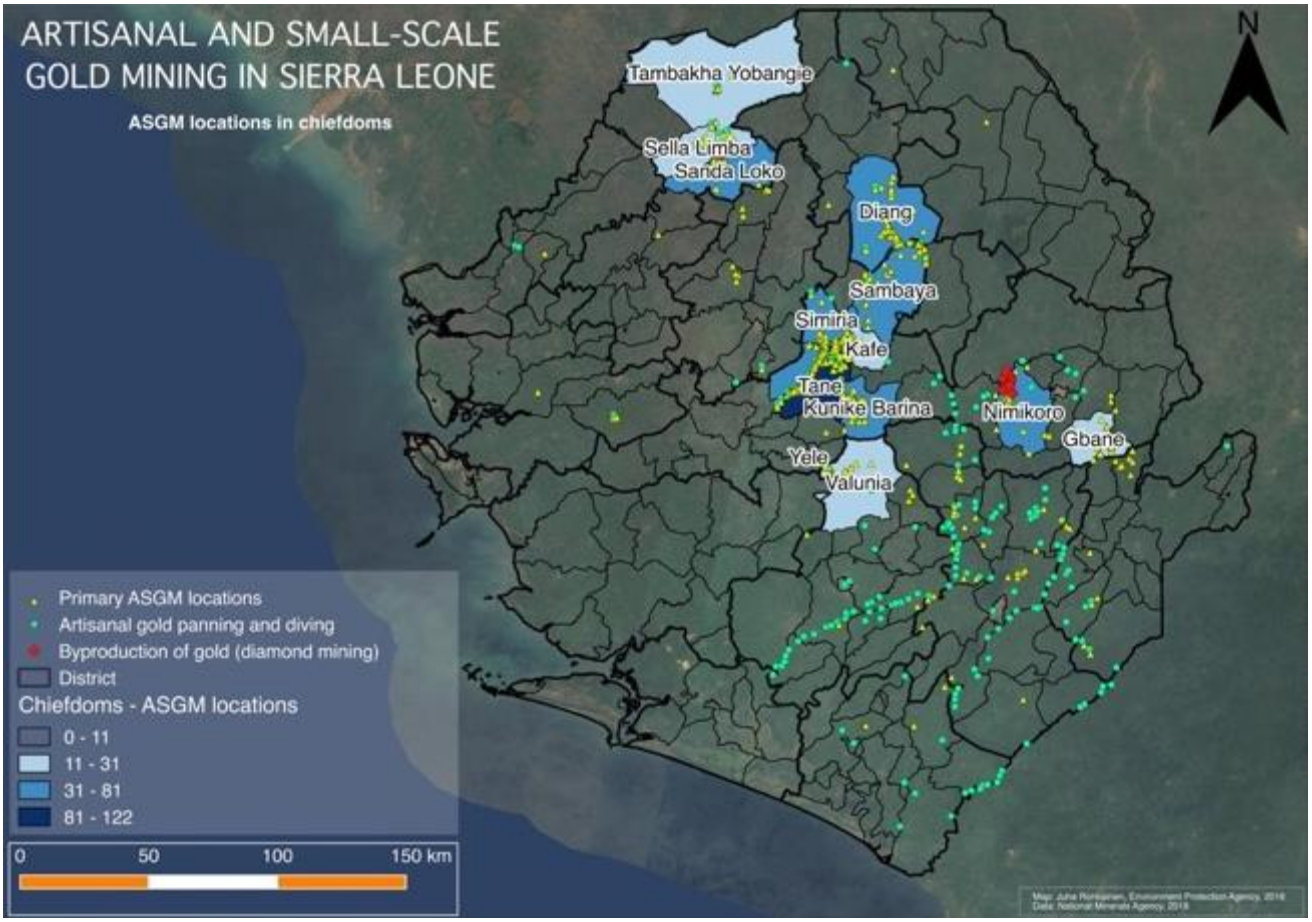


Figure 17: ASGM locations at chiefdom level

These findings, are not surprising and are fully in line with the field research findings. The same data can also be presented in a table format combined with the population data.

Table 3: Populations and ASGM operations in selected districts and chiefdoms

Chiefdom	Alluvial or hard rock ASGM operations	Panning or diving	By-production	District	Population
Tane	122	9	0	Tonkolili	33285
Diang	81	3	0	Koinadugu	29063
Kunike Barina	61	3	0	Tonkolili	25245
Simiria	59	4	0	Tonkolili	18335
Nimikoro	53	2	25	Kono	61225
Kholifa Rowala	53	2	0	Tonkolili	66128

[59] Kumaru (Komao)

Sambaya	42	2	0	Tonkolili	31993
Sanda Loko	39	0	1	Karene	45075
Sella Limba	31	3	0	Karene	58401
Gbane	27	0	0	Kono	24 404
Kafe	23	1	0	Tonkolili	31993
Valunia	20	2	0	Bo	35558
Tambakha Yobangie	16	3	0	Bombali	38 493
Yele	11	4	0	Tonkolili	33852.5

4.4.2 Industrial Mining Locations

One of the interesting aspects of gold mining in Sierra Leone is the fact that despite years or decades of exploration, there is not a single operating large-scale gold mining company. There is no one explanation for that, but apparently the primary deposits of gold have not been found despite all the efforts done by various exploration companies: Whereas artisanal miners operate in the timescale of months, and small-scale mining companies might exhaust their licensed land within years, large-scale mining companies need a time horizon of a decade or more to cover the high infrastructural costs.

Currently there are two large-scale gold mining operations, which should start their operations in 2017: Kingho Investment Company (SL) Ltd has contracted Dayu Mining, to mine their deposit in Simiria Chiefdom in Tonkolili district. It is going to be underground mining, where they are targeting the quartz vein hosting the gold. The exploration area is currently also mined by artisanal miners, who will need to find another area for themselves once the operations begins. In Baomahun community in Valunia chiefdom, Algom Resources Ltd have taken over a previously owned exploration license and is in the process of applying a mining license for an open pit mine. The constructed open pit would eventually erase the entire hill next to the community where there are currently few hundred artisanal miners conducting underground gold mining. As large-scale mining companies seems to be only interested in primary deposits, which are difficult to exploit using artisanal methods, it is unlikely that there will be greater conflicts on resources between artisanal miners and large-scale mining companies. However, both operations in Simiria and Baomahun will provide important feedback on how these companies are addressing the possible land issue with the artisanal miners.

The greater concern is caused by the fact that easily accessible alluvial surface deposits favoured by artisanal miners are getting exhausted: More and more artisanal mining is actually small-scale mining, while still holding an artisanal license, as miners now need to regularly go beyond the ten-meter limit to reach the gold rich gravel zone. The question can be asked, what is the future of artisanal gold mining under the current legal framework, as already numerous artisanal operations cannot comply with the regulations, and the situation is only going the get worse with the lack of viable alternative livelihood options. There is gold to be mined, if maybe not for so long by artisanal methods, but at least by small-scale mining methods, but the facilitation of this transition is likely to be challenging and poses numerous questions. Already the research team was able to see multiple foreign-run small-scale operations, operating without any license next to the artisanal miners, and at least one violent outbreak has already been recorded, as artisanal miners have felt being side-lined.

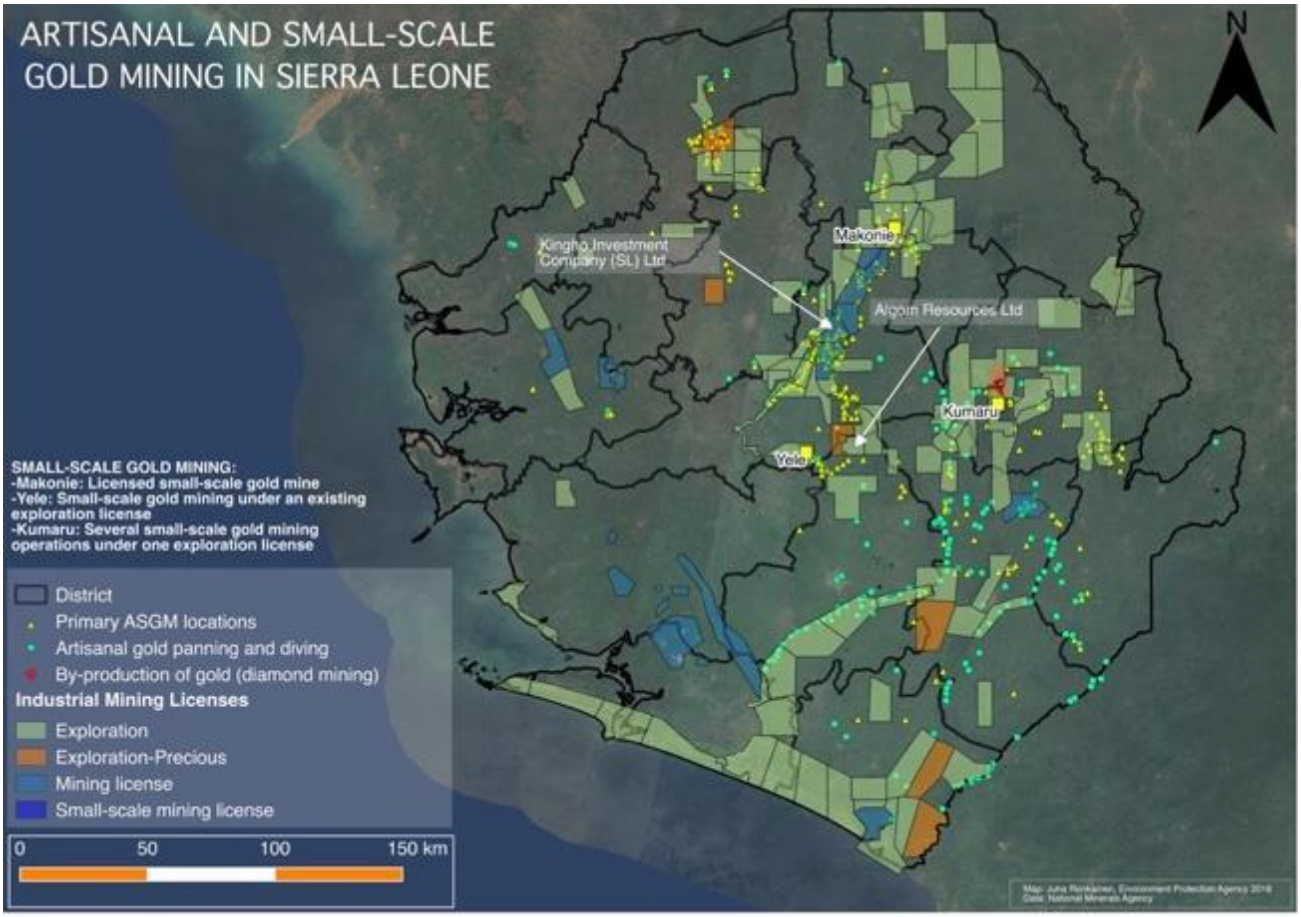


Figure 18: Artisanal, small-scale and industrial mining in Sierra Leone

4.5 Legal and regulatory status

The Mines and Minerals Act, 2009, and the National Minerals Agency Act, 2012, are the principal legislative instruments regulating the Sierra Leone mining sector. The 2012 Act establishes the National Minerals Agency (NMA) as the key institution responsible for regulating the mining sector. Its responsibilities include the promotion of the development of the minerals sector by:

i) effectively managing the administration and regulation of mineral rights and minerals trading in Sierra Leone; and

ii) ii) providing technical and other support to the mineral sector including geological survey and data collection activities.

The 2009 Act defines "artisanal mining operations" as mining operations that do not exceed a depth of ten meters. Furthermore, it stipulates that artisanal mining can be carried out by individuals, co-operatives, joint venture, partnerships or corporate bodies under the name of a Sierra Leonean person in possession of an artisanal mining license. Licenses are valid for 1 year and can be renewed up to three times for a period not exceeding one year at a time but cannot be transferred to other individuals. Artisanal mining may be carried out in an area not larger than 0.5 hectare and not employing more than 50 mining workers (laborers) per mining license. Moreover, if the license holder is not personally supervising the mining operation, he or she should employ a 'Mines Manager' to supervise its mining operations. The Act also stipulates miners' obligations to protect the environment. For artisanal mining, this only includes the license holder's obligation to carry out rehabilitation and reclamation of a mined-out area.

"Small-scale mining" is defined as the intentional winning of minerals in mechanised operations not exceeding twenty metres in depth or involving the sinking of shafts, driving of adits, or other various underground openings. This activity should cover a land area between one hectare and no more than 100 hectares. With regards to validity and transferability of licenses, the same conditions of artisanal mining apply. Small-scale miners are required to be organized in co-operatives and corporate bodies. Small-scale miners have many more obligations than artisanal miners. Importantly, in contrast to artisanal miners, small-scale miners are required to obtain an environmental impact assessment license in accordance with the 2008 Environmental Protection Agency Act, prior to applying for a small-scale mining license. Moreover, under certain conditions in extraction, small-scale miners are required to have and implement a community development agreement with the primary host community.

In order to obtain an artisanal and small-scale mining license, applicants must first obtain consent in the form of a certified agreement to use the land for mining purposes with the Chiefdom Mining Allocation Committee. After this, applicants for an artisanal mining license may apply for a license at the regional and district offices of the NMA, and applicants for small-scale mining licenses may apply for a license at the Mining Cadastre Office in Freetown. The environmental impact assessment licenses are issued by EPA, at a cost pre-defined by a fee scale taking into consideration various aspects regarding mining techniques and surrounding environment.

4.6 Leadership and organization of ASGM at national and local levels

Figure 19: A mining gang and one of the deepest open pits seen during the field research

Most of the people involved in ASGM are organized in ‘gangs’, small groups of 4-10 people, while others chose to work individually. Only a small portion of the gangs and individuals visited operated under an active license. In those cases where it was claimed that someone was in a possession of a license (whether it concerned an active or an expired license that was planned to be renewed), the number of miners typically exceeded the prescribed number of 50 labourers per license. Most license holders, community chiefs and paramount chiefs to allow this because ‘‘these people need a living”. The license holders are typically community leaders, chiefdom leaders and businessmen, and they may also be the leader of mining gangs.

Gangs usually operate in one pit, although in some cases, a big gang splits the workers over two pits. In an alluvial mine site, gangs typically include 5-6 people consisting of several ‘diggers’ who dig most of the gravel with shovels; washers who wash the ore in sluice boxes; a panner who pans the concentrate; and one ‘gang leader’, ‘boss’ or ‘manager’. In some cases, this ‘boss’ is involved in the work, and in other cases, he or she only supervises the work and motivates and supports the workers. The gang leader may also appoint one of the labourers as a ’team leader’ who is responsible for overseeing the work in the gang leader’s absence. As such, there is substantial social mobility in the ASGM sector because labourers can get positions as such a ’team leader’ and after gaining experience and accumulating capital they may start their own mining gang or become a (typically unlicensed) gold trader. In a hard rock mine site, gangs are usually bigger as this type of mining is harder and also includes the tasks of crushing the ore and transporting it from deep in the pits to the surface.

Within a gang, labourers often work on a rotational basis so that diggers start washing and vice-versa, or that one person takes a break and another person takes of this person’s work. This is especially the case in the hard rock mines visited, where the work is physically more demanding than in alluvial mines, but where labourers may rotate so that the gang can work even 24 hours per day, 6 days in a

week. [60] However, there is a clear separation in sex. Whereas the digging work is exclusively done by men as this work is typically very demanding, panning is typically (but not always) done by women who are traditionally viewed as 'panning experts'. The organization of women, which is more often on an individual basis, is discussed in Chapter 4.11. The washing activities are carried out by both men and women.

The gangs are usually established by the gang leader who gathers labourers to work for him or her, or by an external 'supporter' who supports the gang leader and his/her gang financially. The gang leader or supporter motivate people to work for them by offering food, and in some cases cigarettes and alcohol. The supporters are in most cases unlicensed gold traders, in some cases the artisanal mining license owners, in some cases the gang leaders, and in other cases local or external businessmen. The role of supporters is further discussed under the next section on gold trade (Chapter 4.7).

Gangs operating in the same area coordinate to some extent. For example, when one gang's water pump breaks down, they may borrow from another gang, and gangs may come together sometimes to discuss collective concerns, often with the involvement of the community chief and/or license holder (which may sometimes be the same person). In Kampala, there is a miners' association whose main purpose is to advocate for miners' rights (e.g. obtaining a license). The association has a mining chairman and holds periodic meetings.

4.6.1 Benefit sharing

In terms of benefit sharing, most gangs maintain a rule of '50/50': 50% of the 'winnings' is for the labourers, and 50% is for the gang leader. The winnings in this case may refer to both the recovered gold, as well as to the cash received for the sold gold. In the former case, the gang leader then usually buys the labourers' 50% to sell it (as further discussed in chapter 4.7). The gang leader uses his/her winnings to recover several costs, which typically include food for the gang labourers (typically Le5,000/day/labourer), shovels, renting or buying costs for a water pump and its fuel (in alluvial settings), and occasionally buying medicines for gang labourers who are sick. [61,62] The remaining 50% is then shared equally among the labourers.

Beyond the distribution of benefits within gangs, there are several payments made to different types of authorities. Miners who operate under a mining license, usually have to pay a percentage to the license owner. The effective payment of this usually only occurs for workers at mine pits which are particularly productive, and typically concern about 10-30% of the winnings (depending on production). The license holder on his turn, pays a license fee of Le 1,750,000 which is distributed over the landowner, the chiefdom administration and the paramount chief. [63] Besides this, according to national laws, ASGM license holder should pay yearly taxes and royalties, but this is not enforced

[60] Most of the miners rested either on Friday or on Sunday depending on their religion. Working around the clock was only seen in hard rock mining sites, and most of the mining activity was carried out between 9AM and 6PM.
[61] In one case, it was reported that these costs were subtracted from the total before splitting the winnings 50/50 between the gang leader and the workers
[62] In primary gold deposits this may also include costs for crushing the ore, as was the case in Masumbirie where a hammer mill was being rented by a private owner, which crushed one bag of ore for 60,000 Le (and in this case the gang leader took 60% of the winnings)
[63] This includes 100,000 Le for the surface rent

in practice.[64] Finally, there have also been reports of additional payments being made to other authorities, including widespread bribes that are paid to Mines Monitoring Officers, in particular by ASGM miners that do not operate under a license. In addition, there have been occasional reports of payments made to other authorities, such as the payment of 'water rates' to the chiefdom authorities.[65]

4.6.2 Kumaru

In comparison with the majority of ASGM areas visited, Kumaru is a special case which differs significantly in benefit sharing and organization and is therefore discussed here separately. Kumaru is a mining community in Nimikoro chiefdom, Kono district, and was by far the largest and most active gold mining community in Sierra Leone at the time of research. The community contains six mining sites and host a few thousands of miners who live in three mining camps. Due to a decline in near surface gold deposits and restricted access to richer deposits, ASGM miners here are employing excavators and crushers to tap into deeper gold deposits, and they are using mercury to form amalgams with the 'floating gold', gold particles that are so small that they float on water which are recovered from the tailings. In this area, ASGM activity does not take place under a license because the mining falls under an exploration concession owned by a company named Nimini Mining Ltd. At the time of research, six companies of Chinese origin were extracting gold in some of the area's richest gold deposits without permission under this same exploration license.

In the ASGM sites falling under the company's concession, miners are still allowed by local authorities to extract gold, but only on the condition of paying a contribution to the mining commander of the chiefdom. In 'New Site', a mining site that was opened in early January 2018, and which falls under the exploration concession, miners of 14 mining pits were forced by chiefdom authorities to quit their mining activities until they paid a sum of Le3,000,000 per mining pit. In other sites in Kumaru, which did not fall under the exploration concession, miners were demanded to pay a percentage of their production (in gravel) to the chiefdom authorities, which was in the most extreme case as much as 40%.

In the hard rock mine sites in Kumaru, gangs consist of 10-15 labourers due to the heavy work and variety of tasks involved, and some of them include more than one gang leader. Winnings were shared in ratios of 80/20 and 62.5/37.5 between the gang leader and the gang labourers, a significant deviation from the 50/50 distribution which is typically maintained in other ASGM sites. The alleged purpose for the gang leader(s)' disproportionate share was to recover the extensive costs involved in gold production in this area, because in addition paying food for labourers, it usually involves paying for the renting and fuel of excavators, for the transport between the extraction sites on the hill and the processing sites down the hill, and in some cases also for the use of the crushing machines.

To close this sub-section, it should be cautioned that the precarious situation of ASGM miners in Kumaru requires dire attention, both from a social, economic, health and environmental perspective. In this context, it is important to consider that many of the ASGM miners active here concern youths

[64] According to the 2017 Finance Act, ASGM license holders should pay an annual tax of Le150,000 to the National Revenue Authority, and 5% of yearly production as Royalty according to the 2009 Mines and Minerals Regulations.

[65] This water rate, as well as other unofficial payments to customary authorities, was also reported in (Hunter & Smith, 2017)

that are ex-combatants from the civil war who generally enjoy low levels of education and a virtual lack of directly accessible and economically viable alternative livelihoods. Based on the researchers' observations among these youths, it is believed that a continued marginalization of these ASGM miners may result in violent clashes between them and local authorities and/or gold extracting companies.

4.7 Gold Trade

The majority of the gold produced in Sierra Leone is smuggled to Guinea, and another large part to Liberia. As stated in section **Error! Reference source not found.**, only a small fraction of the gold produced is exported through official channels to these and other countries. The diverse legal and illegal trade routes and actors involved can be best understood by considering Sierra Leone's ASGM value chain. Sierra Leone's ASGM value chain contains a diversity of actors which may or may not be present and may take different roles in different situations. The figure below attempts to illustrate the diverse actors that are typically directly involved in ASGM production and trade at the national level, and also contains principal the actors that are typically involved at the international level.

As has been discussed in the previous Section, at the level of the mine pit, gold may be sold both by gang labourers, individual workers, gang leaders and in some cases, by license owners. These actors then typically sell the gold to a small, unlicensed trader which is usually the agent of a bigger trader and sells the gold to this big trader. The small traders may be based in towns close to the mine site or in towns in the same district. In some cases, in particular when it is the gang leader or license holder who sells at the mine pit level, the gold may be sold from the mine pit directly to a big trader. In most cases, this big trader concerns an unlicensed trader based in one of the country's regional and district capitals, such as Makeni, Magburaka, Koidu or Bo, or in the capital, Freetown. In some cases, it may concern a licensed gold dealer who is typically based in those some cities. In yet other cases, the small trader may be the agent of a regional buyer and smuggle the gold over the border to neighbouring Guinea or Liberia to sell to his boss. Similarly, the small, unlicensed trader may sell directly to licensed exporters.

The big trader (referred to locally as the 'customer' and sometimes as 'boss') typically has three options: he/she may smuggle the gold to neighbouring Guinea or Liberia (this option is most common), he/she may sell to domestic licensed exporters, and he/she may sell to domestic goldsmiths. Licensed exporters may then sell to international buyers based overseas, or to regional buyers in West Africa. The goldsmiths usually sell directly to end consumers, who may be domestic buyers, or regional or international buyers who come to Sierra Leone to buy the gold products. Goldsmiths add further value by melting the gold to make jewellery, including wedding rings, earrings, bracelets and necklaces. In general, there are not so many goldsmiths in Sierra Leone, and the few can be found in regional capitals

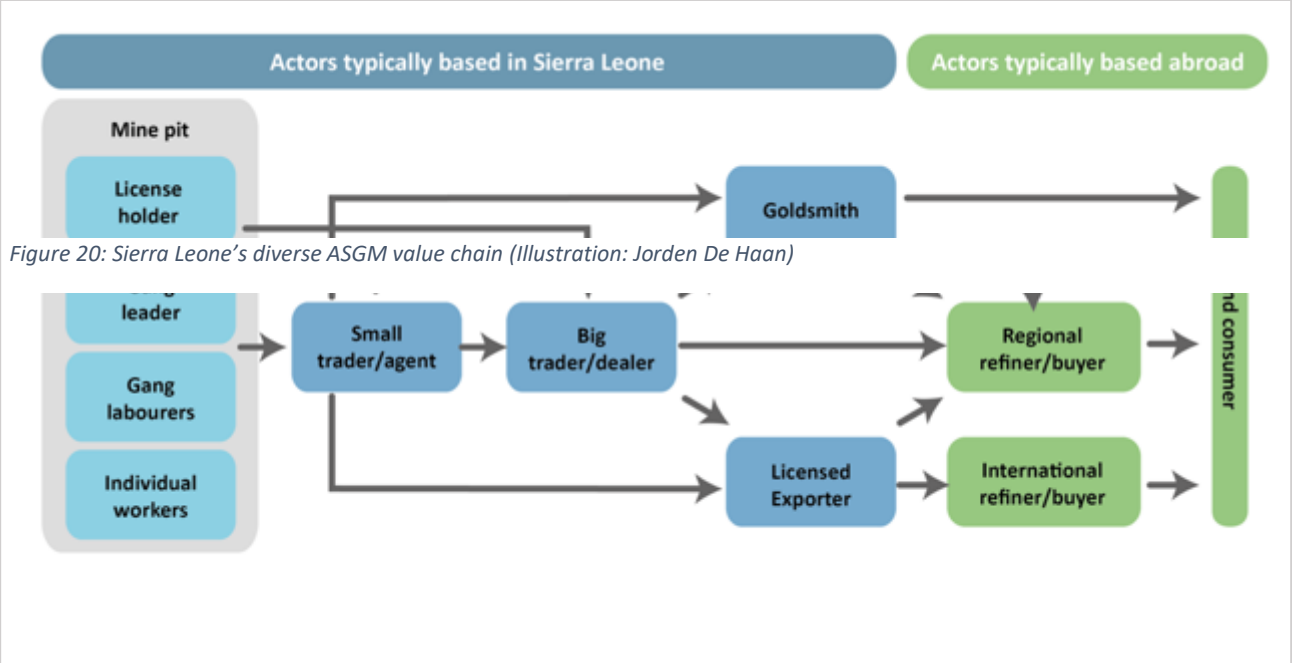


Figure 20: Sierra Leone's diverse ASGM value chain (Illustration: Jorden De Haan)

or in Freetown.

4.7.1 Organization of traders and trade relations

Most of the traders, both licensed and unlicensed, are not organized in formal organizations, but rather work together with their family and close friends who may serve as buying agents for them. In rare cases, traders are more formally organized. For example, there is a small association of gold traders in Makeni, but it only consists of one licensed dealer and several of the dealer's assistants and agents. In Kumaru, the unlicensed traders (locally referred to as 'Julahs') are organized in an association. The local traders who are based in Kumaru are obliged to become a member of this association by paying a membership fee for which they receive a membership card in return. The association includes a chairman, a secretary and a treasurer, and 17 members. The association was established with the purpose to pool resources of local traders to pay contributions to chiefdom authorities, and the association further determines local prices for trading gold.

While according to data available at NMA's online repository[66], there should be 26 licensed gold dealers and 9 licensed gold dealers' agents, it was often difficult to trace these traders in practice, and

[66] GoSL Online Repository. Accessed on 25/3/2018. URL: https://sierraleone.revenuedev.org/dashboard

the research team has only managed to meet with a few of them. This experience has equally been documented elsewhere.[67] It is also difficult to identify unlicensed traders, because they do not have a formal organization, may have different roles and typically keep a low profile. For example, it was found that most of the unlicensed gold traders are involved in different types of businesses and that many of them buy gold from small shops where household products such as toothpaste and soap are sold. Indeed, many unlicensed traders who smuggle gold to Guinea, use the dollars they receive in turn for the gold to buy other merchandize and sell this in Sierra Leone. This information can provide as another way to identify potential gold smugglers. In addition, traders may 'straddle' between formality and informality. For example, there may be licensed gold dealers, goldsmiths and exporters who trade according to the channels prescribed by law, and keep accurate track of these activities, but who also trade in informal channels and do not report these activities.

Although the gold buyers do not seem very organized from a formal point of view, they still maintain certain principles which provide some type of order to their business. The trade routes chosen, and investments made are largely determined by principles of trust and loyalty in social relationships between actors within and outside the country, as well as kinship and family ties. For example, most traders only sell to Guinea when they have good friends or business partners there. Moreover, as has been reported elsewhere, it has been observed that Fulani typically work for Fulani and Mandingos typically work for Mandingos.[68] Furthermore, gold buyers may establish relationships with miners by giving them food, drinks, clothes and shovels as a present, which is often considered to be necessary in order to keep up with the competition.

In addition to this, as has already been mentioned, gold buyers, including goldsmiths, often invest in mining gangs, which may take the form of financial loans which are typically between one to three million Leones and material loans in the form of shovels, water pumps or crushers. [69] Such investments may be loaned directly to the gang leader, or indirectly through smaller traders who work on a commission basis and subsequently invest it in diverse mining gangs. Gold buyers typically pre-finance mining gangs by giving interest-free loans under the agreement that the beneficiaries have to sell back to the supporter, while in the case of external supporters who do not buy gold, there is usually an interest rate. As small traders and miners often depend on this support and loyalty is considered to be very important, they generally stay faithful to their buyers by selling exclusively to them. To illustrate this with an example, an unlicensed trader which was interviewed by the researchers, had decided to stay in Baomahun to buy gold rather than moving to Kumaru, as opposed to many other traders from Baomahun who had moved there because the gold production had risen dramatically. This reason for this was that his 'boss' (a big trader), whom he has been working with for five years, prefers to buy gold from Baomahun and because he does not know people personally in Kumaru.

4.7.2 Price distribution

An example of the price distribution in the value chain is given below, which illustrates two different trade routes between mine sites in Dalakuru, Koinadugu chiefdom, and Guinea. The prices listed under

[67] (Hunter & Smith, 2017)
[68] (Hunter & Smith, 2017)
[69] The lowest and highest investments in ASGM production reported concern Le250.000 and Le20.000.000 respectively

the actors reflect how much the respective actors receive for the gold, both in Leones/carat[70] and the equivalent of USD/gram. It must further be noted that the prices listed here concern the prices that are paid for the impurified gold, and that they are higher than in other parts of the country because the gold from Dalakuru is high in purity. [71] In this example, a gang leader buys the gold from his gang and sells it to the local unlicensed trader who supports his group. The local unlicensed trader then usually takes the gold to Guinea himself to sell to buyers he knows in Guinea. In other situations, he may sell the gold to traders in the local market of Badala in Koinadugu chiefdom, from which it is transported and smuggled into Guinea.

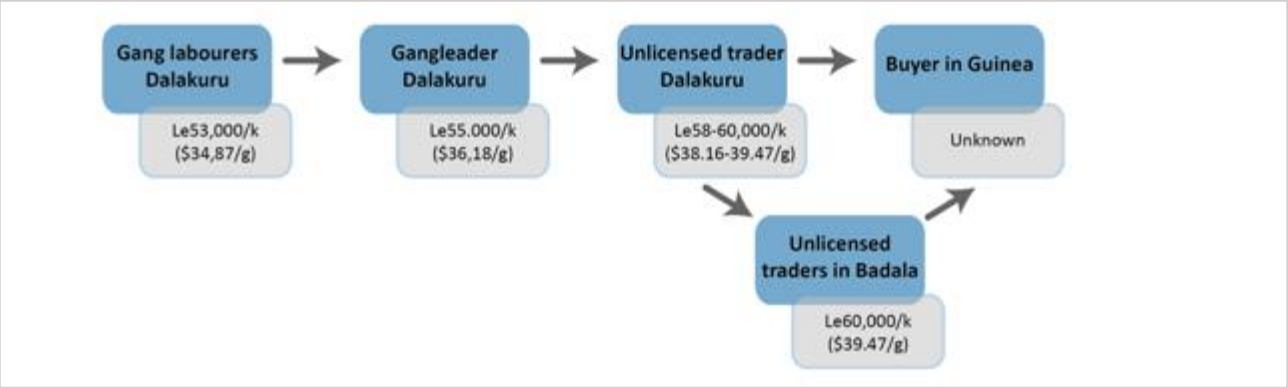


Figure 21: An example of price distribution for gold originating from Dalakuru. (Illustration: Jorden De Haan)

What is remarkable in this example, and what was also observed in the gold price distributions investigated in other parts of the country, is that a gang leader can get as much as $38,08/gram, or 89.19% of the world market price, and that the smuggler can get as much as $41,55/gram, or 97.31% of the world market price (these prices have now both been adjusted for the purity of gold).[72] In other cases, it has been reported that gold has at times been sold for rates above the world market price.[73] This finding raises some red flags. When buyers are willing to pay more than the formal market rate for gold, it is an indication that gold has more value out of the formal supply chain than in it. This could mean that, as was mentioned by several respondents, gold may be used for money laundering, and potential other illicit and criminal activities. Notwithstanding this concern, it is also worth noting that in many places in Sierra Leone, gold is used as a currency which can be directly used to pay for goods and services. Besides this, its capability to earn a foreign currency such as the US dollar, which is more accessible in international trade and less volatile than the local currency (Leone). But this can only partly explain the high prices paid for gold in Sierra Leone.

4.7.3 Challenges in curbing gold smuggling

> *These guys, the MMOs... they earn Le 300-400,000 per month. Now just imagine that you are an MMO and you see the miners who are getting a lot of money without having a license, what do you do?*

[70] The influence of diamond mining can be seen in the usage of weight unit *carat* which is typically used to weight diamonds (1 carat =0.2g).
[71] The purity of gold from Dalakuru has been reported to be as high as 22.8 karat, i.e. 95%.
[72] Compared against the spot gold price of $42,70 on 11 February 2018.
[73] Several interviews in this study as well as (Hunter & Smith, 2017)

There are numerous challenges in curbing gold smuggling, which mostly relate to the lack of incentives and an enabling environment to trade gold through official channels. One aspect to keep in mind in gold trade is that the density of gold makes it transportable: One cubic centimetre of pure gold is worth nearly $1000. From an economic point of view, smuggling of gold is attractive for gold traders because it enables them to avoid taxes and related administrative processes. This point is especially important in Sierra Leone, where a 3% export duty is levied as prescribed in the 2009 Mines and Minerals Act, while in Guinea, the rates have been set at 1% for gold.[74] Such a context further creates high levels of competition for buyers selling through formal channels, because other traders may offer more attractive prices to ASGM miners. In addition to this, gold smuggling becomes especially attractive in Sierra Leone because as indicated by respondents, the numerous borders are porous and monitoring capacity and infrastructure in the regional NMA offices and at Customs is low.

In addition to this, regulations concerning gold trade are rarely enforced. All of the regional NMA offices visited lack capacity, in particular in terms of vehicles, human resources (staff), technical expertise, in particular about the ASGM sector, and other resources. In addition, so far this year, none of the regional NMA offices visited had distributed receipt books among licensed dealers to track their sales, and likewise, none of the traders interviewed possessed receipt books. This makes it more difficult, if not impossible, for these offices and in particular the MMOs to monitor gold sales. Another obstacle to curbing smuggling relates to the ease with which MMOs and customs officials can be bribed, which also relates to their low levels of education and low salaries. As one of the respondents put it:

> *These guys, the MMOs... they earn Le 300-400,000 per month. Now just imagine that you are an MMO and you see the miners who are getting a lot of money without having a license, what do you do?*

Or as one respondent from a regional NMA office (which had cracks in the roof) answered, after being asked about their capacity to monitor gold trade:

> *Just look at the office. Look at me! Just look at our salaries... and now you want me to monitor a rich man who is embarked on a very large scale of mining activities with precious minerals. What do you expect [me to do]?*

When considering such conditions, it becomes more understandable that officers take bribes for turning a blind eye to gold smuggling. Finally, further challenges to curbing smuggling relate to wider (dis)incentives for ASGM miners, traders and exporters to formalize, which includes also their access to financial, administrative and technical assistance. In particular, access to finance is important to consider, because as this chapter has demonstrated, the ASGM sector currently relies mainly on financial support from informal actors, which have little interest in formalizing the sector. These aspects are further elaborated in chapter 4.15.

[74] (KPMG Global Mining Institute, 2014)

4.8 Mining and processing information

Figure 22: Hard rock shafts following gold mineralization in Maranda

The basic principle of gold mining remains the same, be it a massive industrial open pit mine in Australia or an illicit mining gang in Kampala: First the gold hosting rock material must be extracted, then depending on the type of ore, it might be crushed or milled before concentration. Concentration is done by gravity, as the gold is a dense material ($19.32 g/cm^3$) compared to quartz mineral ($2.65 g/cm^{3)}$, which is typically associated with gold. If different methods of gravity concentration (sluicing, panning, floatation) are not efficient enough, chemicals (e.g. mercury, cyanide) can be used. Mercury amalgamation has been replaced in industrial operations long ago, as more efficient methods has been found. However, despite its toxicity, mercury continues to be popular among artisanal miners because it is a reliable and easy to use, compared to other methods.

Whether something is called artisanal, small-scale or large-scale is a matter of taste and national legislation. Extraction and processing styles used, scale of operation and capital available, are among the aspects taken into consideration when the nature of operation and the license type are defined. The following matrix illustrates the key defining factors of different mining styles in Sierra Leone.

Table 4: Basic characteristics of different mining types in Sierra Leone

	Artisanal mining	Small-scale mining	Large-scale mining
Applicant	Citizen of Sierra Leone	Corporation or co-operative having a minimum of twenty-five percent of its shares held by citizens of Sierra Leone	n/a
License area	area<0.5 hectare	1 hectare< area <100 hectares	n/a
Duration	<1 year	<3 years	<25 years
Environmental Impact Assessment	Not needed	Needed	Needed
Labour restriction	<50/license	n/a	n/a
Extraction	depth<10 meters, No heavy machines, No underground mining	depth<20 meters,	n/a
Processing	No heavy machines	n/a	n/a

In this chapter, each step needed to liberate gold are discussed highlighting the different characteristics of different mining styles. Mining styles are classified as follows[75]:

- Alluvial mining (AM & AMGB),
- Hard rock mining (HR & HRGB),
- Panning and diving in rivers
- By-production of gold
- Small-scale mining

4.8.1 Extraction[76]

Hard rock mining refers to mining where gold is still associated with a host rock, and it is not yet liberated by weathering or erosion. Hard rock mining is not typical among artisanal miners in Sierra Leone, but it makes sense to understand where the gold originates from. Typically, gold particles are associated with quartz veins, with a possibility of other minerals, such as sulphides. In Sierra Leone hard rock mining was only encountered in Dalakuru, Kumaru, Masumbirie, Maranda, Baomahun and Makong.

Figure 23: Mining of fresh quartz vein in Kumaru

Hard rock mining in Sierra Leone, occurs in three different formats: Miners might be targeting fresh bed rock (Kumaru, Masumbirie), deeply weathered bedrock (Maranda, Baomahun) or miners are simply collecting weathered pieces of rocks known to contain gold (Dalakuru, Makong). Less the rocks have been exposed to weathering, the more likely it is that there is still gold available in greater quantities. Most of the exposed bedrock in Sierra Leone is deeply weathered, and to get the fresh non-weathered material miners must dig deep, as was demonstrated in Kumaru and Masumbirie.

As quartz is one of the hardest minerals[77], it is understandable that mining fresh quartz vein is extremely laborious for artisanal miners with their rudimentary tools, but in the hope of greater recovery there is always those who are willing to engage into this laborious work. In Sierra Leone extraction of hard rock is done using a hammer and wedge either in an open pit (Kumaru) or in narrow tunnels (shafts) when the lingering quartz vein is followed (Masumbirie, Maranda, Baomahun). No hydraulic machines were seen to be used in hard rock mining. The process of extraction becomes easier as the host rock gets more weathered, as it is in Baomahun, but at the same time this means that erosion has already disseminated some of the gold originally present in the ore.

[75] These are actually the same as introduced in chapter 4.3

[76] For detailed geological account of the locations visited, please see the attached country-wide geological report by Dr. Kelvin Anderson, who was one of the members of the field research team.

[77] 7/10 in the Mohs scale of mineral hardness

Figure 25: Alluvial open pit mining in Kampala

Alluvial open pit mining is arguably the most wide-spread mining style in Sierra Leone. These miners target alluvial gold deposits, where gold - originally hosted by hard rocks - has been disseminated by erosive processes, and where heavy gold particles have been eventually deposited by gravitation. This kind of deposits can be typically found at the bottom of hills and by rivers (ancient or active).

Alluvial deposits allow many creative methods to extract the ore: Open pits were the most widely seen method, but the research team also witnessed narrow vertical shafts called ‘Malian pits’, supported by tree branches, reaching below 10 meters in depth. Rods were used to support the loose material and were told to have prevented many miners from being killed by collapsing shafts: The branches indicate beforehand if the shaft is about to collapse allowing the miner to come up in time.

Figure 24: 'Diver' descending into a 'Malian pit' in Dalakuru

In Sierra Leone, the gold rich zone typically occurs just above the bedrock and miners might need to dig more than 10 meters in order to reach the gold rich gravel. However, if not yet exhausted, the shallower layers also contain gold particles and are worth mining. Unfortunately, those shallow zones seem to be gradually exhausting in Sierra Leone, as alluvial gold mining has been going on for nearly a century. Most of the time, miners are simply using shovels to extract soft soil material. This is time consuming and in some cases most of the time (ca. 75%) is used for excavating the already depleted surface. Single women panning gold by the rivers and streams are a specific case of alluvial mining, where they either directly pan the loose river bed material, or when working close to the existing mines, are given tailings to operate with.

Figure 26: Alluvial small-scale mining in Makoni. For scale, note the excavator in the centre-right of the figure.

All five small-scale mines encountered in Sierra Leone were engaged into alluvial mining, but only one of them in Makoni, was known to operate with a proper small-scale mining license (Figure 26). The dredge operating in the Toyo river near Yele is a specific case of alluvial mining, where loose river bed is excavated using a chain of buckets as can be seen in figure 26. The dredge operates under an exploration license, but it seems to be in full mining operation based on the observations and interviews made. As all the other small-scale operations, the dredge is operated by Chinese.[78] The alleged mercury use and the general environmental impact of the dredge are addressed in the respective chapters.

[78] The exploration license holder M & S Ventures Ltd. is a Sierra Leonean company, and the dredge manager is Sierra Leonean. However, the dredge is not allowed to be in operation without the presence of the Chinese staff, as told by the local crew members.

Figure 27: The dredge operating in the Toyo river

4.8.1.1 The use of excavators

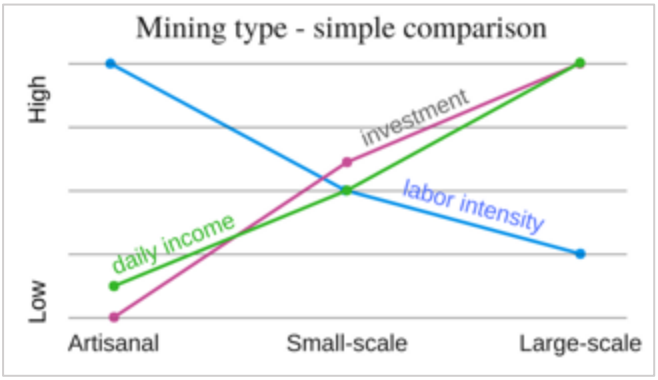


Figure 28: Mining type - simple comparison

Practically all small-scale mining operations, excluding the dredge, were using excavators and they were also witnessed to operate in artisanal mines in Masumbirie and Kumaru. Considering the gradual depletion of surface deposits, their use is understandable and can be assumed to increase: Depending on the type of soil, excavator can move up to 350m^3 in an hour whereas a human can only reach a rate of 0.3m^3 in an hour.[79] In other words, when working for a full day of 10 hours, a group of 5 brisk men or women can excavate approximately 15m^3. Even if renting an excavator costs 1,000,000Le/h, it is actually cheaper option that paying 20,000Le a day for artisanal miners. In the other hand, excavators are only available, if there is local demand and capital, only made possible if the area is rich enough on gold.

[79] Excavator productivity: (Felix Ng, 2016); For estimations on manual productivity, see discussion at: http://www.contractortalk.com/f62/hand-excavation-productivity-108557/, accessed 1 April 2018.

Use of excavators also illustrates a dilemma facing ASGM sector in Sierra Leone in the near future. Their usage would definitely increase productivity in alluvial mining, but in the other hand, the more mechanized the mining becomes the less people the sector can employ. As surface gold deposits are gradually depleting in many areas, this is the key questions which needs to be answered by the decision makers: How to transform the ASGM sector from artisanal operations to small-scale operations – thus allowing the use of heavy machines - without alienating tens of thousands manual workers currently engaged in artisanal mining?

4.8.2 Processing

4.8.2.1 Crushing

In hard rock mining, to liberate the gold, it must be first mechanically disseminated from the host rock. This can be done by crushing and milling. Crushing is needed to break large pieces of rock into smaller, and the output of milling is supposed to be sand or powder like ore material suitable for gravity concentration. In Sierra Leone, crushing was always done manually by hammers or mallets, and no mechanical crushers were seen.

In alluvial mining, the ore has already been crushed (and even milled to some extend) by erosive processes taking place over millions of years. As gold occurs in free form or associated with already small particles, crushing is not needed in alluvial mining.

Figure 29: Manual crushing. Note that the person is currently testing a geological hammer from the research team, and his typical tool can be seen on the ground.

4.8.2.2 Milling

Figure 30: Typical Guinean-made hammer mill with an integrated sluice in the hills near Maranda

Crushing typically does not yet liberate gold, and second treatment is needed, when gold is either milled with a mill, or broken down into sands by mortars. Both methods can be witnessed in Sierra Leone. For higher gold recovery, the process of milling is probably the most crucial. In order for gravity concentration to work properly, grain size of milled sand should be of a similar size as the size of gold particles: If the sand is too coarse or too fine, gold particles will get lost.[80] In hard rock mining in Sierra Leone, mechanical Guinean-made hammer mills were seen in Kumaru, Masumbirie and Maranda. In rest of the places (Dalakuru, Baomahun), ore was milled manually.

Figure 31: Manual 'milling' in Baomahun with a steel tube attached into a stick.

In alluvial mining, part of the gold occurs in a free form in nuggets, flakes or gold sands, where some gold can be recovered without milling. However, introducing milling would increase recovery rate even in alluvial mining, as those deposits might still contain non-liberated gold particles as stated by professor Marcello Veiga.[81] In alluvial mining in Sierra Leone, milling is only seen in Kumaru, where practically all extracted material goes through hammer mills. Better liberation explains why in Kumaru, same ore material can be treated even three times. The treatment of highly weathered rock in Baomahun, could also be called milling, as the outcome of such treatment is relatively fine grain sand.

[80] It must be noted, that typical artisanal miner should be happy if he or she can reach a recovery rate of 50%, and typically most of the gold is washed away. (Veiga M. M., 2006)

[81] (Veiga M. M., 2006), p. 11

4.8.2.3 Concentration

Figure 32: Miners sluicing (too coarse material) in Maranda

After the ore has been liberated by crushing, milling or purely erosive processes, gold can be recovered using gravity concentration methods such as panning, sluicing or both in combination. Only sluice boxes and pans were recorded to be used in Sierra Leone, and those are also globally the most typical concentration methods used by artisanal miners. There are various designs available for a sluice box, but the fundamental principle is the same: Fine sands are washed along the sloped wide gutter, which floor is covered by rugged material (carpets), to capture heavy gold particles, while lighter gangue material gets washed away.

Figure 33: A simple sieve made out of gas can, is optionally used in Baomahun to produce fine sands more suitable for gravity concentration.

There are multiple fundamental aspects to consider in order the gain a high recovery rate: The water flow should be steady, and the velocity of water adapted to the unique particle size of gold present in the host ore. Velocity can be adapted by controlling the water input rate or by adjusting the inclination or width of the sluice. There is no standard solution for this, and therefore in order to increase recovery rate, the particle size must be studied carefully.

Washing the carpets should be done often enough, as once the carpet is filled, no more gold can be captured by it. Washing the carpet is done in head pans or plastic containers, where gold and other heavy minerals captured by the carpet, are rinsed into. This slurry is further concentrated by panning, often done by women, who always use sleek-surfaced metal head pans for this purpose.[82] They simply

[82] In principle, a gold pan should not be sleek-surfaced.

pan until the moment the gold is visible to a naked eye. At that moment, they typically stop the work and collect the concentrate containing traces of black sands[83] and the visible gold particles.

This remaining portion is further concentrated by gently blowing the lighter mineral traces of black sands away, or by using a magnet as accompanying black sands typically contain magnetic minerals.

Figure 34: Final concentration using a magnet

4.8.2.4 Mercury use

Concentration with panning is the moment when mercury is added in two places in Sierra Leone. Both in Kumaru and in Baomahun, miners add mercury to the concentrated ore containing black sands and small gold particles. They do this because they do not believe gold can be recovered otherwise, or because they believe the recovery would be lower if mercury were not used. Both of these believes might well be true, due to the rudimentary and arbitrary concentration methods applied.[84] As toxic as mercury is, it is undeniable fact that it is also very effective at capturing gold in typical ASGM site conditions.[85]

A portion of mercury is added to the pan containing maybe a kilogram of concentrate (Figure 35). This panning phase lasts approximately 45 minutes, which is actually quite ideal time to bring mercury into good contact with gold. In the very last stages, mercury is rubbed against the remaining ore to enable the maximum contact with gold particles. After this, the liquid mercury is poured on a piece of cloth and excess mercury is squeezed away (Figure 36).

Figure 35: Panning with mercury in a pond of water in Kumaru

Finally, the produced silver-coloured mercury-gold amalgam ball is burned (heated up) on fire to vaporize the remaining mercury. Remaining gold is typically referred as ‘sponge gold’ due to its spongy looking surface. Sponge gold still contains traces of

[83] ‘Black sands’ is a typical phase in panning, when only dense minerals, such as ilmenite (titanium oxide) and magnetite (iron ore) are left along with gold.

[84]To understand the reason better, and to introduce a mercury-free method, at least a particle size analysis of the ore should be carried out. Such analysis can either be carried out manually, as described in (Veiga M. M., 2006), or using the laboratory facilities of NMA in Freetown.

[85] (Telmer, 2009) While reducing mercury use is possible, eliminating its use in ASGM has turned out to be more difficult for various reasons.

mercury, which will vaporize when gold is further purified using hydrochloric or nitric acid. This last phase is typically done by gold byers.

From environmental point of view, the good thing is that miners categorically do panning with mercury in sealed small ponds, which is known practice to reduce direct mercury releases to environment. However, eventually those ponds are most probably emptied in a non-environmentally sound manner, and the mercury in them is believed to be re-released to land. In Kumaru, the tailings captured in ponds are panned again, as they still contain gold, illustrating both the richness of the gold deposit, as well as the effectiveness of gold liberation when a mill is used.

4.8.3 Remarks on mining and processing

Even though, no technical interventions were carried out during the field research, concentration is probably the most problematic part of artisanal mining in Sierra Leone. As mills are not used, the sluices are typically fed with too coarse material full of rocks. These rocks block the sluice, fill the carpet with excess material and cause turbulences. All this together cause fine gold particles to be washed away which leads to poor recovery and eventually to poor daily income for artisanal miners. Simple tools, such as sieves, were not used or if they were they were way too coarse.

Figure 36: Squeezing the excess mercury away

Figure 37: Silver coloured gold-amalgam ball being burned openly

It can be argued that the claimed exhaustion of alluvial surface deposits is partly due to the poor techniques, where ore is not crushed or milled, particle size control is not applied (sieve) and adjustment of the sluices is arbitrary. Introducing milling, teaching miners to use sieves and adapting the sluices with good carpet materials, would probably make a big difference in Sierra Leone and could revive the sector. At least this is a relatively cheap option and worth testing, as viable alternative livelihood options are not immediately present. Simple demonstrations could easily be organized by professional miners knowledgeable of these aspects, for example.

Finally, at least two of the worst practices were identified in Sierra Leone[86]: Both in Kumaru and in Baomahun, mercury was categorically burned openly, and no fume hoods or retorts were seen to be used. Furthermore, in Kumaru mercury was practically always

[86] The term 'worst practices' refers to the actions to be eliminated according to the Annex C in the Minamata Convention. They include (i) Whole ore amalgamation; (ii) Open burning of amalgam or processed amalgam; (iii) Burning of amalgam in residential areas; and (iv) Cyanide leaching in sediments, ore or tailings to which mercury has been added without first removing the mercury.

burned in residential area, exposing thousands of miners and children to easily absorbed gaseous mercury. In Baomahun, mercury was observed to be burned in the mining area, far enough from the community, but it was also told to be sometimes burned within the community.

4.9 Mercury use and trade

4.9.1 Mercury Use Baseline

As measures in article 7 of the Minamata Convention only apply to artisanal and small-scale mining in which mercury amalgamation is used, it is important to clearly define this subset of artisanal miners in Sierra Leone. After visiting nearly twenty gold mines, interviewing a dozen of gold traders and meeting with numerous key stakeholders in the country, the research team was able to confirm mercury use only in two locations. However, while not geographically wide-spread, the use of mercury is notable in those two locations.

Currently the only known places where mercury is used among artisanal miners are Kumaru and Baomahun.[87] Based on the gold production in those locations, it can be estimated that in combined 4000 artisanal miners are annually consuming 190kg of mercury in average. [88] The baseline information is presented below.

Mercury use in small-scale mining is not a fully established fact, as the research team had never a chance to see mercury amalgamation in practice. However, based on on-board interviews, it was approximated that 163.8kg of mercury is annually consumed in a dredge, currently operating in Teye river in Yele.[89] The mere allegation is important to document, as the research team encountered at least three other small-scale mining companies operating without a proper mining license. The indication serves as a warning that the illicit small-scale mining is likely to increase in Sierra Leone, and is possibly engaging into environmentally harmful practices, such as mercury amalgamation.

[87] Due to the time limitations in Baomahun, not all hard-rock mining areas were visited, and results have been extrapolated for those areas using Sentinel-2 satellite data as on 28 February 2018. The extrapolation has been done using land area estimations for areas which were told to be active by locals.

[88] In Kumaru and Baomahun, the mercury use was estimated using the mercury:gold ratio, as described in (O'Neill & Telmer, 2017). Based on the observations, high price of mercury and physical measurements, the established standard estimate of 1.3:1 was adopted for this study, meaning that for each kilogram of gold (24K), 1.3kg of mercury is needed. This standard estimate applies to concentrate amalgamation and is based on the research done by Kevin Telmer and Marcello Veiga, (Telmer, 2009).

[89] See chapter 4.13.3

Table 5: Mercury use in ASGM[90]

Type	Community	Work force			Mercury use (kg)		
		min	max	mean	min	max	mean
Artisanal	Kumaru	1163	6656	3909	4.94	309.74	157.34
Artisanal	Baomahun	75	197	132	11.61	48.73	30.17
Artisanal	**Total**	**1238**	**6853**	**4041**	**16.55**	**358.46**	**187.51**
Small-scale	Dredge (Yele)	7	7	7	163.8	163.8	163.8
All	**Grand Total**	**1245**	**6860**	**4048**	**180.35**	**522.26**	**351.31**

Currently, most of the time miners seem to be simply unaware of the amalgamation method. Furthermore, there are several other reasons, why mercury use is not more prevalent in Sierra Leone: Most of the gold deposits available for artisanal miners are alluvial in nature where most of the gold occurs in a form of sands or nuggets. This already liberated gold can be most of the time recovered even with the present rudimentary gravity concentration methods by sluicing and panning. Mercury is also fairly expensive in Sierra Leone (3500 Le/g[91]) in comparison to their modest daily earnings. However, due to the mobile nature of artisanal mining in Sierra Leone, the situation might change over-night and the use of mercury must be addressed pre-emptively before its use becomes a real country-wide problem.

Limited use of mercury in ASGM is also reported in neighbouring Guinea, which is in line with the findings in Sierra Leone.[92] Further evidence can also be found at the Strategic Environmental Assessment report, which doesn't even mention mercury being used in Sierra Leone.[93,94]

4.9.2 Mercury Trade

This is a very good market. But only if you have money. If you have one million you are going to gain one million.[95]

In the areas where mercury use was observed, most miners do not know where mercury comes from because only a few people are involved in the mercury trade. This has to do with the fact that mercury is very expensive: it has been reported in Kumaru (in early February 2018) to cost Le80.000 and Le100,000 for a small cup (more precisely, the top of a water bottle), which is equivalent to 1 oz

[90] The estimated mercury use only counts the mercury directly used in amalgamation. As mercury becomes ineffective over time due to the impurities and oxidation, it must be either discarded or 'reactivated' to be used again. 'Reactivation' of mercury is not technically difficult and at least three simple techniques are available (Telmer, 2009). Due to the high price of mercury, it would be sufficient to expect mercury traders to collect old mercury from miners for reactivation, but no information on this was acquired during the research. However, this is an aspect which should be addressed when beginning to implement plans to reduce mercury use (See chapter 5).

[91] Kumaru: 100,000Le/Oz, Baomahun: 90,000Le/Oz

[92] http://artisanalgold.blogspot.fr/2017/04/mercury-use-in-guinean-asgm-sector.html, accessed 27 March 2018.

[93] (EPA & NMA, 2016)

[94]The given average estimation is fairly close to the estimate given by the UN Environment Global Mercury Assessment (225kg), which is probably a mere coincidence but still worth pointing out. The Global Mercury Assessment 2013 only counted emissions to air. (UNEP Chemicals Branch, 2013)

[95] Gold trader interviewed in Kumaru

($0.37-0.64/g). In contrast, in December 2017, the same amount of mercury would only cost you Le40.000/oz (i.e. $0.19/gram); the price has thus more than doubled in only a matter of two months. According to local informants, this is due to scarcity of mercury in Sierra Leone.

As the current world market price for mercury flask of 34.47kg is 2000USD (0.058 USD/g), it can be estimated that mercury worth 10,875 USD is imported to be used in artisanal mining. However, there is more to that when we look at the street price of mercury in Sierra Leone. Using an average estimate of 100,000 Le/Oz (0.47 USD/g), means that there is close to 100,000 USD circulating in the mercury trade in Sierra Leone.

The mercury users interviewed here usually buy 1-4oz of mercury at once. It was mentioned by mercury users in Kumaru that mercury comes mostly from Liberia. The respondent shared that he buys mercury from a businessman in Monrovia who exports gold to Dubai. If he wants, he can get as much as 1000oz (ca. 28kg) of mercury from his buyer in Liberia. This man allegedly has agents working for him to buy gold from 'Julahs' in Kumaru and sell mercury in return, complemented with the difference between the mercury and gold value in cash. The 'Julahs' buying the mercury then usually sell part of it to make more cash, as it has now become a very lucrative business in Sierra Leone. This was illustrated by the enthusiastic statement of one of the respondents: "This is a very good market. But only if you have money. If you have 1 million you are going to gain 1 million". These informants were not aware of any health effects from mercury.

It was also indicated by the same informants from Kumaru that a small part of the mercury used in the area comes from Ghana where it is cheaper than in Liberia, while there are obviously more travel costs involved in getting it from there. It was also mentioned by an unlicensed trader in Kumaru that the Chinese brought in the mercury and also use it there in their own operations; and by other unlicensed traders in Kumaru that mercury can be bought from gold buyers in Guinea. Cheaper mercury in Ghana is understandable in the larger context: Neighbouring Togo is known to be the import hub of mercury to western Africa, providing mercury to Ghana's mercury-intensive ASGM sector, as illustrated in Figure 38.[96] Evidence collected seems to confirm that mercury is flowing from Togo via various channels, as suspected in the referred report by World Bank/COWI.

To put the mercury trade into a context, it is illustrative to think of the volume of consumed mercury in artisanal mining (187 kg). As extremely dense liquid metal, it would only take less than 14 litres in volume, to pack 187kg of elemental mercury.[97] Such quantity can be easily imported by few people carrying light backpacks, or by a single person making few trips to neighbouring countries in a year. When it comes to alleged mercury use in small-scale mining (163.8kg), they have very little reason to use same trade channels as artisanal miners. Small-scale mining companies visited, imported raw materials for their own use directly from China, giving them ample opportunities to import some liquid mercury along with steel and heavy machinery, if so needed.

[96] (World Bank/COWI, 2016)

[97] Density of elemental liquid mercury 13.69kg/litre

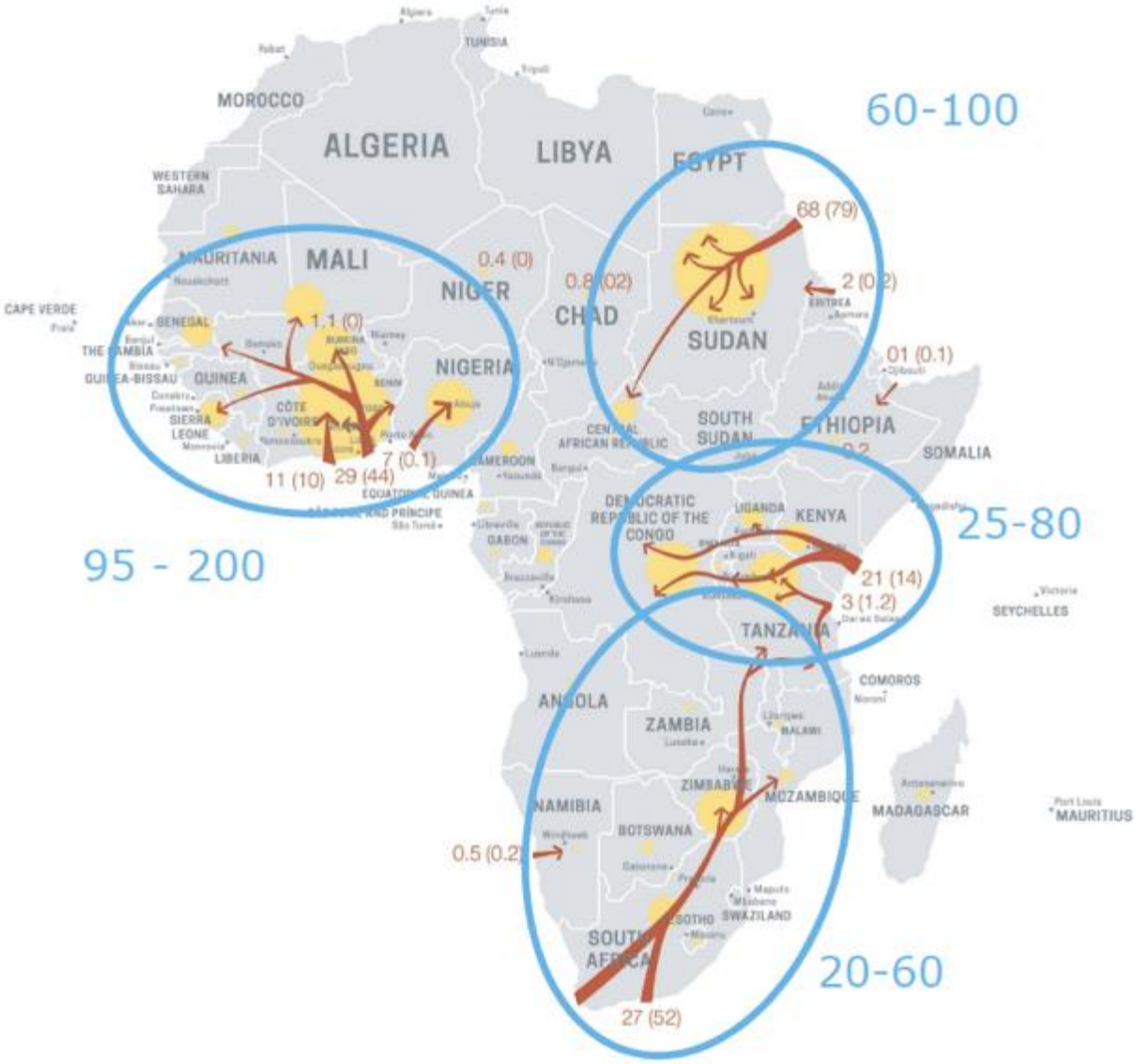


Figure 38: Overall trade flow of mercury in Sub-Saharan Africa. Red numbers indicate the average official import for the period 2010-2015 from countries outside the region with 2015 import figures in brackets. The actual import may be up to twice the indicated official import. The area of yellow circles, indicate the estimated mercury consumption for ASGM in the countries (mean estimate). The blue number indicate the likely total mercury consumption within the sub-regions indicated by the blue circles. (Illustration from (World Bank/COWI, 2016). Used with permission.)

4.10 Impacts on local development

The ASGM sector has an important but complex relationship with local development in rural Sierra Leone. This chapter discusses the main implications, and both positive and negative impacts on socio-economic development (environmental and health aspects are discussed in following sections). It first discusses the impacts the sector has on ASGM miners and their families, and on local economies. Subsequently, it discusses perceptions of local authorities about ASGM's contributions development in their communities. The two subsequent sections after this one discusses more deeply the roles and position of women, youth and children, which also touches upon issues of local development.

4.10.1 Impacts on ASGM miners and their families

In judging any sector's impact on local development, it is important to situate it in the local context and to consider how this context gives rise to the sector. It this respect, all respondents interviewed as part of the socio-economic assessment were first asked what motivates them to engage in ASGM. The most common motives given include:

- To earn "fast money" needed to feed their families and provide them with clothes, books and medicines
- To earn "fast money" money needed to pay for their children's school fees
- To accumulate capital needed to pursue their own education, with the aspiration to get a specialized job
- To accumulate capital to invest in agricultural inputs, in vehicles or housing for their family, and different businesses
- To cope with shocks (e.g. the death of a loved one, loss of a job, loss of money, etc.)
- Engaging in ASGM does not require much knowledge or significant start-up capital
- The lack an alternative livelihood which is economically viable and easily available

The quotes below reflect some of the typical motives:

> *In gold mining, you are assured of your survival. You know that at the end of the day, you can have your Le50,000. They are there to survive and to help their families. Gold mining has more assurance than diamond mining.*

> *You see this place, we are very poor. Poverty is finding people right here, you see people mining this and that, just to feed themselves.*

The first quote underscores an important distinction between gold and diamond mining. An often-heard observation from respondents was that "with goldmining, you can get your living everyday [...] with diamond mining may get rich, but it is difficult", alluding to the fact that while with diamond mining you can get rich, there is much more risk involved. In contrast, with gold, you have less chances of getting rich, but you have a much more stable income. This is the main reason why women in Sierra Leone have historically been involved in gold mining, while men mainly focused on diamonds. As was indicated by a female panner in Kumaru: "In those days, if men saw gold they threw it away, because they thought it was bad luck. All they wanted was diamonds... Today, finding diamonds is very difficult, so many more men engage in gold mining now". This has been changing recently, as is further elaborated in the next section on women.

When considering these motives, it is important to note that most of the miners use this occupation as an instrument to pursue development in other domains, such as education for their children, accumulating cash to pursue other businesses, or to pursue their own education in the hope to pursue better jobs in the future. As a labourer in Kumaru said: “I want to make money to go to school and become a doctor!” The question is, to what extent ASGM effectively helps these people to pursue these goals. For some people, it turns out relatively well. This was underscored by a labourer from Kumaru who had lost his job as a technician during the Ebola crisis and had turned to ASGM where he had managed to accumulate enough capital to construct a house for his family, and was currently saving money from ASGM to pursue his studies in electrical engineering:

> *It made some difference really because when I first came here things were very difficult when I compare it with now... there is future improvement, there are future plans.*

For others, it has been more difficult to realize their envisioned results. Many ASGM miners who planned to mine temporarily with the aspiration to pursue more specialized livelihoods, have failed to accumulate enough cash to pursue further studies or make other necessary investments. Similarly, it has been difficult for many miners to accumulate enough cash to make investments in businesses. As a result, many of them stay in the mines for years, where working and living conditions are typically harder than elsewhere. In terms of living conditions, ASGM miners living at the mine sites typically live in simple huts without proper roofs, and alcohol consumption was observed in most ASGM areas. The mobile nature of young miners has occasionally been reported to have caused teenage pregnancies. Besides this, it should be mentioned that the overall atmosphere in these areas is calm and peaceful, and that no prostitutes have been witnessed at the mine sites.

In Kassasie, in Sella Limba chiefdom, some women that used to be ASGM miners now mine coltan as this mineral had been recently identified in the chiefdom and the price for coltan had recently risen. This trend can be explained for a large part because in many areas, the near surface gold deposits are gradually getting exhausted, and with a lack of capital it is difficult for many miners to go deeper to hit the richer parts of the mineral deposits. However, it is for a large part also due to the multiplicity of actors that benefit from ASGM, and challenges in effective formalization of the sector (this is further discussed in chapter 4.15).

However, despite the declining near surface deposits, ASGM activity still raises significant wealth in poor areas. Based on this field study, ASGM miners in Sierra Leone have been found to earn between Le11,250-88,000 ($1.48-11.58) on a daily basis, and Le28,320 ($3.73) per day on average. It should be mentioned that taking into account the seasonality of alluvial gold mining, on average, ASGM miners work only 7 months per year.[98] This is much more money than is earned in most other livelihoods pursued in rural areas. For instance, when compared with farming (which is obviously a very different livelihood which has the advantage of providing direct food for people and is mainly done on a subsistence level), farmers approached in this study have reported to earn between Le23,788-780,000 ($3.13-102.63) per year, or Le65-2.136 ($0.0086-0.28) per day.

The fast cash earned in ASGM has important implications for local development beyond the individual miner. As has already been underscored, miners have reported to mainly spend their income on school fees for their children. This is especially important because, as has been discussed in section 4.2.4, primary schools in rural areas (at least those areas visited in the school study) and their teachers are often not officially recognized by the government, which causes parents to pay teachers informal financial contributions to enable their children to be educated. Besides this, it has been reported by several ASGM miners that they also use their revenues for sending their children to secondary school and in exceptional cases even to university.

4.10.2 Impacts on the local economy

The fast cash earned in ASGM serves as an engine for local economies and has significant spillover effects on other local economic sectors. First of all, the sector creates markets for farmers and small traders. Indeed, during the visits in mine sites, the researchers often observed children and women selling foodstuffs such as maizepap, bread and grannots to miners. It also attracts other goods and services, especially in established ASGM communities such as Kumaru which host many shops of traders, restaurants and hairdressers, and where many bike riders operate. In these places, demand for such products and services is high, and as a result, prices are typically also higher. As was explained by a shop owner in Kumaru, who lived in Makeni before but had moved to Kumaru with his wife to sell goods, because: “wherever there is mining, demand is high… for example, if some certain good costs 5,000 in Koidu, it could cost 6,000 here”. Miners reportedly buy especially a lot of fuel and rice from such shop owners and other traders. In Baomahun, it was reported by a local farmer that farmers from surrounding villages come there to sell their produce to ASGM miners.

This finding is particularly important for agriculture, because farmers have reported to face big marketing challenges as they have limited means to transport their products to suburban areas where

[98] Further limitations and clarification about this estimate can be found in chapter 4.2.2

demand and prices are higher, and they lack warehouses to store their products and sell when prices are high, as has been investigated and documented more extensively in other studies.[99] In such a context, the ASGM areas serve as spontaneously emerging 'proto-urban centres' which can serve as decentralized markets that are closer to the farmers.[100] In a few cases, it was also mentioned that revenues earned in ASGM were invested in engaging labourers for agricultural activities and in farming tools, but not as much as was reported in other studies before, which is likely linked to the fact that near surface deposits are declining.

With regards to agriculture, there are also negative economic effects stemming from ASGM. Most significantly, as was indicated by several farmers living close to ASGM sites, AGSM miners do not rehabilitate the land and leave behind large pits (the environmental and health impacts related to this are discussed in later Sections). As a result, farmers cannot use this land for farming anymore, and in some cases, farmers have taken it upon themselves to recover the land, costing them significant effort.

But beyond analysing positive and negative impacts from one type of livelihood on the other, one of the clearest observations has been that as has been documented before, farming and mining in Sierra Leone should not be considered as 'livelihood alternatives', but as 'livelihood complements'. Indeed, in many of the areas visited, people engage both in alluvial goldmining, as well as in farming activities. Combining these two activities provides people with the possibility to enjoy both the food generated through farming, and the cash generated through ASGM on the short term, and better enables households to spread risks and becoming resilient in coping with shocks. The practical deviation of work tasks between the two activities is facilitated by both sectors' seasonality. In the rainy season, when alluvial mining activities typically stop because the river beds are full of water, people mainly focus on farming: they are occupied with planting seeds and ploughing and weeding the soil. In dry season, people mainly focus on alluvial mining, and their farming activities are less demanding, as they are typically restricted to harvesting crops. On days where both activities require attention, farming miners or mining farmers do most of their farming work in the morning and their mining work in the afternoon.

4.10.3 Perspectives from local authorities

Most of the paramount chiefs and community chiefs visited also underscored the sector's importance for development on their land. For instance, as was indicated by the community chief in Kampala, Sanda Loko chiefdom: "goldmining is the only activity here generating income for school fees"; or by the town chief in Masumbiri, Simiria chiefdom: "The economic impact of goldmining is important here. It is creating business activities in town". At the same time, among some local authorities, a frustration was expressed that mining in general over the past century has not managed to alleviate poverty in their communities. As one paramount chief put it:

> *My whole contention with mining is that having mined from the 1930s to now the 20th century, there is nothing to hold on to say: this is what we have benefited from this mining.*

Or as another paramount chief put it, when discussing panning activities by the river in his chiefdom:

[99] (Cartier & Burge, 2011); (Maconachie & Hilson, 2011); (Hilson, 2011)
[100] For more on this, see also (Cartier & Burge, 2011)

It is a small part of what is going on [in the country] but for the women it is very important. My perspective is that nobody except for the women is benefiting.

This paramount chief does not receive any revenue from the ASGM activity as they are unlicensed and does not want to force the miners to pay it because the miners in his chiefdom (who mainly pan along the river) do not earn very much. When asked about the reason for the sector's inability to translate to long term development, it was expressed that it has to do with the way the sector is governed:

The ASM sector is where we hope the Sierra Leoneans will benefit because it is exclusively for Sierra Leoneans. But the supporting mechanisms for people working in this sector are missing... So that's why, even though it is our own terrain, we allow them because: what else have the people got?

This statement alludes to the governance of the ASGM, which has been identified by several respondents as a barrier to the full exploitation of the sector's potential.[101] Besides governance, the statement also underscores the importance for nationals and for locals to benefit from ASGM activity. Related to this, a common cause for frustration among many local authorities is the strong presence of (domestic) migrants and foreigners in the sector. In most of the ASGM areas visited, roughly half of the concern people that originate from other areas in Sierra Leone and have come there to seek their living. Most of these migrant miners have shared to use their savings to take care of their primary and extended families which typically do not live near the mining area. For instance, as was shared by a female labourer in Kumaru, she travels back to Freetown once in a month to share her savings with her poor husband and her six children, or she uses Airtel to send money to her husband. While such actions contribute to wider development in Sierra Leone, it leaves less of a tangible impact in ASGM communities (aside from the miners' own consumption of local services and goods). Furthermore, as has been discussed in Section 4.7, the gold trade in Sierra Leone is largely controlled by powerful traders from Guinea and Liberia, and their Sierra Leonean agents who have the Sierra Leonean nationality but typically share these traders' ethnicity and/or family and kinship ties. This further undermines the ability of local people to reap the full benefits from ASGM activity.

4.10.4 Comparison with industrial gold mining companies

Finally, in understanding ASGM's relevance to local development, it is useful to draw a brief comparison with industrial gold mining companies. As has been underscored in several parts of the report, industrial gold mining companies are on the rise (though officially often under an exploration license), and their role will become more important in the future as many ASGM miners now have to dig deeper to reach rich gold deposits. When asked about their future, several ASGM miners have expressed their hope to get employed by such companies. However, after the arrival of such companies, many of these miners have been disappointed, as the companies did not employ as many locals as expected. Most of the industrial companies visited employed only a handful to several dozens of

[101] In this respect, it should be mentioned that chiefdom authorities themselves have an important role to play, because in some chiefdoms, they do receive substantial benefits from ASGM activity. Governance of the sector is further discussed in Section 4.6.

people, and the technical jobs are typically reserved for foreigners from the company's country of origin (typically Chinese). Among the companies visited, this left predominantly manual labour for Sierra Leoneans, though some of the locally hired employees also shared to have learned how to drive excavators.

Based on interviews with local workers for such companies, the companies typically hire local employees at daily wages around Le20-30,000 with little to no social benefits. Whereas some of these workers had prospects to work for several years, the majority of local workers encountered were only hired for the short-term and had no guarantee for the future. Still, those workers were typically happy that at least they had a job. But when compared with the ASGM sector, such companies clearly create much less employment as much of the labour that is performed by human beings in ASGM, is performed by machines in industrial operations.

Besides the creation of employment, it is also to consider company's wider impacts on the environment and local communities. Paramount chiefs having industrial mining companies in their chiefdom have often expressed frustrations about such issues, as is illustrated by the quote below:

> *Most mining companies that come in to explore are expatriates who do not have an environmental management plan… the picture is very good when they come in. But they have no community development plan. They say they do, but they do not do anything.*

This perspective has been largely reflected by the communities surrounding the industrial companies visited, which shared to have had very limited communication with the company. Only in exceptional cases, such as in Baomahun, had a former company invested in the local community by for instance establishing a well for pumping drinking water, and has the company present at the time of research established positive relations and actively engaged with the community.

4.11 Women in ASGM

Figure 39: Women mining in Teye river near Yele

Women have a special role in Sierra Leone's ASGM sector. Whereas historically, men have dominated the diamond sector in the hope to get rich one day, women have steadily focused on gold. As discussed before, this has to do with the fact that gold mining brings more stable returns than diamonds, which is an important attribute for women as traditional caregivers for their families. Besides this, diamond mining has historically been considered more of a men's job in Sierra Leone because it involves more hardship, which may be another reason that many Sierra Leonean women have historically opted for gold mining.[102]

The majority of women that are involved in ASGM in Sierra Leone concern single mothers, whose husbands/man have either passed away or have abandoned them. Alternatively, they may be mothers whose husband/man does not earn much or take much responsibility in caring for their families. In fewer cases, women are involved in ASGM together with their husband. There are only few young women involved in ASGM. As these women carry the major responsibility of obtaining their families' basis necessities, they engage in ASGM to earn an income to be able do so. Many of the women interviewed have decided to do so shortly after they had lost their husband, or after they had experienced another type of shock, such as loss of land to farm on, loss of business, or disappointing returns from other activities. They mainly spend their revenues earned in ASGM on food, clothes, medicines, and school fees for their children. Younger women can also be seen around mine sites, but these are typically only engaged in selling food, clothes and other products.

4.11.1 Women's role

In terms of roles, women are mainly involved in the panning of gold. Throughout Sierra Leone, they are recognized as "panning experts" and often engaged by men for this purpose. [103] Besides panning, women are also involved in washing the ore in sluice boxes. They are usually not involved in the digging of ore, because this concerns a physically demanding task and men are deemed to be more

[102] Pijpers, 2011

[103] The story goes that women are naturally good at panning because they have historically panned rice to sort the rice grains

suitable for this type of work. In some areas, women are also involved in prospecting for gold, which they do by digging small holes with shovels and taking soil samples to check the ore grade by crushing, washing and panning. This is for instance so in Tonkolili district, as was explained by an MMO officer:

> *Women are local geologists for the men... They take their shovel and their head pan and 'tjook tjook' until they find a very good deposit of gold there, and they 'tjook' and 'tjook' ... until they find the limit, they cannot go any further, then they call the men… They are professionals, they are super professionals!*

This role as prospectors was also confirmed in other areas but was not observed to be as common in Sierra Leone as has been reportedly elsewhere in the literature.[104] Around the Pampana river, in particular in Yele, there were also women who were involved in 'diving' to get gravel from the bottom of the river, which they then sluiced and panned.

In addition to women's commitments in ASGM, it is important to note that as mothers, they have further responsibilities in their household, including in particular cooking and taking care of their children. When asked about how these tasks are combined, most of the women explained that they wake up early in the morning to prepare food, work between 8am-4pm, and then come home to prepare food again. Most of these women have family members and friends to take care of their children in their absence, and many women working together also support each other in combining these tasks and replacing each other at the household. Besides this, there are also many women who combine mining with farming. This is particularly so because women are predominantly involved in alluvial mining which only takes place during the seven months of the year, which provides them with more time to engage in complementary activities. Women's role in combining ASGM and farming activities, and their use of ASGM earnings for agricultural activities is further documented elsewhere in the literature.[105]

4.11.2 Women's organization

Most women in Sierra Leone's ASGM sector work on an individual basis. Those women who pan along the rivers are often found in a small group of two to four women, typically consisting of family members of friends. But in most cases, this company is merely chosen to make the work more enjoyable and out of practically (e.g. because the specific area they work in is rich of gold or because they can combine looking after their children they have taken with them in this way) and the women still conduct their tasks of panning ore and selling gold individually. In other types of mines, for instance in alluvial open pit mines, women may be engaged by male-dominated gangs of diggers for the specific task of panning the concentrate and/or washing the ore. This engagement is usually on men's initiative and women typically do not have easy access to these gangs, unless their husband, a relative or a friend is part of the gang and invites her.

There are several reasons why women do not organize themselves more solidly. First, as a general challenge in Sierra Leone, make people do not trust each other easily and do not want to take the risk

[104] Averill, V. (2006) Sierra Leone eyes a golden future. BBC News, 20 August. Accessed at: http://news.bbc.co.uk/1/hi/business/5262960.stm

[105] (Maconachie & Hilson, 2011)

of sharing their ore with others. Indeed, many women interviewed have indicated that they are afraid that others will free ride on their hard work. Second, different persons may have different preferences in selling the gold, which may cause disagreement and conflict in groups of female miners. For instance, some people want to sell directly to get the fast cash, while others prefer to accumulate gold for a certain period and then sell the gold altogether, often at better prices. Third, women alone cannot work in an open pit or hard rock mine because they would always need men to do the hard work of digging and shovelling the ore. Finally, women lack several assets required for organizing themselves, including access to finance and access to land (discussed further below).

4.11.3 Women's access to assets: gangs, leadership positions, land & licenses, and capital & markets

As has been mentioned above, it is difficult for women to access mining gangs as this typically requires that you know someone in the gang, and the labour performed by women in the gang is often on a short-term basis. Besides this, it is difficult for women to access gangs (as well as leadership positions, licenses and land, discussed hereafter) operating in hard rock mining sites as they are often not allowed by superstitious beliefs to go up in the hills. [106] In addition to these beliefs, the working conditions in those places are usually pretty rough as it concerns heavy work, and there have been reports (but no observations in this study) of male miners mining naked up the hills in Baomahun.

This is also related to women's access to leadership positions. As has been discussed in Section 6.5, there is quite some social mobility in Sierra Leone's ASGM sector and diggers can climb the hierarchy by becoming for instance a gang leader. However, as Sierra Leone is a masculine society and still faces significant challenges in reducing gender equality, this is more difficult for women. [107] As discussed above, women already have restricted access to mining gangs, which makes it more difficult to become a gang leader. This is coupled with the fact that recent years have seen a transition of men from diamond mining to gold mining, which has made it more difficult for women to assume leadership positions. Still, a few female gang leaders have been met during the field study. For example, in Makong, a female miner identified a new area in her prospecting work, and she became a gang leader after engaging three men and four women to work with her. It is thus possible for women to acquire leadership positions, but it typically requires talent, hard work, capital and good social relationships.

Access to land is a bigger challenge for women. In Sierra Leone, the land is owned by families, and access to the land has to be negotiated directly with them, in consultation with the paramount chief of the respective chiefdom. In such negotiations, possession of social ties and financial resources play an important role, and women often face more difficulties than men because of local gender norms. There are currently no ASGM licenses owned by women. To go back to the example of the female gang leader in Makong, she wanted to become license owner and he had enough capital for it, but they had a discussion with the men and then became the license owner because "it is usually the men who take the license". In addition to this, she lacked the full capital required to obtain the license. In another

[106] In all mountaneous areas visited, there is the unchallenged, a common belief that there is a devil spirt of a woman up there which you cannot see, but who can stop giving gold when there are other women around. The miners visited up in the hills believe that the presence of other women, who reproduces, "stops the devils reproduction", i.e. the gold the mountain gives.

[107] The 2014 female Human Development Index value for Sierra Leone is 0.370 in contrast with 0.454 for men, resulting in a Gender Development Index (GDI) value of 0.814

case, a female gang leader in Masumbiri owns the land of her pit, but this has cost her a lot of money which has been paid by her husband, whom she is effectively representing at the mine pit.

Access to capital is a general challenge in Sierra Leone, as is elaborated in later chapters. Women's access to capital is strongly related to women's access to markets because it is often the gold buyers that support the miners financially. Since the majority of women operate individually, it is less interesting for gold buyers to invest in their operations as their production is lower. As a result, most women do not have a fixed buyer and usually just sell their gold to the small traders and gold buying agents who visit their communities and mine sites. Some women also shared that they prefer not to have a fixed buyer because they have the impression that traders try to cheat on them when for instance measuring the gold with their balance, which many of the women cannot read. Similarly, there are very few female gold traders. Most women interviewed would like to become a trader, but the majority of them, who typically enjoy very low levels of education, cannot do this because they do not know how the scales work, and further have little knowledge about the gold business, financing, and pricing, etc. On top of this, there is a lot of competition among traders, so it is more difficult to stay up with the competition. From the perspective of gold traders, it is also strange for a woman to be a trader, and they generally only meet female traders who are assisting or replacing their husband if he is busy or sick.

4.11.4 Women's income

The women interviewed in this study have reported to earn between a range of Le10,000-65,000 ($1.32-8.55) per day, and the average daily wage calculated is Le22,178 ($2.92). It should be mentioned that this average contains input from two female gang leaders and several women interviewed in Kumaru, where production was at the time of research very high. In many settings where women are engaged by men, they are paid in gravel and typically receive one full "head pan" per day, which typically contains 0.3 carat and was sold for approximately Le15,000 ($1.97) at the time of research. It is expected that the average income for a random woman working in Sierra Leone's ASGM sector is somewhere between these averages (Le15,000-Le22,178). This is a lot less than what men earn.

Indeed, gang leaders admit paying men more than women. For instance, a gang leader in Baomahun reported to pay men Le20,000 ($2.63) and women Le15,000 ($1.97) per day. The reason given for this is the unequal physical effort in the work, as the digging work performed by men requires much more strength and energy than the washing and panning work (typically) performed by women. Another reason for women's low income, is the fact that they are usually given the tailings to work on, while men typically work on the primary ore in alluvial mining and the primary deposits in the case of hard rock mining, which is typically also richer in gold.

Beyond income, another problem related with the tailings is that an effective recovery of gold from those tailings that contain "floating gold", requires the use of mercury. Thus, for example in Kumaru, many women are involved in treating the concentrate with mercury. However, it should be noted that from the observations made in this study, it is only men who possess the mercury, and that in some cases, it was also men who performed the mercury treatment of the women's concentrate. Moreover, the amalgams were usually burned by gold buyers, who are exclusively men.

4.11.5 Women's ambitions and opportunities

When asked about their ambitions for the future, many women shared their hope to do a small business in clothes, food, and products for daily use. Most of them cannot yet make this happen because they lack capital. Similarly, some women shared that they want to engage in commercial farming, but this also requires capital, and they need cash on the short term, which they are not likely to get in farming. This results in many women staying in ASGM because although they would prefer to have something else, they have no alternatives which are economically at as viable as ASGM and directly available to them. There was also a significant number of women who want to stay in ASGM, and hope to one day become a gang leader, do business on the side, or combine this with agriculture.

Finally, it is important to note that women in ASGM, who are mainly involved in panning and washing and do not cause significant environmental damage as they do not dig, are adversely affected by environmental degradation as they depend most on the environment for making fire and feeding their families. For this reason, and for the fact that women are traditional caregivers in their families and communities, they are well positioned to lead efforts that aim to promote environmental stewardship and health protection in their communities.

4.12 Youth and Children

The majority of ASGM miners concern young men. Since youth and children represents a large part of Sierra Leone's population which faces pressing challenges, understanding their attitudes, ambitions and the challenges they are facing has been another important focus of this study. Therefore, in every ASGM community visited, the research team tried to meet with youth leaders as and also representatives from the district youth councils that have been established in Sierra Leone as part of wider efforts in the post-conflict reconstruction in the country.

4.12.1 Youth

When local youth leaders were asked about the challenges youth are faced with, the typical answer was: "the biggest challenge facing youth is unemployment". One youth leader elaborated on youth's attitudes towards different livelihoods:

> *they don't see farming as a viable, lucrative sector…*
> *they are looking at agriculture as slow cash... This is different in gold... This is also why they want to be bike riders*
> *a lot of people nowadays go for fast-cash. They want to get daily payment for labour*

These attitudes help to better contextualize many youth's preference for ASGM (in addition to the motives listed in Section 4.10). As discussed in Section 4.10, many youths in ASGM do not want to be in the sector for ever and the majority indeed hopes to be able to pursue more specialized jobs in the future (e.g. as an electrician or a carpenter). But as was discussed by the youth leader quoted before, they lack the knowledge and skills for such jobs. This concern for education amongst children and youth was also shared by a paramount chief:

> *Presently, all the youths are okada riders... Are you surprised when they are in drugs? They have nothing to do. Their educational background is so poor.*

However, in order to obtain the education required for pursuing such professions, youth needs to have capital. As discussed earlier, this is one reason why many youths mine gold. As one youth leader explained:

> *That is what the youth are doing now on a short time basis, forgetting their impacts on the environment… I just have to exploit all avenues to ensure that my own suffering will stop with me along, it does not continue through my daughter [because at least she can have decent education]*

However, it should be mentioned that the respective youth leader quoted here emphasized that in its current form, the ASGM sector is not organized and not sustainable. According to him, youth, in both mining, agriculture and other sectors, mainly prefer to work on an individual basis and with a fixed daily wage because distrust is still deeply rooted amongst them and they do not want to take any risks by for instance organizing into a credit cooperative. Similarly, it was shared that the formalization of the sector is a big challenge because youths do not want to commit to paying taxes because they believe that the government will not give them anything in return. Therefore, youths need to be assisted and this trust has to be built, because: "without these taxes, we cannot survive as a nation".

Nevertheless, when the young ASGM miners themselves were asked about their ambitions for the future, many of them welcomed the prospect of formalization. For instance, as a gang leader and several labourers from Baomahun shared, if they have a license, they can claim their rights, exercise more authority and use milling machines. However, in the case of Baomahun, and also in other ASGM areas in Sierra Leone, the ASGM miners cannot get a license because they are on a concession of an industrial mining company. At the same time, as has been discussed in Section 4.10, many other young miners want to pursue their education to eventually pursue more specialized livelihoods, and a formalization of the sector, if effective, could potentially better help them in accumulating the capital to do so. This is further discussed in Section 4.12.

Finally, when considering the employment and educational challenges that Sierra Leonean youth are faced with, combined with the anticipated population growth in Sierra Leone[108] discussed in Section 4.3, it is important to consider potential social unrest that may arise from an ineffective addressing of the issues discussed in this section. As the experience in Kumaru underscores, and as has previously been cautioned in the literature, the continued creation of a 'socially-excluded economic class' and a 'loss of a sense of hope in the future' among these Sierra Leonean youths may (re)create the preconditions for war.[109]

4.12.2 Children

Worldwide, children's participation in the ASGM sector occurs across Africa, Asia and South America, including in West Africa.[110] Child labour in ASM is recognized by the International Labour Organization as one of the worst forms of child labour because it concerns physical, strenuous labour, often resulting in muscle pain and stiffness, back pain, skin lesions, poor appetite and sleep disorders, and in the worst cases, resulting in death, all depending on the precise tasks they perform and for what periods. [111] [112] Concerned with issues of child labour, Sierra Leone is Party to the 'UN Convention on the Rights of the Child'. [113]

In Sierra Leone, children play an integral role in contributing to the survival of the household, both economically and in terms of ensuring food security. However, they seem to have a limited role in the domestic ASGM sector. In the majority of mine sites visited, children, if present, were mainly selling foodstuffs to ASGM miners and accompanying their mothers while they were working. For instance, in Dalakuru, children go to school during the day but after school they join their mothers who are panning along the river and play with each other. In only a handful of mine sites visited, a few children

[108] 2015 Housing and Population Census – Final Results, https://www.statistics.sl/wp-content/uploads/2017/01/final-results_-2015_population_and_housing_census.pdf, accessed 29 March 2018.
[109] Quoted from (Maconachie, 2017: 744) and (Maconachie & Hilson, 2011: 599)
[110] According to the 2014 US Department of Labour List of Goods produced with Child Labour and Forced Labour, child labour is used in gold mining in Bolivia, Burkina Faso, Colombia, Democratic Republic of the Congo, Ecuador, Ethiopia, Ghana, Guinea, Indonesia, Mali, Mongolia, Nicaragua, Niger, Peru, Philippines, Senegal, Suriname and Tanzania.
[111] The ILO define child labour in Article 3 of C182 as labour which jeopardizes the physical, mental or moral wellbeing of a child, either because of its nature or because of the conditions in which it is carried out. URL: www.ilo.org/ipec/facts/WorstFormsofChildLabour/lang–en/index.htm
[112] "Gold from children's hands Use of child-mined gold by the electronics sector," The Centre for Research on Multinational Corporations (SOMO), November 2015
[113] See Article 28 of the UN Convention on the Rights of the Child. URL: www.un.org/documents/ga/res/44/a44r025.htm

were seen to be engaged in ASGM activity. As opposed to the situation other countries in the region such as Ghana, no children were observed in hard rock sites or deep mining pits, and no children were observed to be involved in treating mercury. With their limited presence, it therefore difficult to interview many children, and not a major focus of this study.

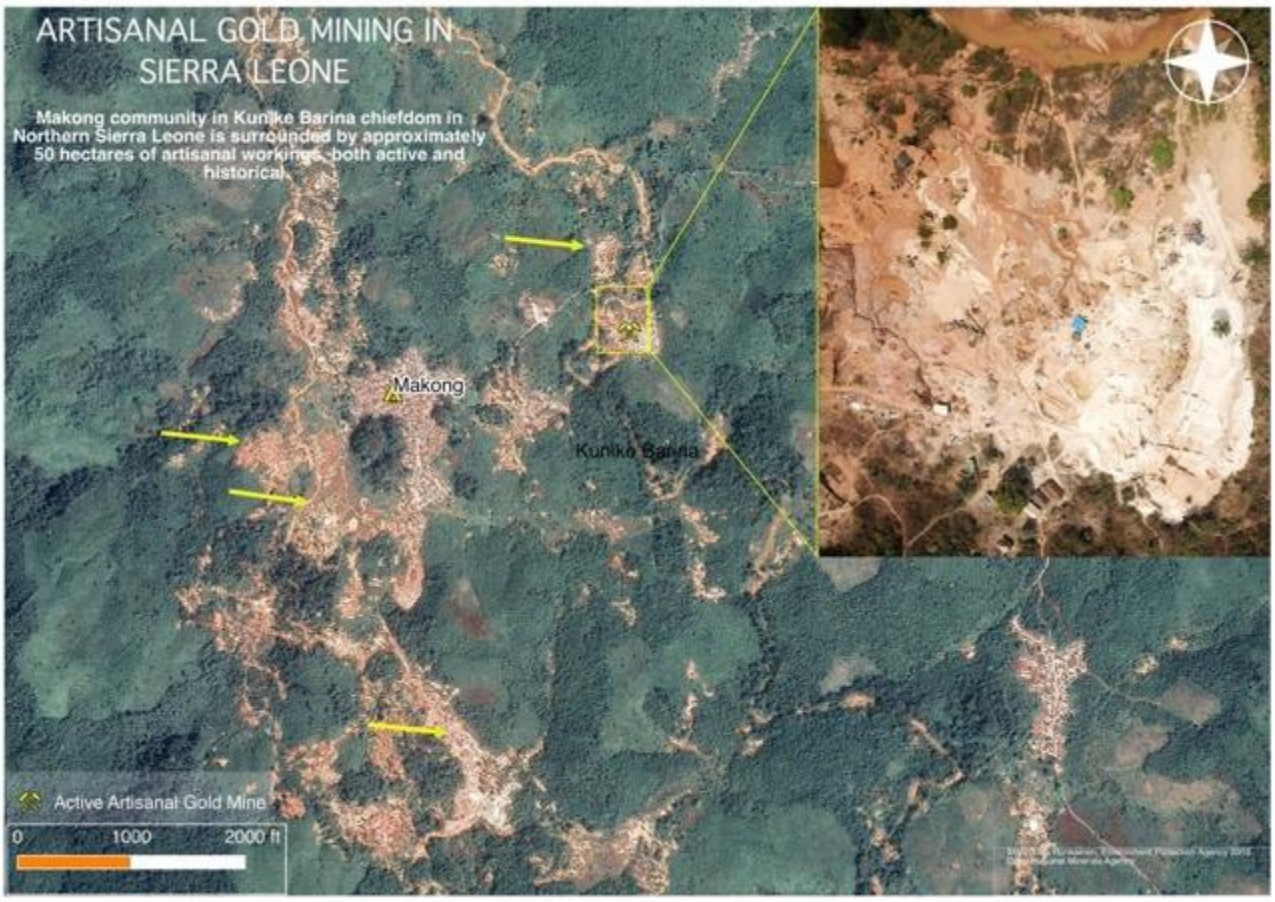
In those sites where children we observed to be engaged in ASGM activity, they were mostly involved in helping their parents by performing tasks such as carrying water, washing ore and panning concentrate. For example, in Masumbiri, two children between of the ages of 6-10 years were observed filling a pan with gravel together on the surface of a mine site. When asked why they were doing this, the children shared that they do this out of school hours to make some cash to be able to pay for their school's lunches, and to earn additional cash for helping their parents to pay their school fees. It was also mentioned by chiefdom authorities in Sella Limba that there are children between the ages of 9-18 (mostly attending secondary school) who are involved in ASGM activity. These authorities were concerned that these children engage in this work, but they equally explained that the children do this because they want to pay for their school fees. In this context, when speaking of the 'worst forms of child labour', it should be remembered that:

> *Child labour in ASM should not be interpreted as an unwillingness to attend school. It is rather a testament to the resilience of the country's rural populations, and a sign of how far many young boys and girls are willing to go in order to improve their quality of life.*[114]

However, notwithstanding the point made, children's presence and in some cases involvement in alluvial ASGM sites exposing them to several health threats. This includes in particular malaria, which is one of the major health concerns in rural Sierra Leone and in particular in ASGM areas, because mosquitos live around riverbeds, and the pits that are created and left open in ASGM activity creates a breeding ground for mosquitos and other notorious insects. These, and other health impacts from the sector are further described in Section 4.15. The participation of children in Sierra Leone's ASM sector is further elaborated and analysed in other studies.[115]

[114] Quoted from (Maconachie & Hilson, 2016: 140)
[115] See for example (Maconachie & Hilson, 2016);

4.13 Environmental information



> *Without question, one of the greatest environmental and social challenges arising from artisanal and small-scale mining is the total failure to achieve any form of land reclamation on the completion of working in all of e areas investigated by the SEA team.*[116]

As mentioned earlier in chapter 4.1, Strategic environmental assessment (SEA) of the artisanal mining sector has been conducted jointly by EPA and NMA. This exhaustive report builds on legal and institutional analysis and extensive field work, and includes 24 recommendations, and an action plan to "transform the sector into a more viable and sustainable one that contributes to growth and development."[117]

It must be emphasized, that the cited report with its recommendations stands to be entirely relevant within the context of the Minamata Convention, and its recommendations should be taken into account in the final NAP. Therefore, this chapter is merely complementing to the SEA, specifically where it has been seen that complementary information is needed on mercury amalgamation, or when analysis carried out is believed to illustrate some of the concerns already raised in the SEA report.

[116] (EPA & NMA, 2016)

[117] (EPA & NMA, 2016), p. 9

4.13.1 Lack of land reclamation

As stated in the SEA report, the lack of land reclamation is probably the cause of the greatest impact ASGM activities are having on environment in Sierra Leone. This aspect has been addressed in great detail in the SEA report, and the reasons for the current practice are summarized in the following quotation:

> *Land is left environmentally impoverished, abandoned, degraded, derelict and useless for any subsequent purpose for the following reasons:*
> *1) Existing legislation requiring rehabilitation is not enforced by the NMA and EPA,*
> *2) The practicality of reclaiming the majority of artisanal mining sites is never factored into the decision by the Director of Mines as to whether or not a licence should be granted in the first place,*
> *3) The rehabilitation fund prescribed in the Act to defray the cost of rehabilitation and reclamation of mined-out areas does not appear to exist,*
> *4) The economics of artisanal mining make it impossible for local workers and communities to carry out effective reclamation,*
> *5) Small-Scale miners can complete an extractive operation within a matter of days or weeks and move to new areas before the authorities are even alerted to their activities,*
> *6) A decision to crack down on illegal operations, to refuse licences in all circumstances where it is unlikely that reclamation and rehabilitation can be achieved and to impose penalties or prosecute offenders would result in an estimated 100,000 to 300,000 individuals losing their livelihoods leading to massive social hardship and unrest;*
> *7) The political will to enforce change does not exist given the lack of alternative livelihood options and the consequences of (5) above,*
> *8) Any attempt to reclaim derelict mineral workings is likely to be undone by subsequent renewal of illegal mining operations based on the 'hope' value which always exists.*

To estimate the scale of land degradation in a year, it is indicative to use the scale of active areas mapped using the spatial information received from NMA and satellite images, as described in chapter 3: We can say that the land degradation is advancing with the minimum annual speed of 500 hectares (652.99)[118]. Considering the fact that ASGM has continued in Sierra Leone at the present scale for maybe two decades, the lack of land reclamation must have had serious impacts on environment. For example, as illustrated in the following figures, the ASGM activity has advanced in the pace of 100 hectares per year in the vicinity of Kumaru (Komau) alone, during the past year.[119]

[118] The figure has been rounded down to one significant figure to establish a more conservative estimate.

[119] At the present state, government immediate response is needed in Kumaru, but in a long run it offers a great opportunity for employment and livelihood generation for thousands of artisanal workers.

figure 42: The scale of ASGM operation in Kumaru

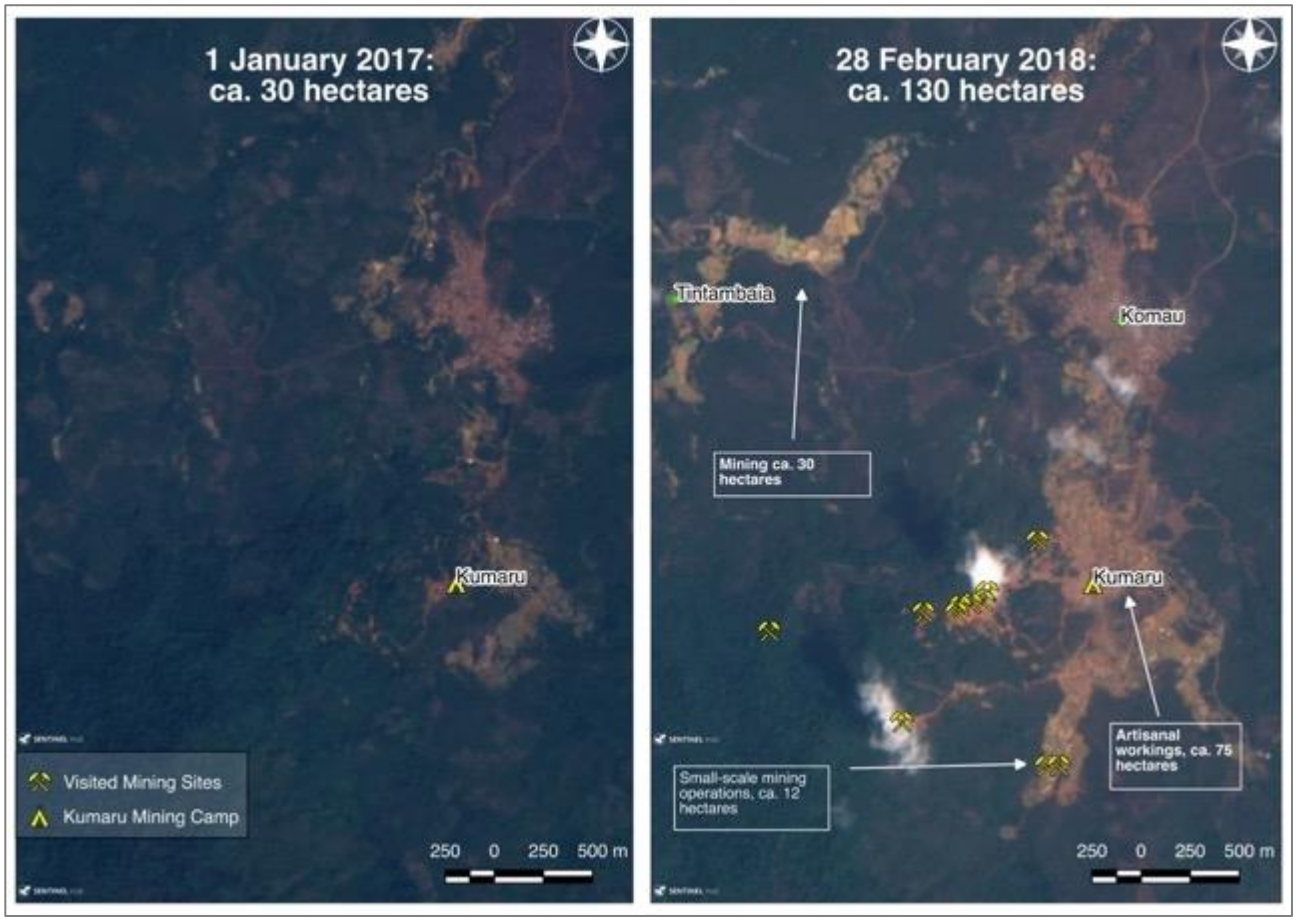


Figure 41: The scale of ASGM operations in Kumaru

4.13.2 Tailings management

Figure 43: In Baomahun, during the wet season excessive water is apparently washing tailings and mining waste down to the valley

Tailings management is one of the key issues in mining in general regardless of the scale of mining. Even if harmful chemicals are not used, the runoff mining waste from tailings is the primary cause of degraded water quality caused by mining. Thus, ASGM as mining in general, can also be considered to reduce access of population to potable water.

If done properly, mining waste from processing is supposed to be collected in sealed tailing ponds, where mining waste is treated in an environmentally sound manner. In Sierra Leone, no such tailings management was seen beyond ponds where mercury amalgamation is conducted.[120] Tailings from sluices are simply released into land and water. In Baomahun, for example, mining waste and tailings including mercury, is apparently washed down to the valley during excessive rains in the wet season (Figure 42).

4.13.3 Dredging

Figure 44: Dispatched processed waste material left behind by the dredge

[120] In all honesty, such tailing ponds are largely missing in other countries with ASGM as well.

The 15-meter long bucket line dredge operating in Teye river deserves to be mentioned alone. Bucket line dredges were popular in the US and other parts of the world in the early parts of the 20th century but has been largely forbidden due to the caused damage to the ecosystems. However, they continue being popular in gold mining in Russia, China and Mongolia.[121]

A bucket line dredge is able to extract and process thousands of cubic meters of river bed material in a day, leaving behind piles of processed material (Figure 43). Although, no specific environmental impact assessment has been carried out for the visited dredge in Yele, the impact on water quality and ecosystem must be substantial, not to mention the visible changes in riverbed. The sediments released to the water due to the practice, increase turbidity, thus reducing the amount of light available to the river habitats. As concluded by (Telmer, 2009), this has two important consequences to the river ecosystem:

- Biological productivity and diversity is reduced;
- Shifts in species composition are extreme.

Alleged mercury use makes the case even worse: Processing waste, containing mercury, is released directly to river, leading to potential methylation, bioaccumulation and contamination of fishes. As stated in chapter 4.9, if mercury use is indeed true, roughly 160kg of mercury might be released to environment in a year in the Teye river. Furthermore, to estimate the scale of dredging in Sierra Leone, it is unknown how long the dredge has been operating in Teye river, and whether it has been operating upstream in Pampana river before. It is also unknown how many dredges there are operating in Sierra Leone in total, but the same company was told to operate at least one another dredge in Sierra Leone.

[121] (Grayson, 2008)

Figure 45: Dredge operating under an exploration license in Teye river

4.13.4 Mercury releases in soil, air and water

According to the estimates presented in 4.9, it estimated that in average 187.51kg of mercury is released to environment due to artisanal operations in Kumaru and Baomahun. Furthermore, it is alleged that 163.8kg of mercury is released in river dredging in Teye river. Based on the various measurement carried out both in Kumaru and Baomahun, and the information on the mercury price, the standard mercury:gold ratio of 1.3:1 was adopted for this study.[122]

Table 6: Example measurement carried out in Kumaru

Mercury added	**Mercury recovered[123]**	**Weight of amalgam**	**Weight of sponge gold (22K)**	**Weight of gold in 24K**
29.820g	30.142g	0.375g	0.192g	0.176

Based on the figures presented in table 6, it can be estimated for each kilogram of gold produced, a kilogram of mercury is released to atmosphere. As described earlier, amalgamation is performed in sealed ponds preventing immediate releases to land and water. Also due to the high price of mercury,

[122] This standard estimate applies to concentrate amalgamation and is based on the work done by Kevin Telmer and Marcello Veiga, (Telmer, 2009).

[123] There is a clear error here, which can be due to the micro droplets of mercury being present in the pond where mercury is happening. However, it also illustrates the fact that only a small fraction of mercury is lost to land and water, and most of it is released to atmosphere in the burning phase.

the miners typically handle mercury carefully avoiding spilling it to the ground. Therefore, the following assumption is made in order to establish mercury releases to land, water and atmosphere: 75% of the mercury is assumed to be released to atmosphere and 25% of it is assumed to be released to land (to water in the dredge).

Table 7: Mercury releases to air, land and water. (Releases to land include possible releases to ground water, whereas direct releases to rivers and water bodies are considered as releases to water.)

Type of mining	Mercury released	Air	Water	Land
Artisanal	187.51	140.63	0	46.88
Small-scale	163.8	122.85	40.95	0

It must be understood, that the figures given in Table 7 are only indicative and only count the direct release pathways. As stated by Kevin Telmer and Marcello Veiga, significant proportion of mercury released to land is believed to be re-released to atmosphere later due volatilization, but the rate of this is not well known.[124]

4.13.5 Contaminated sites

The fate and transport of mercury is a complex topic on its own and to understand the release pathways and contamination in Sierra Leone would require dedicated research being carried out on the topic. Mercury amalgamate burning is known to create recognizable spots of mercury contamination with a radius of approximately one kilometre, as two percent of the emitted mercury is estimated to be deposited back to land, making it possible to detect mercury contamination by laboratory analysis.[125]

As use of chemicals in ASGM is not wide-spread in Sierra Leone, it is unlikely that serious land contamination has been caused by present operations beyond the already documented cases of Kumaru and Baomahun. These two locations can be established as known mercury contaminated sites. With reservations, the small-scale dredge operating in the Teye river should also be mentioned, meaning that the downstream sediments and water in Teye river are potentially contaminated by mercury.

Historically, the research team heard stories of mercury use in Kampala and Masumbirie. In Kampala, a small-scale operation with a dredge was told to have used mercury in the operation which ceased few years ago. In Masumbirie, some artisanal workers coming from Baomahun, had been apparently using mercury in 2017 for a short period of time, until the practice had been stopped by authorities. These places should be considered as potential contaminated sites, and further investigation is needed to fully establish them as contaminated sites.

Eventually, soil samples should be taken and analysed in order to determine the level of contamination in known places, as well as to confirm the contamination in the potential sites.[126] It is a completely another question what remedial actions can be taken to mitigate the existing contamination in these

[124] (Telmer, 2009)

[125] (Cordy, 2014)

[126] Using devices such as the portable mercury analyser Lumex RA-915M

places. Many of the traditional methods, including excavation and treatment, are not feasible due to the high costs associated, and the research on most cost effective in-situ actions are still on going.[127]

[127] The whitepaper from Marcello Veiga and Jennifer Hinton summarizes the key available techniques: https://unites.uqam.ca/gmf/globalmercuryforum/files/articles/marcello_veiga/Minamata_Forum_2001.PDF, accessed 3 April 2018.

4.14 Health information

4.14.1 General health status of the ASGM communities

The communities visited face significant health problems, resulting from the limited availability of basic health infrastructure, including proper sanitation and clean water. Besides this, the housing conditions are typically bad in those areas as most houses have only a plastic roof covered with grass. Pregnant women, lactating mothers and under-five year old were consistently listed as vulnerable groups. The following health complaints were frequently mentioned by workers of health clinics, community leaders and other stakeholders:

- Malaria
- Diarrhoea and vomiting
- Intestinal worms among children
- Skin infections
- Sexually Transmittable Diseases (STDs)
- Acute Respority Infection (ARI), including acute ammonia
- Gastric issues

Malaria was by far the most commonly mentioned health complaint, mentioned in every community visited. According to health workers, a major cause for the wide spread of this diseases is the lack of proper huts that people in the communities visited live in, and it was mentioned to be especially common among people living near water stream sources where mosquitos breed. Diarrhoea, vomiting and intestinal worms among children were also frequently mentioned, which is related to the limited availability of proper sanitation in most areas visited. As a result, defecation is often done openly. It was explained by local health workers that children, who usually play outside in the soil, may therefore get affected by bacteria which gives rise to these health complaints. Skin infections and skin rashes were also common. In Masumbiri, the lack of clean drinking water had brought cholera in the community, which especially affected children. Measles among children were mentioned on several occasions but were not listed to be frequent.

STDs were also frequently mentioned, including in particular Ghonorrea and Syphilis. HIV was less frequently mentioned. ARI was also mentioned frequently, and it was explained by health workers that it may result in acute pneumonia, an inflammatory reaction in lung tissue that is normally caused by an infection. In addition, gastric pains were mentioned, which concern pain or discomfort in the upper abdomen. In relation to this, dysentery (diarrhoea with blood) was also mentioned in one community to occur. Moreover, black flies were often mentioned as a health threat, and skin aches resulting from their bites which were experienced by people living close to streams and rivers where the black flies appear. Finally, it was mentioned in Yele that tuberculosis was coming up, and typhoid fever was also listed as a health complaint.

Finally, a general concern for health issues often mentioned is the late reporting of people who are sick. One reason mentioned for this is the presence of traditional healers whom many people turn to in the first place but may then find out that they need more formally recognized health treatment. It was

mentioned by health workers that they do interact with traditional healers to coordinate the treatment of different complaints and referrals to health clinics and hospitals.

4.14.2 Health impacts of ASGM activities

Various health impacts resulting from ASGM activity have been listed by respondents during the field study. The following are the main health impacts from ASGM activity on local communities:

- Drinking water has been contaminated by mining activity
- Mosquitos have spread in mining areas
- The release of acid vapours by gold traders
- The release of mercury vapours by miners (in some cases)

Many respondents have shared that water resources, in particular streams and rivers have been contaminated. In some villages they do not directly rely on it for drinking water as they use water bottles but in other villages and especially in farms they rely on this polluted water. It has been observed in many places that the water has changed colour and that the turbidity of the water has increased. According to local authorities, this issue has been observed since a long time since diamond mining first started in the 1920s, but it keeps increasing throughout the years.

Another major issue is that the many mining pits that are left behind contain stagnant water, which serve as a breeding ground from mosquitos. Those mosquitos spread malaria, especially among the people living, working or playing close to the streams and rivers. Those people especially concern female ASGM miners and the children who are accompanying them (and in a few cases, working with them), the most vulnerable groups in the communities.

The next issues concern the release of acid vapours in residential areas. Virtually all gold traders encountered in the field study use acid to remove impurities from the gold like iron and stone. With few exceptions, the traders displayed no awareness of its health impacts because they did not wear any mouthpieces or took other protective measures. In fact, one trader even mentioned that he thinks that acid does not affect them, because “no one has died yet”. Another trader was more aware of it because the effects are visible: the use of acid had affected his finger which was bended in a strange way. These findings support the perception that people with limited exposure to education and awareness raising activities do not know of the health hazards resulting from hazardous chemicals until the effects become visible.

As has been discussed in Chapter **Error! Reference source not found.**, there are not many children involved in Sierra Leone’s ASGM sector, but there are many children living in ASGM communities and children have often been witnessed on ASGM sites where they are selling foodstuffs or simply accompanying their mothers who work there. For those children, it was mentioned that they often have headaches, coughs and fever. Finally, in two cases, it had been shared that babies had fallen and drowned in mining pits. A health worker from Tonkolili district also shared that tuberculosis is more common in mining areas because they are often overcrowded. This was not mentioned by others.

The following health complaints were mentioned to be particularly common among miners:

- Backpain, coughing
- Cold and fever
- Skin aches
- Malaria
- Dysentery
- STDs

Most of the miners complain about backpain and muscle aches resulting from their hard work, and cold, fever and coughing due to the extended time some miners spend in the water. For the same reason, dysentery and pneumonia were also mentioned. With the presence of black flies, skin aches and skin rashes were also often reported by miners, especially female miners who typically spend more time in the water. In one case, also cholera was listed as a health threat resulting from contaminated water. Malaria is also a health complaint often reported by ASGM miners.

With regards to STDs, these were reported to be especially common amongst those who spend a lot of time in the water (especially women do so) where the STDs spread. It was also mentioned that the higher turbidity and contamination of the water further enables the spread of bacteria. However, it was mentioned by most health workers that these diseases are not particularly more common among miners than non-miners.

Besides the reported complaints, an important health issue to consider is the risks miners face in terms of occupational safety. Although most of the ASGM miners operate in alluvial mines, miners increasingly work in deep pits which may collapse. This is especially the case in for instance mine sites around Dalakuru where there are very small cylinder-shaped pits that run as deep as ten meters. On a few occasions, for instance in Kumaru, where excavators have been used, there are large holes in the mountain which may cause landslides and potentially kill miners working in close proximity to these holes.

Finally, an important general issue to consider is miners' behaviour in seeking for health assistance. It has frequently been mentioned that those miners who are organized in mining gangs typically first report to their gang leader and that this person takes responsibility for ensuring that the miner gets proper treatment. In other situations, it was mentioned that miners can take a long time to decide to look for help, as they first need to find out who can financially support the treatment According to the nurse, the miners do not have any barriers to come, nor is any shame stopping them

4.14.3 Access to services such as hospitals, sanitation & clean water

The Global Healthsites Mapping Project maintain and updates a database on all health care centres in Sierra Leone.[128] According to the most recent data, there is approximately 1400 health facilities in Sierra Leone including hospitals, health clinics and smaller health posts. When comparing the locations of these facilities to known ASGM locations, it seems that most of the miners have a health care facility within their reach (Average straight-line distance from a known ASGM location to a health facility is

[128] https://healthsites.io, Data available at https://data.humdata.org/dataset/sierra-leone-healthsites

3.2 km (0.4-7.3km). This analysis is also in line with the findings of the field research, as only few of the visited communities didn't have their own health facility.

Most notable mining community without its own health care facility is Kumaru, where several thousand miners need to travel four kilometres to nearby Mbaoma town to access health care. Furthermore, it unknown whether this facility in Mbaoma town can really welcome such a rush of patients, as the mining population of Kumaru has increased rapidly over the past year.

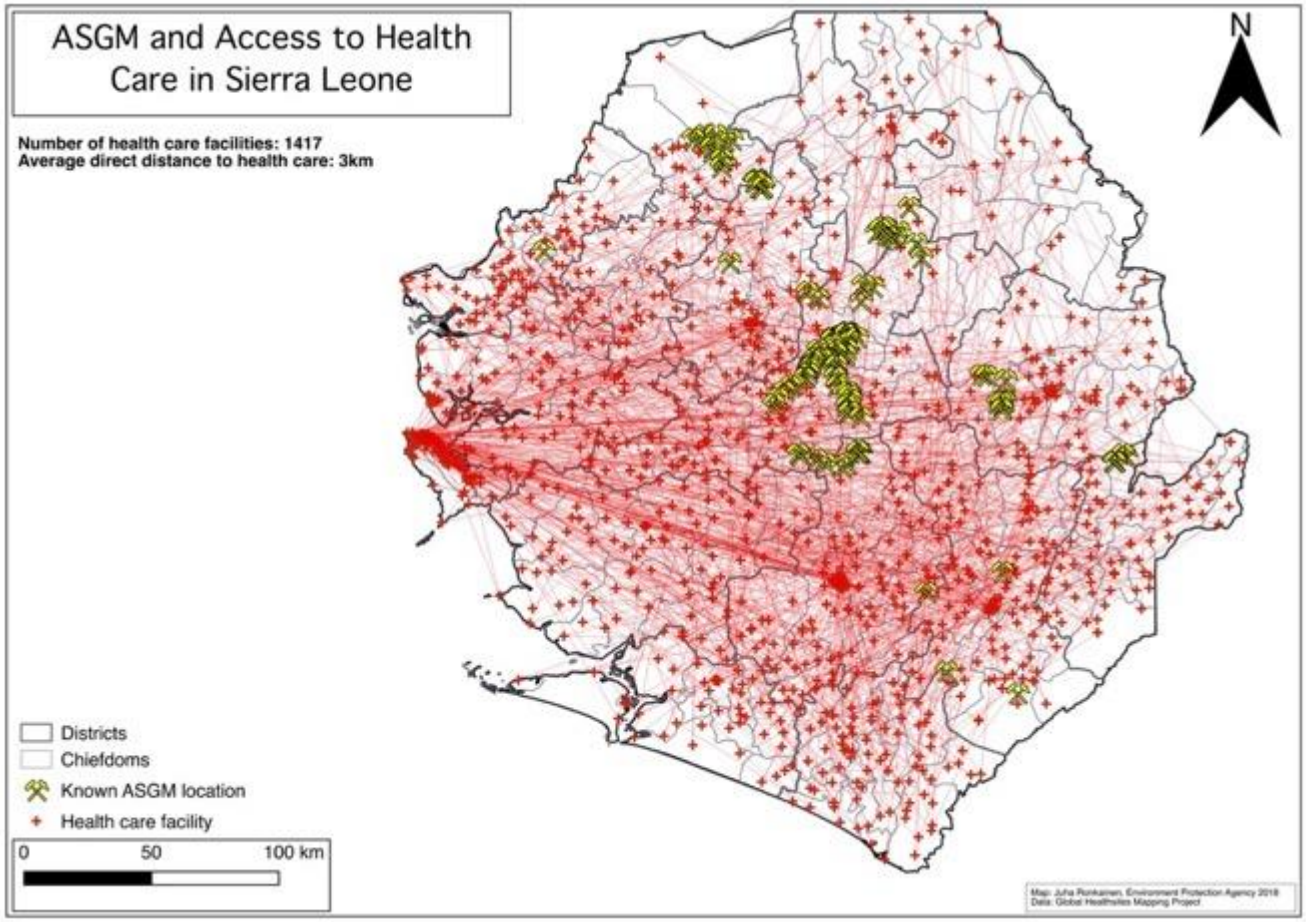


Figure 46: ASGM and access to health care

The health clinics are mainly concerned with delivering assistance with birth giving, supporting pregnant women and examining their babies, and the immunization of children. They also perform first aid treatment and minor surgencies but for complex operations they need to refer people to hospitals. The clinics visited lack significant capacity. The following aspects were most commonly observed and mentioned by health workers to be lacking or to be in shortage:

- Professional and trained staff
- Standard delivery and examination beds
- Delivery kits
- Access to clean drinking water
- Appropriate space and furniture for patients waiting for assistance
- Basic equipment
- Electricity

- Accommodation for staff
- Vehicles

Most of the clinics are small buildings and only have between 3-10 staff members and potentially a few volunteers, including a Community Health Officer who supervises the clinic. This number is very small when considering the local population and people living surrounding villages depending on their services. Indeed, it was mentioned in several clinics that sometimes patients who are sick or wounded have to wait outside because the clinic is overcrowded by people in need of their services. The clinics also lack educated and trained staff and typically rely on one professional health expert. The average clinic only has 2-4 beds and has no vehicle in case people need to be brought to the nearest hospital (usually around 1.5 hours driving from the clinic). An ambulance can be called and can be there in a bit more than one hour.

In terms of drugs, they do own a variety of drugs but often face shortages, and when they do, it can take 1-3 months for these drugs to arrive. Those drugs are usually given free to the identified vulnerable groups, while other users have to pay for them. Most of the clinics do have test kits for Malaria and for some STDs, but not for all of them. Besides this, most health clinics visited lacked basic infrastructure, such as electricity, clean water and proper sanitation. Lack of accommodation for staff has also been mentioned on several occasions.

During visits to ASGM communities, the field team was able to witness some engineered ventilated pit latrines (VIP), but in general most of the toilet facilities were traditional ones with a pit surrounded by dried reeds for privacy. In Kumaru, there is a mining camp of several thousand people next to the town where access to sanitation is lacking[129].

[129] Open defecation was widely seen

4.15 Access to financial and technical assistance and formalization

Formalization of the ASGM sector can be understood as "a process that ensures that ASGM stakeholders are legalized and organized in legitimate entities which represent their needs; policies are implemented, monitored, and enforced; and that ASGM stakeholders receive technical, administrative, and financial support that enables them to adhere to standards".[130] It includes legal, institutional, socio-economic, geo-environmental and financial aspects, and remains a complex process that governments struggle with worldwide.

In Sierra Leone, some progress has been made in formalizing the sector, in particular in issuing licenses to several gold miners, and a smaller portion of the existing gold dealers and exporters. But when going beyond such legal aspects and comparing Chapter 4.5(legal and regulatory framework) to Chapter 4.6 (Leadership and organization of ASGM at national and local levels), Chapter 4.7 (gold trade) and other parts of this research report, it becomes clear that the ASGM sector is informal at virtually all different nodes of the gold value chain. This is further illustrated by the tremendous contrast between official gold exports (127.79kg exported in 2017) and effective gold production estimated in this study (951.29-3129.15kg estimated annual production).[131]

As has already been mentioned, challenges to formalization are largely related to disincentives for ASGM stakeholders to formalize, which are especially common among traders and exporters (less so among ASGM miners). Such disincentives stem from the presence of more attractive taxation regimes in other countries, a long and burdensome process of obtaining licenses, high fees for EIAs (among small-scale miners), and a virtual lack of capacity building initiatives (further discussed in subsequent paragraphs). Further disincentives for traders and exporters are discussed in Section 4.6. At the same time, as discussed in Section 4.12, many ASGM miners do want to formalize, but they are often blocked by the increasing presence of industrial mining companies which may access the land ASGM miners are working on, whether this is through formal or through informal channels. Indeed, it has been reported by a paramount chief that the presence of exploration companies has increased informal ASGM activity because they cannot get licenses now that the company owns the land. This also raises the question whether there is sufficient political will to formalize the ASGM sector.

Besides this, when considering the institutional aspects of formalization, it is important to keep in mind the capacity challenges that the regional NMA and EPA offices, which both constitute important stakeholders in the formalization process, are faced with. Most pressingly, those challenges include a shortage of vehicles and motorbikes, human resources, scientific equipment, and technical expertise, in particular about socio-economic and geological aspects of the ASGM sector, among other things. In addition to this, it has also been pointed out by customary leaders that there are significant overlaps in mandate between the EPA, NMA and NPAA (National Protected Areas Authority) with regards to the governance of the ASGM sector, which make a transformation of the sector more difficult.

[130] UN Environment Global Mercury Partnership, forthcoming. Formalizing Artisanal and Small-scale Gold Mining: A Practical Toolkit for Countries Preparing National Action Plans.
[131] See chapter 4.3

Despite the informal nature of the sector, it has become clear from Sections 4.5 and 4.6 that the sector is characterized by different forms of self-regulation, that there are well-established norms between different stakeholders involved in the sector, and, most importantly, that the sector already makes significant contributions to local development in its currently (largely) informal form. An important area wherein the formalization of the sector can be improved, as was acknowledged by virtually all stakeholders interviewed, is in facilitating ASGM miners' access to formal finance and technical assistance.

Worldwide, the AGSM sector's informality and associated perceived risks causes financial institutions perceive the AS(G)M sector as a risky investment. This is compounded by the fact that a lack of access to geological data makes it difficult for miners to demonstrate any mining area's economic viability. In Sierra Leone, this situation is no different. During the field study, no single miners was met who receives formal financing. As documented in another study recently conducted in Sierra Leone, local banks with experience lending to small and medium enterprises (SMEs) voiced a strong prejudice against the ASM sector and considered it too risky.[132] Besides financial institutions, when considering the activities of government agencies or NGOs, there equally seems to be no single initiative aimed at providing ASGM miners with access to finance.

This lack of access to formal means of finance causes ASGM miners to either finance themselves (less typical), or to depend on the investments made by informal 'customers' and 'supporters' as detailed in Section 4.6 (more typical). In cases where miners finance themselves, they typically use personal capital diverted from other sources of income, often small-scale general merchandise trades, or from their family's savings. Self-financing miners may still enjoy support from external 'supporters'.

In terms of technical assistance, the research team has not been able to identify a single initiative that targets the ASGM sector. Historically, projects that have targeted artisanal mining in Sierra Leone, have mainly targeted diamond mines. According to interviewed staff members from NGOs, this has to do with the fact that for long, people in Sierra Leone haven't been interested in gold, and that this has only changed in more recent years with the rapid increase in the international gold price. With regards to diamonds, several projects (mainly lead by NGOs) have focused on mitigating environmental impacts from the artisanal diamond mining sector and reclaiming land for local communities after diamond mining, and other projects have focused on improving the effectiveness of the Diamond Community Development Fund (DCDF) in contributing to local development.

To highlight the importance of technical assistance, it can be argued that the alleged exhaustion of alluvial surface deposits is partly due to the poor techniques used by artisanal miners. Technical assistance is a relatively cheap option to revive the sector and worth testing, as viable alternative livelihood options are not immediately present. Simple demonstrations could easily be organized by professional miners knowledgeable of these aspects.

Figure 47: Silver coloured gold-amalgam ball being burned

[132] (Hunter & Smith, 2017)

Nevertheless, there have been several important sensitization activities carried out by government agencies. For example, the NMA has engaged in several workshops and a former radio show to sensitize ASM miners about mining laws, the importance of obtaining a mining license, as well as adopting good mining practices and protecting occupational health and safety. The MMOs have also reported to sensitize miners about the importance of obtaining a mining license in their interactions with them. Finally, the EPA has conducted several sensitization activities about environmental issues in which artisanal gold and diamond miners have been included, including on rehabilitation of the land as well as the use of mercury.

Altogether, there have been some forms of assistance to ASM miners, but they have typically not targeted ASGM miners as a specific group. Moreover, they have mainly focused on the consequences of their activities (e.g. environmental impacts) and compliance with the law, rather than on the root causes underlying this lack of compliance, i.e. the lack of finance and technical skills and tools required to improve their mining practices.

5 Conclusions

This research report has analysed social, economic, geological, environmental and health aspects of the Artisanal and Small-scale Gold Mining (ASGM) sector in Sierra Leone. The contents of this report have important implications for the development of the National Action Plan (NAP), as well as other projects and policy initiatives concerning the sector.

5.1 Importance of the ASGM sector

First and foremost, this report has demonstrated that the ASGM sector continues to provide many young people and single mothers in rural areas with economically viable livelihoods that enable them to feed their families and to pay their children's school fees. In the context of widespread poverty and unemployment, especially among youth, as well the anticipated population growth and the social unrest these factors may bring combined, these livelihoods hold invaluable for ASGM miners and their families. Besides this, the sector injects cash into the local economy and creates a market for agricultural outputs and other goods and services, thereby catalysing local development.

This report states that the current ASGM sector employs over 80,000 miners, who produce gold worth over 130,000,000USD by export value. These findings, even if uncertain, clearly indicate the scale and importance of the ASGM sector for Sierra Leone. Indeed, this report places the national ASGM sector among the most important extractive sectors in Sierra Leone, right next to well-acknowledged rutile and diamond production. The importance of gold mining is further emphasized with the fact that there is hardly any other raw material, which is sold for a price as high as 80% of the world market price, in rural Africa.

5.2 Challenges

At the same time, the sector has substantial environmental and health impacts. These include, most pressingly, the contamination of water sources, and the degradation of lands by mining pits which are categorically not reclaimed after the mining activities end. These pits make the land unavailable for farming activities, and further serve as a breeding ground for mosquitos in areas that are already heavily affected by malaria. These concerns become increasingly important as near-surface gold deposits are rapidly declining and miners now have to go deeper to reach richer layers of ore. In addition to this, the study has identified the wide use of acid for gold purification and a more limited use of mercury. Both of these chemicals are used with little awareness of their consequences, which puts local communities' health at risk.

Finally, mentioned depletion of near-surface deposits sparks many fundamental questions: Milling and/or machine excavation could arguably increase the productivity of the sector, making deeper deposits more accessible, and increasing recovery even at near-surface mines. Should the ASGM sector be driven more towards mechanized mining? If so, how this transform can be done without alienating tens of thousands manual workers currently engaged in artisanal mining? Should the transformation be done by promoting small-scale mining under the current legislative framework, or by policy changes and dismantling the restrictions on artisanal mining?

5.3 Solutions

In order to identify entry points for addressing the identified and interrelated issues in an effective manner, it is necessary to appreciate how the sector functions. In this regard, it is important to note that the organization of gold production, trade and export deviates significantly from the regulations that currently govern the sector, and that the sector is indeed largely informal at all nodes of the value chain. There are substantial barriers to formalization and in particular with regards to preventing gold smuggling, which includes among other things, the limited institutional capacity of regional NMA and EPA offices. Moreover, the trade of mercury is encapsulated in similar informal trading networks that partly overlap with those of the gold. Innovative efforts to formalizing the sector, and an enhanced political will for doing so, are therefore a prerequisite for addressing the raised issues in a meaningful and sustainable manner.

When considering the root causes of ASGM miners' adoption of unsustainable mining practices and their lack of compliance with laws, two issues particularly stand out: their lack of financial, administrative and technical capacity, as well as their (related) deeply-rooted dependence on an informal network of regional gold buyers. In this context, it is important to consider that at present, there are virtually no initiatives aimed at providing financial and technical assistance to ASGM stakeholders. Based on the observations in the field, it is believed that provision of such assistance and positive engagements with ASGM miners could go a long way in addressing the identified negative impacts of the sector. Beyond these issues, provision of such assistance and the formalization of the ASGM sector serves as an opportunity to address wider development challenges Sierra Leone is currently faced with, and empowering women and youth in the process.

In terms of improving mining practices, there are several relatively simple interventions that can have significant impacts. It can be argued that the claimed exhaustion of alluvial surface deposits is partly due to the poor techniques, where ore is not crushed or milled, particle size control is not applied (sieve) and adjustment of the sluices is arbitrary. Introducing milling, teaching miners to use sieves and adapting the sluices with good carpet materials, are cheap technical interventions worth testing. Positive and empowering interventions can be accompanied by awareness raising on mercury and acid use, as well as on land reclamation. Comprehensive approach to technical assistance and awareness raising, which offer direct benefits (better recovery) to miners, are more likely to be well received by mining communities.

Women have historically played a significant role in Sierra Leone's ASGM sector and carry the most responsibility in safeguarding their children's health. Within this context, they could potentially take a leading role in promoting sustainable mining practices and protection of health and environment in their communities. In terms of already existing land degradation, efforts should focus on rehabilitating mined lands, and should include both government, chiefdom authorities, local communities and ASGM miners in the process. This complex issue has been examined in detail in the recent Strategic Environmental Assessment (SEA) report, and practical recommendations have been made, including cost estimations. This report with its recommendations should be taken into account in development of the NAP.

The ASGM sector is currently largely controlled by foreign gold buyers, who by financing illicit mining activities and enabling smuggling of gold, undermine the sector's contributions to local and

national development. Formalization of the sector can help to address these issues by reasserting national ownership of the sector. Central to discussions about formalization of the sector should be the question of how the sector's impacts on local development and education can be invigorated, to ensure that those impacts become more tangible for local communities and the national economy. In this respect, lessons should be drawn from the diamond sector and the DCDF. In addition, formalization efforts should concentrate on identifying and developing incentives for ASGM stakeholders to formalize. Potential options include decreasing the costs of compliance, provision of services and financial incentives, provision of geological data and reservation of land for ASGM miners, and regional harmonization of the tax regime.

Finally, efforts aimed at formalizing the sector further present an opportunity for the government to engage youth in multi-stakeholder dialogues about how the sector can be better governed. Such an approach can further serve to build trust between government and youth in the process and could help to prevent an escalation of conflict in volatile areas such as Kumaru. However, before formalization efforts are further pursued, the development potential of the ASGM sector has first to be more formally recognized and included in the National Poverty Reduction Strategy and similar policy documents.

6 Bibliography

Andrew Stubblefield, S. C. (2005). Impacts of Gold Mining and Land Use Alterations on the Water Quality of Central Mongolian Rivers. *Integrated Environmental Assessment and Management*, 365-373.

Bank/ILO, S. S. (2015). *Sierra Leone 2014 Labor Force Survey Report.*

Barrie, I. J., & Touret, J. L. (1999). Fluid inclusion studies of gold-bearing quartz veins from the Yirisen deposit, Sula Mountains greenstone belt, Masumbiri, Sierra Leone. *Ore Geology Reviews, 14*, 203-225. doi:https://doi.org/10.1016/S0169-1368(99)00005-0

Cartier, L. E., & Bürge, M. (2011). Agriculture and artisanal gold mining in sierra leone: alternatives or complements? *Journal of International Development, 23*, 1080-1099. doi:10.1002/jid.1833

Cordy, P. (2014). *Urban atmospheric mercury contamination from artisanal mining : mapping, modeling, and mitigation.* University of British Columbia.

Davies, G. R. (2014). A toxic free future: Is there a role for alternatives to mercury in small-scale gold mining? *Futures, 62*, 113-119. doi:https://doi.org/10.1016/j.futures.2013.11.004

Davies, T. C., Friedrich, G., & Wiechowski, A. (1989). Geochemistry and mineralogy of laterites in the Sula Mountains greenstone belt, Lake Sonfon gold district, Sierra Leone. *Journal of Geochemical Exploration, 32*, 75-98. doi:https://doi.org/10.1016/0375-6742(89)90049-6

Drace, K., Kiefer, A. M., Veiga, M. M., Williams, M. K., Ascari, B., Knapper, K. A., . . . Cizdziel, J. V. (2012). Mercury-free, small-scale artisanal gold mining in Mozambique: utilization of magnets to isolate gold at clean tech mine. *Journal of Cleaner Production, 32*, 88-95. doi:https://doi.org/10.1016/j.jclepro.2012.03.022

EPA & NMA. (2016). *Strategic environmental assessment of the artisanal mining sector in Sierra Leone (SEA).*

Felix Ng, J. A. (2016). An eco-approach to optimise efficiency and productivity of a hydraulic excavator. *Journal of Cleaner Production*, 3966-3976.

Fileccia, T. P., & Mastrocola, P. (2017). *Hydrogeology of Sierra Leone.* Ministry ofWater Resources.

Gibb, H., & Grace O'Leary, K. (2014, 3). Mercury Exposure and Health Impacts among Individuals in the Artisanal and Small-Scale Gold Mining Community: A Comprehensive Review. *122*.

Gitelson, A. A., Kaufman, Y. J., Stark, R., & Rundquist, D. (2002). Novel algorithms for remote estimation of vegetation fraction. *Remote Sensing of Environment, 80*, 76-87. doi:https://doi.org/10.1016/S0034-4257(01)00289-9

Grayson, R. (2008). Bucket-line gold dredges - a review of world techniques. *World Placer Journal*, 1/41.

Hilson, G., & Pardie, S. (2006). Mercury: An agent of poverty in Ghana's small-scale gold-mining sector? *Resources Policy, 31*, 106-116. doi:https://doi.org/10.1016/j.resourpol.2006.09.001

Hilson, G., Hilson, C. J., & Pardie, S. (2007). Improving awareness of mercury pollution in small-scale gold mining communities: Challenges and ways forward in rural Ghana. *Environmental Research, 103*, 275-287. doi:https://doi.org/10.1016/j.envres.2006.09.010

Hunter, & Smith. (2017). *Follow the Money: Financial Flows linked to Artisanal and Small-Scale Gold Mining in Sierra Leone.* Global Initiative against Transnational Organized Crime.

Hunter, M. S.-N. (2017). *Follow the Money: A handbook for identifying financial flows linked to Artisanal and Small-Scale Gold Mining.* Levin Sources.

Jalloh, A. B., Sasaki, K., Thomas, M. O., & Jalloh, Y. (2013). The Geology, Mineral Resources of Sierra Leone and how the Resources can be Used to Develop the Nation. *Procedia Earth and Planetary Science, 6*, 131-138. doi:https://doi.org/10.1016/j.proeps.2013.01.018

Lebbie, J. (2016, 1). Directorate of Geological Survey Sierra Leone - Mineral Commodity Profile: Gold.

Maconachie, R., & Hilson, G. (2011). Artisanal Gold Mining: A New Frontier in Post-Conflict Sierra Leone? *The Journal of Development Studies, 47*, 595-616. doi:10.1080/00220381003599402

Maconachie, R., & Hilson, G. (2011). Safeguarding livelihoods or exacerbating poverty? Artisanal mining and formalization in West Africa. *Natural Resources Forum, 35*, 293-303. doi:10.1111/j.1477-8947.2011.01407.x

Maconachie, R., & Hilson, G. (2016). Re-Thinking the Child Labor "Problem" in Rural sub-Saharan Africa: The Case of Sierra Leone's Half Shovels. *World Development, 78*, 136-147. doi:https://doi.org/10.1016/j.worlddev.2015.10.012

Mayring, P. (2007). On Generalization in Qualitatively Oriented Research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 8*. doi:10.17169/fqs-8.3.291

McKinnon, T. a. (2017, May 17). *Comparing RGB-Based Vegetation Indices With NDVI For Drone Based Agricultural Sensing.* Retrieved January 14, 2018, from https://agribotix.com/blog/2017/04/30/comparing-rgb-based-vegetation-indices-with-ndvi-for-agricultural-drone-imagery/

Obiri, S., Mattah, P. A., Mattah, M. M., Armah, F. A., Osae, S., Adu-kumi, S., & Yeboah, P. O. (2016, 2). Assessing the Environmental and Socio-Economic Impacts of Artisanal Gold Mining on the Livelihoods of Communities in the Tarkwa Nsuaem Municipality in Ghana. *13(2)*. (N. Basu, S. Keane, & P. B. Moher, Eds.)

O'Neill, J. D., & Telmer, K. (2017). *Estimating Mercury Use and DocumentingPractices in Artisanal and Small-scale Gold Mining (ASGM).* UN Environment.

Patrick, & Forward. (2005). *Review of a portfolio of exploration properties held in Sierra Leone by Sierra Leone Diamond Company Limited.* Tech. rep., ACA Howe International Limited.

Rebecca Adler Miserendino, B. A.-L. (2013). Challenges to measuring, monitoring, and addressing the cumulative impacts of artisanal and small-scale gold mining in Ecuador. *Resources Policy, Volume 38*(Issue 4), Pages 713-722.

Ringrose, S. M. (1983). Geological exploration and landuse using Landsat data, Sierra Leone, West Africa. *Advances in Space Research, 3*, 81-89. doi:https://doi.org/10.1016/0273-1177(83)90106-0

Sana, A., De Brouwer, C., & Hien, H. (2017). Knowledge and perceptions of health and environmental risks related to artisanal gold mining by the artisanal miners in Burkina Faso: a cross-sectional survey. *The Pan African medical journal, 27*, 280.

Seccatore, J., Veiga, M., Origliasso, C., Marin, T., & Tomi, G. D. (2014). An estimation of the artisanal small-scale production of gold in the world. *Science of The Total Environment, 496*, 662-667. doi:https://doi.org/10.1016/j.scitotenv.2014.05.003

Spiegel, S. J., & Veiga, M. M. (2010). International guidelines on mercury management in small-scale gold mining. *Journal of Cleaner Production, 18*, 375-385. doi:https://doi.org/10.1016/j.jclepro.2009.10.020

Statistics Sierra Leone. (2013). *Demographic and Health Survey Key Findings.*

Statistics Sierra Leone. (2015). *ECONOMIC AND FINANCIAL SURVEY 2014.* Freetown: Statistics Sierra Leone.

Statistics Sierra Leone/World Bank. (2013). *A Poverty Profile for Sierra Leone.*

Szentpeteri, K., Reza Setiwan, T., & Arief. (2016, 10). Drones (UAVs)in mining and Exploration. An application example: Pit Mapping and Geological Modelling.

Telmer, K. V. (2009). World emissions of mercury from small scale artisanal gold mining and the knowledge gaps about them. In N. M. Pirrone, *Mercury Fate and Transport in the Global Atmosphere: Measurements Models and Policy Implications* (pp. 96-129). UNEP United Nations Environmental Program.

Trotter, R. T. (2012). Qualitative research sample design and sample size: Resolving and unresolved issues and inferential imperatives. *Preventive Medicine, 55*, 398-400. doi:https://doi.org/10.1016/j.ypmed.2012.07.003

Umeji, A. C. (1983). Archaean greenstone belts of Sierra Leone with comments on the stratigraphy and metallogeny. *Journal of African Earth Sciences (1983), 1*, 1-8. doi:https://doi.org/10.1016/0899-5362(83)90025-8

UNEP. (2015). *Guidance Document: Developing a National Action Plan to Reduce, and Where Feasible, Eliminate Mercury Use in Artisanal and Small Scale Gold Mining.* UN Environment.

UNEP Chemicals Branch. (2013). *Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport.* UNEP.

UNITAR. (2017a). *Mobile Data Collection Tool for National ASGM Overview - User Guide.* UN Environment Global Mercury Partnership. UN Environment.

UNITAR. (2017b). *Methodology for a Qualitative Socio-economic ASGM Study - Draft.* UNITAR.

United Nations Environment Programme, C., & Branch., H. (2017). *Global mercury supply, trade and demand.* Tech. rep., UN Environment.

Warnsloh. (2011). Geology and Mineral Industry of Sierra Leone. *n/a*.

Veiga, M. M. (2006). *Manual for Training Artisanal and Small-Scale Gold Miners.* Tech. rep., GEF/UNDP/UNIDO.

Veiga, M. M., Angeloci-Santos, G., & Meech, J. A. (2014). Review of barriers to reduce mercury use in artisanal gold mining. *The Extractive Industries and Society, 1*, 351-361. doi:https://doi.org/10.1016/j.exis.2014.03.004

Villegas, C. T. (2013). *Can artisanal mining and conservation co-exist?* WWF-World Wide Fund for Nature and Estelle Levin Ltd.

Williams, H. R. (1978). The Archaean geology of Sierra Leone. *Precambrian Research, 6*, 251-268. doi:https://doi.org/10.1016/0301-9268(78)90017-7

World Bank/COWI. (2016). *Mercury trade and use for artisanal and small-scale gold mining in Sub-Saharan Africa - Final Report.* Tech. rep., COWI.

7 Annex 1: Desk review and analysis of the research topics

The national overview of the ASGM sector covers a long list of topics[133] - all of them important in and of themselves. In order to develop a methodology for research on such a wide-ranging set of topics, for the purpose of the ASGM Sector Overview in Sierra Leone each of them has been examined in detail, to better understand how it contributes to the final NAP.[134] Furthermore, the existing literature has been scoped to consolidate already available information and to understand the data gaps. In this context, the relative importance of each research topic is indicated by the number of relevant NAP components. Based on the nature of the topic, the most relevant approach to data collection has also been proposed. The research topics are grouped under the four dominant research themes.

Table 8: Policy, regulatory, and institutional framework;

1. What is the institutional and legal framework of the ASGM sector?			
Topic	Relevant NAP component[135]	Approach to data collection	Notes on implementation in Sierra Leone
Legal and regulatory status of ASGM;	3: (c), (f), (g)	Desk review	Done separately by a consultant
Policies surrounding ASGM;	3: (c), (f), (g)	Desk review	Done separately by a consultant
Previous experiences in addressing ASGM;	6: (c), (f), (g), (i), (j), (k)	Desk review[136], Key informant interviews	Interviews with EPA and NMA in Freetown on 15-18 January 2018
Information gaps and perception of information at the local and national scale that can be addressed	1: (g)	Key informant interviews	Interviews with EPA and NMA in Freetown on 15-18 January 2018

[133] The coverage of topics in the national overview of the ASGM sector are given at (UNEP, 2015: 20). Note: As this work was carried out before the more streamlined list of topics was made available, this listing slightly differs from the one eventually followed in the research report. The present suggested list of research topics can be found at http://web.unep.org/chemicalsandwaste/nap-starter-kit.

[134] Regardless of the approach to data collection, the final overview will contain examination of each research topic.

[135] Components of the NAP are given in the Minamata Convention (Annex C), and they are also listed earlier in this report.

[136] (Maconachie & Hilson, 2011) addresses experiences on regulating and formalizing ASGM in Sierra Leone.

Table 9: Socio-economic aspects

2. Who are the people involved in the ASGM sector?			
Topic	Relevant NAP Component	Approach to data collection	Notes
Size of the formal and informal ASGM economy;	4: (c), (f), (i), (k)	Desk review[137,138]; Mining community surveys; Key-informant interviews; Remote sensing;	Interviews with EPA and NMA in Freetown on 15-18 January 2018.
Economics, such as earnings per capita, mercury supply, use and demand, information on gold trade and export, cost of living, access to finance for miners, social welfare options for miners and their communities;	3: (a), (e), (f)	Desk review[139] Mining sites surveys • mercury supply[140]; • earnings per capita; Key-Informant interviews • mercury supply	Key-informant interviews with EPA and NMA in Freetown on 15-18 January 2018.
Information about access to basic education, health care and other services in mining communities;	2: (h), (i)	Desk review[141]; Mining community surveys;	Mapping of schools and health care centres in Sierra Leone. Comparison of this data with the information on the locations of mining communities using a GIS software.
Information about access to technical assistance for miners;	1: (e)	Desk review[142]; Key-informant interviews; Mining community surveys;	Interviews with EPA and NMA in Freetown on 15-19 January 2018.
Leadership and organization of ASGM at national and local levels;	6: (c), (f), (g), (i), (j), (k)	Desk review[143]; Mining community surveys;	Leadership and organization of ASGM is probably the most well recorded topic, as it is typically always covered attempts do research in the country.

[137] Estimated total ASGM population: 437,000 (Seccatore, Veiga, Origliasso, Marin, & Tomi, 2014) or 200,000-400,000 (World Bank/COWI, 2016).

[138] The National Minerals Agency (NMA) has an online repository and map of the active small-scale mining licenses in Sierra Leone (https://sierraleone.revenuedev.org/). At the time of this writing it only contains a record of three active small-scale licenses. There are no records of artisanal licenses in the repository.

[139] Access to finance and gold trade are very well covered by (Hunter & Smith, 2017).

[140] "It is not known if the mercury to these countries [e.g. Sierra Leone] is imported via the well-established routes from Ghana and Togo, or the mercury is illegally imported directly from countries outside the region." (World Bank, 2016: 60).

[141] Data sets on locations of schools and health care centres are available at https://data.humdata.org/group/sle.

[142] (Hunter & Smith, 2017: 6)

[143] (Hunter & Smith, 2017: 5), (Cartier & Bürge, 2011), (Villegas, 2013: 20)

Structure of the ASGM sector (i.e., single family miners, community mines, etc.);	6: (c), (f), (g), (i), (j), (k)	Desk review[144]; Mining community surveys	The cited resource stands as a good resource regarding the organization of miners in Sierra Leone. Some further data is collected in Mining community surveys as well.

Table 10: Technical and environmental aspects

How do artisanal and small-scale miners work?			
Topic	Relevant NAP Component	Approach to data collection	Notes
Information on mining practices, including information on ore bodies exploited, processes used, the amount of mercury used	6: (a), (b), (c), (e), (i), (k)	Desk review[145]; Mining community surveys;	Is there actually hard-rock ASGM activities beyond Baomahun area?
The number of people directly involved in ASGM and indirectly exposed to mercury (disaggregated by gender and age)	5: (c), (f), (h), (i), (k)	Desk review[146]; Key-stakeholder interviews; Mining community surveys; Remote sensing;	This is one of the key baseline questions and relates also to the possible reduction targets set by the government.
Information on gold processing practices/burn off of mercury in gold processing shops or community retorts;	6: (a), (b), (c), (e), (i), (k)	Desk review[147]; Mining community surveys;	The limited use of mercury was further confirmed by the NMA official on a personal communication on 5 October 2018. However, EPA has indicated that even 50% of the gold is produced with mercury (World Bank/COWI, 2016).
Geographic distribution of ASGM, including potential future areas of exploitation;	6: (e), (f), (g), (h), (i), (j)	Desk review[148,149]; Key-informant interviews; Mining community surveys; Remote sensing;	Interviews with EPA and NMA in Freetown on 15-19 January 2018. To what extend does artisanal and small-scale miners have access to claim profitable licence areas?

[144] (Cartier & Bürge, 2011: 1087)

[145] The extensive alluvial mining is recorded by (Cartier & Bürge, 2011). Furthermore, the already recorded articles on geology can be used.

[146] Estimated total ASGM population: 437,000 (Seccatore, Veiga, Origliasso, Marin, & Tomi, 2014) or 200,000-400,000 (World Bank/COWI, 2016).

[147] In the Kangari Hills area, as in most other gold-producing areas of Sierra Leone, mercury and cyanide are not used for amalgamation. (Cartier & Bürge, 2011: 1087).

[148] Locations of mining sites available at (Maconachie & Hilson, 2011) and (Hunter & Smith, 2017). Future areas of exploitation can be done based on the bedrock geology (Warnsloh, 2011), (Umeji, 1983)(Williams, 1978), (Patrick & Forward, 2005), (Lebbie, 2016), (Barrie & Touret, 1999), (Davies, Friedrich, & Wiechowski, 1989) and (Jalloh, Sasaki, Thomas, & Jalloh, 2013)

[149] (Maconachie & Hilson, 2011) examines the importance of equal treatment of ASGM and large-scale mining companies, when mineral rights are allocated.

Information on the location and demographics of ASGM miners that operate without the use of mercury and the techniques that they use	2: (e), (i)	Desk review[150]; Key-informant interviews; Mining community surveys;	The locations for alluvial mining are relatively well-known. Interviews with EPA and NMA in Freetown on 15-19 January 2018.
Known information on mercury level of the environmental media (as a baseline data), overall environmental impacts, contaminated sites, mercury releases in soil, air and water, including distribution relative to population centres.	5: (a), (e), (h), (i), (j)	Desk review[151] • distribution of releases relative to population centres. Mining community surveys; Information on • environmental impacts; • mercury releases; • distribution of releases relative to population centres.	Baseline information on mercury levels in the environmental is not available.

Table 11: Health aspects

What are the health and environmental impacts of ASGM?			
Topic	Relevant NAP Component	Approach to data collection	Notes
Information on mercury exposure, through various media, and studies on impacts in ASGM communities and downstream communities;	5: (e), (h), (i), (j), (k)	Desk review[152]; Key-stakeholder interviews, Mining community surveys;	Some topics listed under socio-economic theme clearly contribute to and overlap with health aspects.

[150] (Cartier & Bürge, 2011)

[151] Spatial data sets on population density in Sierra Leone can be found in https://data.humdata.org/group/sle.

[152] (Maconachie & Hilson, 2011) lists several studies done in other African countries on health and environmental impacts. However, there is nothing on Sierra Leone directly.

8 Annex 2: Strategy for the mining community surveys

8.1 Background

The selection of the sites is based on the preliminary data collection carried out by EPA. Detailed remarks can be found annexed to this document. National Minerals Agency was also consulted regarding the travel plan.

The most important research question where statistically representative sample is important relates to the requirement to include 'baseline estimates of the quantities of mercury used' in the national action plan. As a direct requirement set in the Minamata Convention, this baseline must be established in a robust manner. Because of that, two groups have been formed when selecting the communities to be visited.

a) Mining communities where mercury is used; and
b) Mining communities where mercury is not used,

A mining community is selected as a primary unit for the survey, as it is often very difficult to distinct different gold mining 'sites', especially when mining is alluvial in nature[153]. For example, the Baomahun mining community in Valunia district is surrounded by approximately 70 hectares of mining activity, where it would be difficult to say where does one 'site' start and one ends.

8.2 Communities where mercury is used

Due to the geological conditions, the gold mining in Sierra Leone is mainly alluvial in nature and therefore the use of mercury seems to be limited. Based on the preliminary data collected, the following communities where identified or suspected to be using mercury: Laminaya, Kampala, Masumbirie, Maranda and Baomahun.

In these communities, a representative sample of mining groups are to be examined, in order to establish the baseline estimates of mercury use, gold production and work force[154]. In line with that, the in-depth case studies are focused on mercury related aspects, such as health, mercury trade and miner's access to alternative methods.

Name of Community	Mercury used	Licensed	Numbers of miners	Extraction type	Organization Structure	Further remarks
	Yes/No	Yes/No		Primary (hard-rock) or Secondary (alluvial)	Formal groups/ Informal groups/ individual miners	
Laminaya	Doubt	Yes	~ 700	Secondary (alluvial)	Mixed	Gravitational using sluices with carpets
Kampala	Doubt	Yes	~ 550	Secondary (alluvial)	Mixed	Gravitational using sluices with carpets
Masumbirie	Doubt	Yes	>1000	Both	Mixed	Grinding, sluicing and panning
Maranda	Doubt	yes	>1000	Primary	Mixed	Grinding, sluicing and panning

[153] Alluvial gold mining refers to mining on secondary gold deposits, where gold is distributed on soft surface soil by erosive processes over time. Often such ore contains visible gold nuggets or flakes which are relatively easy to extract using only simple methods such as sluicing and panning. However, as (Veiga, Angeloci-Santos, & Meech, 2014: 356) point out, even secondary gold mining would significantly benefit from using more effective tools for concentrating the ore, such as a ball mill.

[154] For example: If there are 100 mining groups in the community, the study performed with confidence level of 95% and confidence interval of 15% would require examining 30 mining groups.

Baomahun	Yes	Yes	>1000	Both	Mixed	Manual crushing, sluicing, panning and amalgamation.

Table 12: The selected communities where mercury is known or suspected to be used

8.3 Communities where mercury is not used

The list of communities to be visited where mercury is not used contains the main known gold mining areas in Sierra Leone, and is representative in terms of size, organizational structure and extraction type. The list also contains the only operating licensed small-scale gold mine in Sierra Leone located in Makonie. The selected list is long and extensive, but it allows the research team effectively to validate the claimed limited mercury use[155].

Table 13: Selected communities where mercury is not known to be used[157]

Name of Community	Mercury used	Licensed	Numbers of miners	Extraction type	Organization Structure	Further remarks
	Yes/No	Yes/No		Primary (hard-rock) or Secondary (alluvial)	Formal groups/ Informal groups/ individual miners	
Kathanthan	No	Yes	>1000	Both	Informal groups	Crushing & grinding with mortars; gravitational using sluices with carpets
Kassasie	No	Yes	~ 1000	Both	Mixed	Crushing & grinding with mortars; gravitational using sluices with carpets
Makonie	No	No	~20	Secondary (tailings)	Individual	The only active licensed small-scale gold mine is here
Dalakuru	No	Yes	> 1000	Secondary	Mixed	Gravitational & panning
Yele	No	Yes	>1000	Secondary	Mixed	Diving(?), sluice gravitation, panning, & burnt in papers (?)
Makong	Not known	Not known	Not known	Not known	Not known	Visit to Makong was suggested by NMA
Komao (Kumaru)[156]	No	No	>1000	Both	Mixed	Use of excavators. Mechanical Crushing of rocks; gravitational using sluices; panning, Cleaned with acid by buyers (Borax?)
Wydallah	No	Yes	>1000	Secondary	Mixed	Gravitation; panning and separated with steel (?)
Tefeyah	No	Yes	>1000	Secondary	Mixed	Gravitation; panning and separated with steel (?)

[155] None of the requirements for ASGM set in the Minamata Convention are not applicable to ASGM without mercury use. (Minamata Convention: Article 7.1).

[156] Paramount chief to be consulted extensively prior to accessing the community due to the slight security concern.

[157] The list contains references to not widely known mining methods, such as 'separation with steel', but those remarks have been left as is.

8.4 Travel Plan

The current plan contains 8 locations and 14 mining communities, with maximum of two locations per each week. The plan covers all the major mining communities in the country and is not vulnerable to the unexpected obstacles faced during the research: The final count of communities will be between 8-14 communities depending on the realities at the ground level. For example, the plan allows a brief scoping visit to Kassasie, even if the main focus would be Kathantan, as the mining sites are within walking distance from each other. The same applies to most of the community pairs to be visited. Detailed Agenda

The following agenda has been prepared while acknowledging that there will most probably be unexpected surprises.

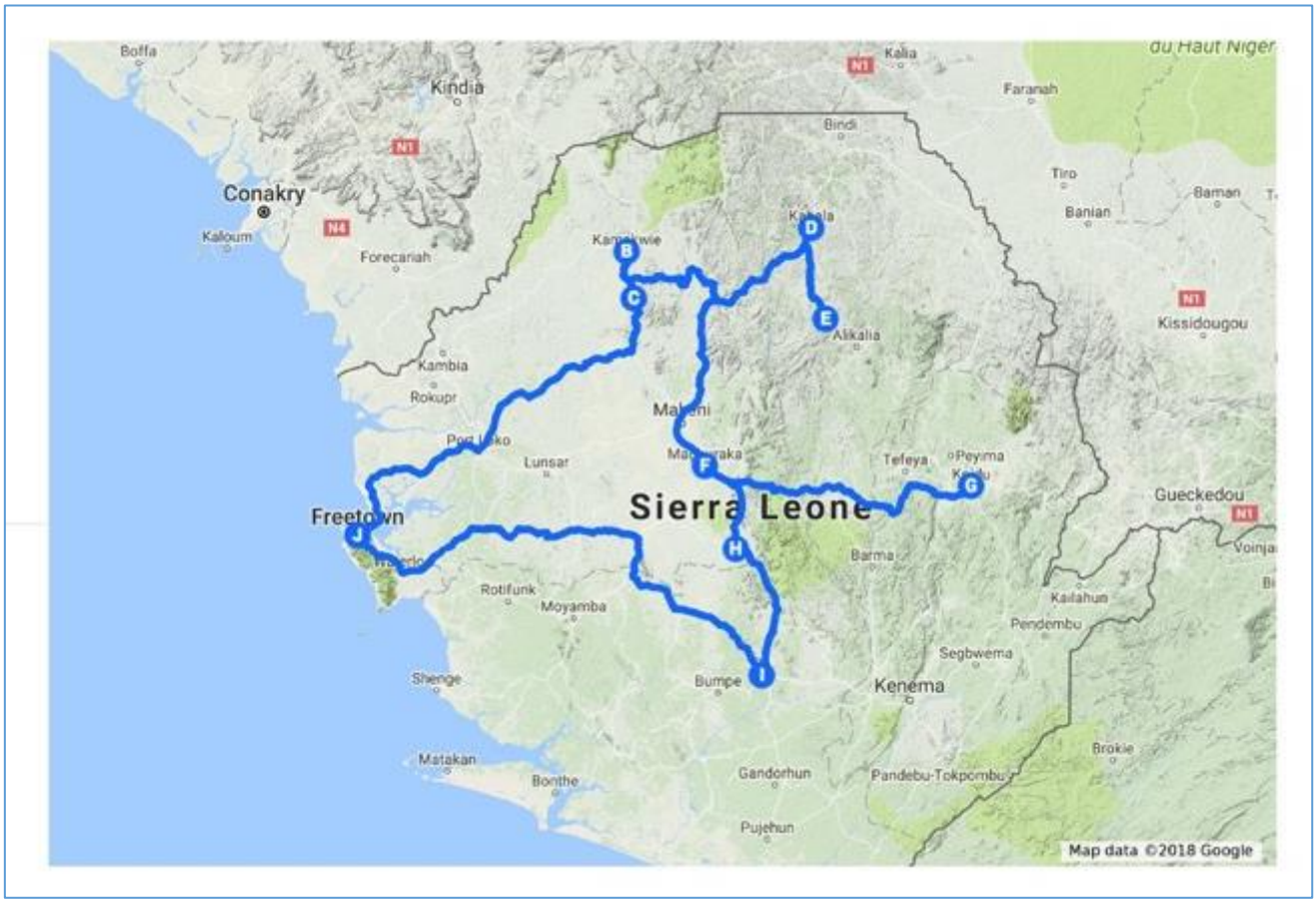


Figure 48: Travel plan and base camp locations

Table 14: Field research agenda

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
North-Western Region							
22-28 Jan	Travel: Freetown-Kamakwie (5h) (Research at **Kamakwie)**	Field research at **Kathantan and Kassasie**	Field research at **Kathantan and Kassasie**	Travel: Kamakwie-Laminaya (5h) (Research at **Laminaya and Kampala)**	Research at **Laminaya and Kampala**	Research at **Laminaya and Kampala**	Travel: Laminaya – Kabala (8h)
Base	**Kamakwie(B)**			**Laminaya (C)**			**Kabala (D)**
Northern Region							
29 Jan-4 Feb	Rest	Kabala-Dalakuru (5h) Research at Dalakuru	Field research at **Dalakuru and Makonie**[158]	Field research at **Dalakuru and Makonie**	Travel: Dalakuru-Magburaka (8h)	Field research at **Masumbirie and Maranda**	Field research at **Masumbirie and Maranda**
Base	**Kabala (D)**		**Dalakuru (E)**		**Magburaka (F)**		
Eastern Region					**Northern Region**		
5-11 Feb	Travel: Magburaka-Koidu (3h) Rest	Field research at **Kumaru**	Field research at **Kumaru**	Field research at **Wydallah and Tefeyah**	Field research at **Wydallah and Tefeyah**	Travel: Koidu-Yele (5h)	Rest
Base	**Koidu (G)**					**Yele (H)**	
Northern Region			**Southern Region**				
12-18 Feb	Research at **Yele and Makong**	Research at **Yele and Makong**	Research at **Yele and Makong** Travel: Yele-Bo (3h)	Research at **Baomahun**	Research at **Baomahun**	Travel: Bo-Freetown (3h)	
Base	**Yele (H)**		**Bo (I)**				

[158] The only operating small-scale mine is located in Makonie: Dojo enterprises international SL

9 Annex 3: On Research Methodologies

9.1 Quantitative Methods

Quantitative data is data expressing a certain quantity, amount or range. Usually, there are measurement units associated with the data, e.g. metres, in the case of the height of a person. It makes sense to set boundary limits to such data, and it is also meaningful to apply arithmetic operations to the data.[159]

There is very little reliable quantitative data on ASGM world-wide, and many estimates are purely based on modelling, rather than primary field data. One of the exciting opportunities of this study, was to produce a country level estimates on gold production, size of the ASGM population and mercury use, among other things[160]. These estimates will further improve our understanding on the subject at the global level, but they will also serve as a basis for implementing the national action plan. Specifically, a quantitative estimate of mercury consumption is an explicit requirement of a NAP[161].

The main methodology followed for quantitative research is developed by the Artisanal Gold Council[162]. According to the methodology, the national quantitative baseline estimates on gold production, mercury use and ASGM workforce are established by extrapolating regional estimates from the data collected from the mining communities. Acquired data is validated by triangulation, i.e. approaching the same research question from various indirect approaches and comparing the results.

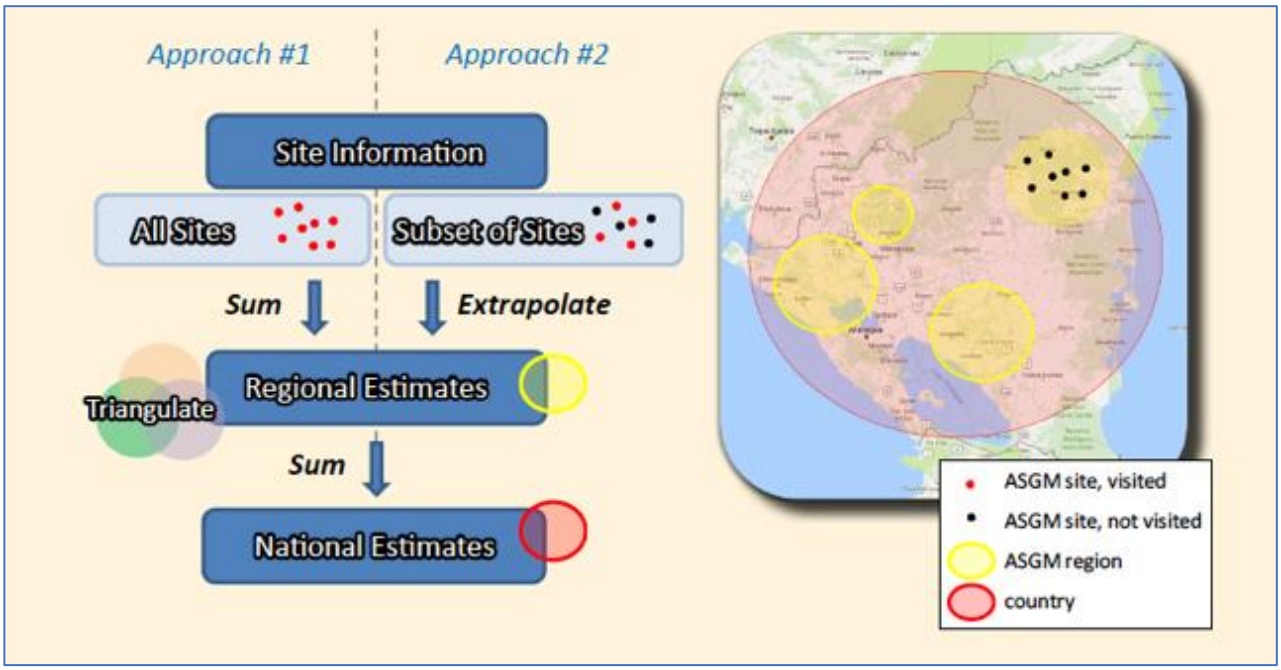


Figure 49: Producing national baseline estimates. (From (O'Neill & Telmer, 2017). Used with permission.)

[159] Economic Commission for Europe of the United Nations (UNECE), "Glossary of Terms on Statistical Data Editing", Conference of European Statisticians Methodological material, Geneva, 2000.

[160] These three quantitative aspects are often referred as 'baseline information'.

[161] Minamata Convention, Article 7: Annex C

[162] (O'Neill & Telmer, 2017)

In reality, as mercury was not used in the majority of the mining communities visited, and as some of the visits lasted merely hours, a much more rapid and straight-forward approach was many times deployed as described in the recent publication by Levin Resources.[163] In this method, information on gold production and workforce, is simply asked from the miners and this data is later on compared and validated with the information received from gold traders. It can be argued that the method developed by Levin Resources is significantly less certain but taking into consideration the limited amount of time available for the field research, small team size, and the wide-set of other topics to be covered, it was thought to be the only feasible approach available in many communities.

9.2 Qualitative Methods

Qualitative data is data describing the attributes or properties that an object possesses. The properties are categorized into classes that may be assigned numeric values. However, there is no significance to the data values themselves, they simply represent attributes of the object concerned.[164]

In order to successfully implement the National Action Plan, descriptive, qualitative data on mining communities and miners was also needed. The qualitative data collected falls into three categories:

1) Generalizable data on mining practices and environmental impacts collected by observation and interviews.
2) Preliminary geological survey.
3) More subtle data acquired by in-depth interviews to prepare case studies on delicate aspects, such as attitudes on formalization and access to alternative livelihoods.

The methodology developed by the Artisanal Gold Council was be followed when collecting more generalizable data. Preliminary geological survey was carried out by an expert geologist participating in the research. The objective was to make a preliminary analysis of the ore bodies, which is necessary for any technical interventions in the future. For example, gold is often associated with sulfide minerals (e.g. pyrite arsenopyrite, galena), but their presence makes it more difficult to liberate gold[165]. Furthermore, in this study a preliminary analysis was carried out to create a link between the geological conditions and the mining methods used by local miners. This work is complemented with the desk analysis using geological maps made available by National Minerals Agency. The geological research report is attached entirely as an annex to this report.

A thorough environmental impact assessment is beyond this study but, as argued in (Obiri, et al., 2016) people living in the mining area have remarkably accurate understanding on the pollution of their environment: Therefore, interviews on aspects such as water quality and deforestation are used to indicate environmental impact of mining in the focus area. Land degradation or disturbance was also photographed by an Aerial Unmanned Vehicle (drone) and located using a GPS device.

[163] (Hunter & Smith, 2017)

[164] Economic Commission for Europe of the United Nations (UNECE), "Glossary of Terms on Statistical Data Editing", Conference of European Statisticians Methodological material, Geneva, 2000.

[165] (Veiga M. M., 2006: 9)

The goal of most qualitative studies is not to generalize but rather to provide a rich, contextualized understanding of some aspect of human experience through the intensive study of particular cases[166].

Research, where the goal is to 'provide a rich contextualized understanding' on ASGM will be done using a methodology developed by UNITAR[167]. This methodology provides means to analyse and collect data in order to have more nuanced understanding on various topics, such as the organization of the ASGM at local levels. For example, even if there is no formal structure in place, human beings tend to organize themselves in some manner or another. Simple observations, or direct questions are often not sufficient to gain such information and more delicate means are needed. The UNITAR methodology describes a research methodology, where participatory semi-structured in-depth interviews and group discussions are recorded and coded in order to see the emerging themes under each research topic.

Figure 50: Cyclical nature of the qualitative research in the UNITAR methodology

9.3 Geospatial Methods

Geospatial methods turned out to be more useful than expected in this study, especially when it comes to extrapolation community level quantitative findings into country-level estimates, as well as when estimation environmental impact. The geospatial methodology is explained here in detail, as it was tailor made for this study.

9.3.1 Collected Data

Based on preliminary visits to the provinces, 35 mining communities were originally identified, with indicated total mining population of over 13,000. Out of those identified communities, 15 were selected in consultation with NMA and EPA for field visits. **Error! Reference source not found.** contains a summary of some quantitative data collected.

Table 15: Summary statistics of the communities visited (including only sites which were visited)

Community	Work force			Yearly Gold production in 24K (kg)			Value (USD)	Area	Extrapolation Type
	min	max	mean	min	max	mean	mean	hect.	
Kathanta	30.00	100.00	60.00	0.35	0.71	0.53	16,380.00	1.38	AMGB
Laminaya	405.00	610.00	507.50	5.47	17.91	11.69	382,590.00	13.81	AM
Kampala	210.00	320.00	265.00	4.31	11.11	7.71	238,680.00	7.24	AM
Dalakuru	9.00	25.00	16.00	0.26	0.44	0.35	13,346.67	0.36	AMGB
Dalakuru	28.00	35.00	31.50	1.26	3.77	2.51	96,096.00	0.30	AMGB
Dalakuru	30.00	36.00	33.00	1.80	5.41	3.61	137,966.40	0.17	AMGB
Dalakuru	50.00	75.00	62.50	6.01	22.54	14.27	546,117.00	0.10	AMGB

[166] (Mayring, 2007)

[167] (UNITAR, 2017)

Masumbirie	32.00	60.00	45.00	5.24	13.92	9.58	328,536.00	1.35	HRGB
Masumbirie	12.00	12.00	12.00	0.54	0.81	0.67	19,413.33	0.59	AMGB
Masumbirie	50.00	80.00	65.00	3.25	5.41	4.33	140,400.00	7.40	AMGB
Maranda	15.00	25.00	20.00	2.12	4.59	3.36	111,150.00	2.72	HRGB
Kumaru	1163	6656	3909	10.92	650.87	330.90	11,618,755.20	44.78	MixedGB
Makong	64.00	144.00	104.00	5.10	5.73	5.41	198,016.00	1.31	Mixed
Baomahun	40.00	105.00	69.00	3.51	14.74	9.13	243,360.00	4.97	HRGB
Yele	56.00	70.00	63.00	0.88	4.08	2.48	90,135.50	1.71	AM
Wydallah	0.00	0.00	0.00	2.00	2.00	2.00	72,800.00	n/a	By production
Baoma Station	12.00	12.00	12.00	0.08	0.20	0.14	5,096.00	n/a	Panning and diving
Yele	6.00	6.00	6.00	0.05	0.05	0.05	1,820.00	n/a	Panning and diving
Makonie	8.00	8.00	8.00	44.85	89.70	67.28	2,574,000.00	n/a	SmallScale
Yele	7.00	7.00	7.00	115.50	115.50	115.50	4,200,000.00	n/a	Small-scale

To be able to extrapolate the site-level statistics into something meaningful at the national scale, the applied mining methods were sorted into six different groups:

- Alluvial mining on greenstone belts (AMGB)
- Alluvial mining outside greenstone belts (AM)
- Hard rock mining (HR)
- Hard rock mining on greenstone belts (HRGB)
- Panning and diving in rivers
- Small-scale mining

9.3.2 Analysis

After this, a simple analysis of results was conducted to characterize each different kind of mining method. Specifically, to extrapolate site level statistics into something meaningful at the national level, average gold production and workforce per hectare was calculated for mining styles AM, AMGB and HRGB.

Table 16: Summary of site level statistics and areas

MineID	**Location**	**Area**	**Average Workforce**	**Average Gold production (24K)**	**Extrapolation Type**
		hect	/hect	/hect	
ASGM867	Laminaya	13.81	36.75	0.85	AM
ASGM40	Kampala	7.24	36.60	1.06	AM
ASGM956	Yele	1.71	36.84	1.45	AM
Averages			**36.73**	**1.12**	**AM**
ASGM139	Kathanta	1.38	43.48	0.38	AMGB
ASGM852	Dalakuru	0.36	44.44	0.97	AMGB
ASGM415	Dalakuru	0.30	105.00	8.37	AMGB
ASGM13	Dalakuru	0.17	194.12	21.21	AMGB
ASGM721	Dalakuru	0.10	69.36	5.44	AMGB
ASGM410	Masumbirie	0.59	20.34	1.14	AMGB
ASGM998	Masumbirie	7.40	8.78	0.59	AMGB

Averages			**69.36**	**5.44**	**AMGB**
ASGM940	Masumbirie	1.35	33.33	7.10	HRGB
ASGM556	Maranda	2.72	7.35	1.23	HRGB
ASGM641	Baomahun	4.97	13.88	1.84	HRGB
Averages			**18.19**	**3.39**	**HRBG**
ASGM897	Makong	1.31	79.39	4.13	Mixed
ASGM87	Kumaru	44.78	87.30	7.39	MixedGB
Averages			**n/a**	**n/a**	**n/a**

9.3.3 Raw spatial data sets

For this research, exhaustive data sets from NMA were made available. These 126,872 records were exported XML files from a relational database, and they were imported and queried using the QGIS software.

Table 17: Data received from NMA

Type of data	Number of records	Years	Minerals
All artisanal applications	11,613	2000-2018	All
All licenses	3,381	2000-2018	All
All locations (GIS)	35,073	2000-2018	All
All minerals sought	11,529	2000-2018	All
All payments	65,276	2000-2018	All
Total	126,872	2000-2018	All

All spatial records were matched with data on type of minerals, dates and types of actions recorded, based on unique application IDs. As it was already known that the number of active artisanal licenses doesn't represent the sector[168], all indicative data was considered relevant for understanding the scale of sector. The data contained unique spatial data points on records of 23 different activities:

Table 18: Records of different activities

Records of different activities		
IncomeTax(SAF)	FinancialSupporterCertifcate	NRAFee(IncomeTaxGold&Diamond)
MonitoringFee	MinesManagerCertificate	MinesSupportersCertificate
PrimaryLicenseFee	FinancialSupporterCertificate	RenewalApplFee
DemarcationFee	RenewalLicenseFee	Other
MineralsSalesCard	OLD-NRAFee(IncomeTax)Gold	Royalty
RehabilitationFee	OLD-NRAFee(IncomeTax)Coltan	Re-activate
ApplicationFee	AnnualPayment	Renewal
Surface&DevelopmentFee	RecordFormC10	

[168] See chapter 4.3.1

This data was further classified into three categories as follows (Figure 51):

A. All records on artisanal mining between 2000-2018: 35,839 records
B. All records on artisanal gold mining between 2000-2018: 4171 records
C. All records on artisanal gold and diamond mining 2017-2018: 3794 records
D. All records on artisanal gold mining 2017-2018: 684 records

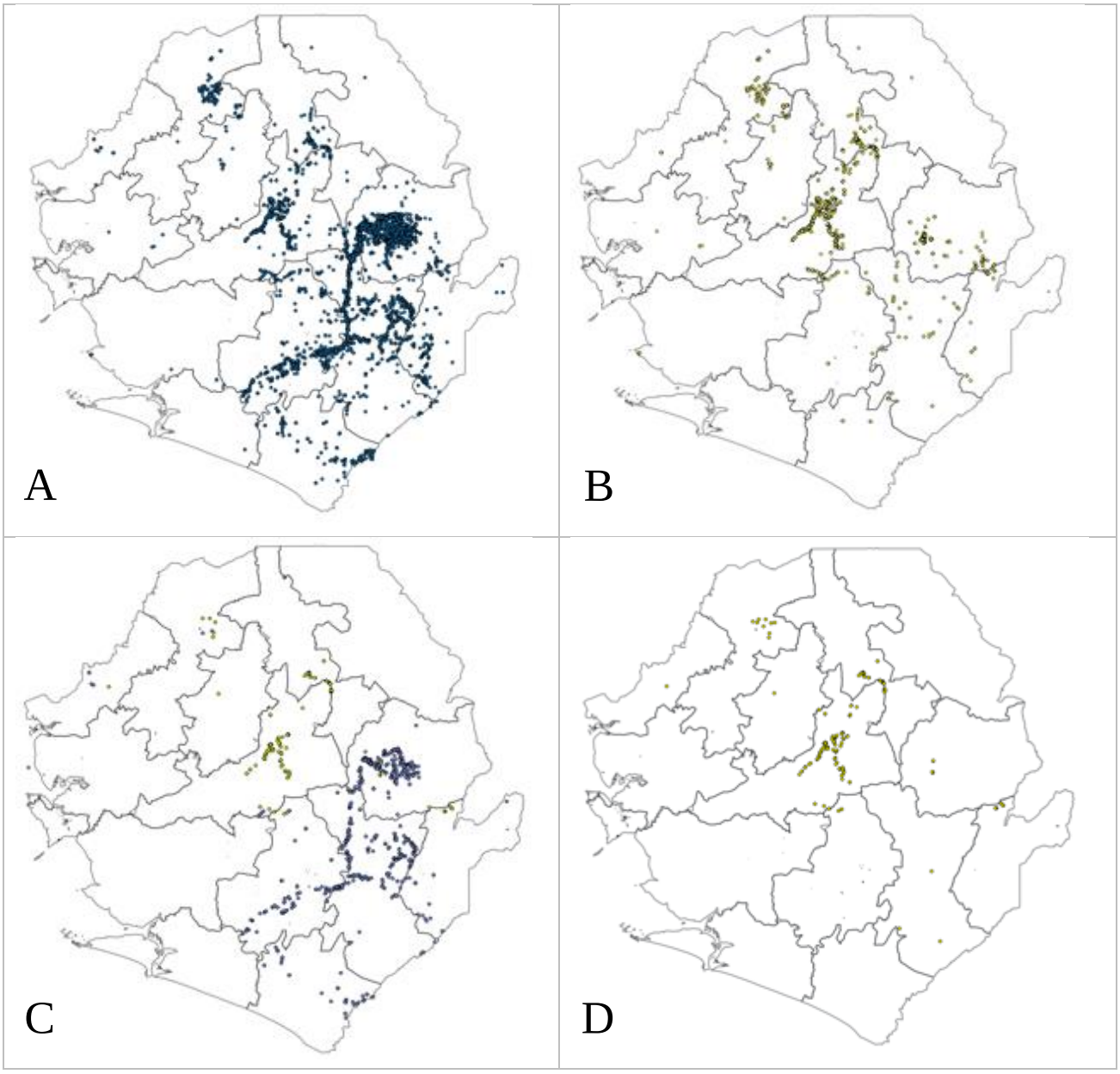


Figure 51: Categorization of individual spatial records

9.3.4 Manual demarcation of ASGM areas

After this, all 684 records on artisanal gold mining between 2017-2018 were individually checked using satellite images. This was easier than it sounds, as these spatial data points occur naturally in clusters as can be seen in Figure 51D. After screening the area using Google maps, the mining activity in the area

was verified using Sentinel-2[169] satellite images on two dates 1 January 2017 and 28 February 2018 (Figure 52A-B). Then the active area was demarked manually (Figure 52C). The same algorithm was performed to all clusters of 684 records of artisanal gold mining. Based on this analysis 135 individual mining areas occupying a total of 600 hectares of land was identified, mostly based on footmark left by deforestation as the land must be cleared for mining. Finally, these 135 individual gold mining locations were further classified into four categories:

Table 19: Classification of remotely sensed mining sites

Classification	Explanation
Alluvial mining on greenstone belts (AMGB)	• Visual marks in satellite imagery[170], • Spatial relation to the greenstone belts
Alluvial mining outside greenstone belts (AM)	• Visual marks in satellite imagery
Hard rock mining (HR) outside greenstone belts	• Visual marks in satellite imagery, • Relative elevation in comparison to the average elevation of the area[171].
Hard rock mining on greenstone belts (HRGB)	• Visual marks in satellite imagery, • Relative elevation in comparison to the average elevation of the area • Spatial relation to the greenstone belts

9.3.5 Algorithmic demarcation of ASGM areas

Finally, a completely algorithmic demarcation process was performed to identify likely areas, where ASGM mining might be happening (as the previous process assumed no mining is happening in visibly static areas). In this method, each of 4171 spatial records of artisanal gold mining between 2000-2018 was enhanced with a half-an-hectare circular buffer, as it were representing a licensed artisanal mining area.

Figure 52: High-definition aerial photo taken in Baoma Station

These 4171 circular buffers formed a total of 832 clusters, when intersecting features were disseminated (Figure 52D). Finally, the mining [illegible] is adopted algorithmically from the nearest manually demarked area (Figure 52C)[172]. By this method, a total of 832 mining areas were detected, occupying a total of 1147 hectare of land. The total area

[169] ESA's Sentinel-2 mission consists of two satellites (Sentinel-2A and Sentinel-2B), providing frequent, free multispectral imagery on earth. https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Overview4.

[170] Alluvial open pit mining is easy to detect, as can be seen in Figure 8A-B

[171] Mining locations with high relative elevation compared to that of the surrounding area, were assumed to be hard-rock mining sites.

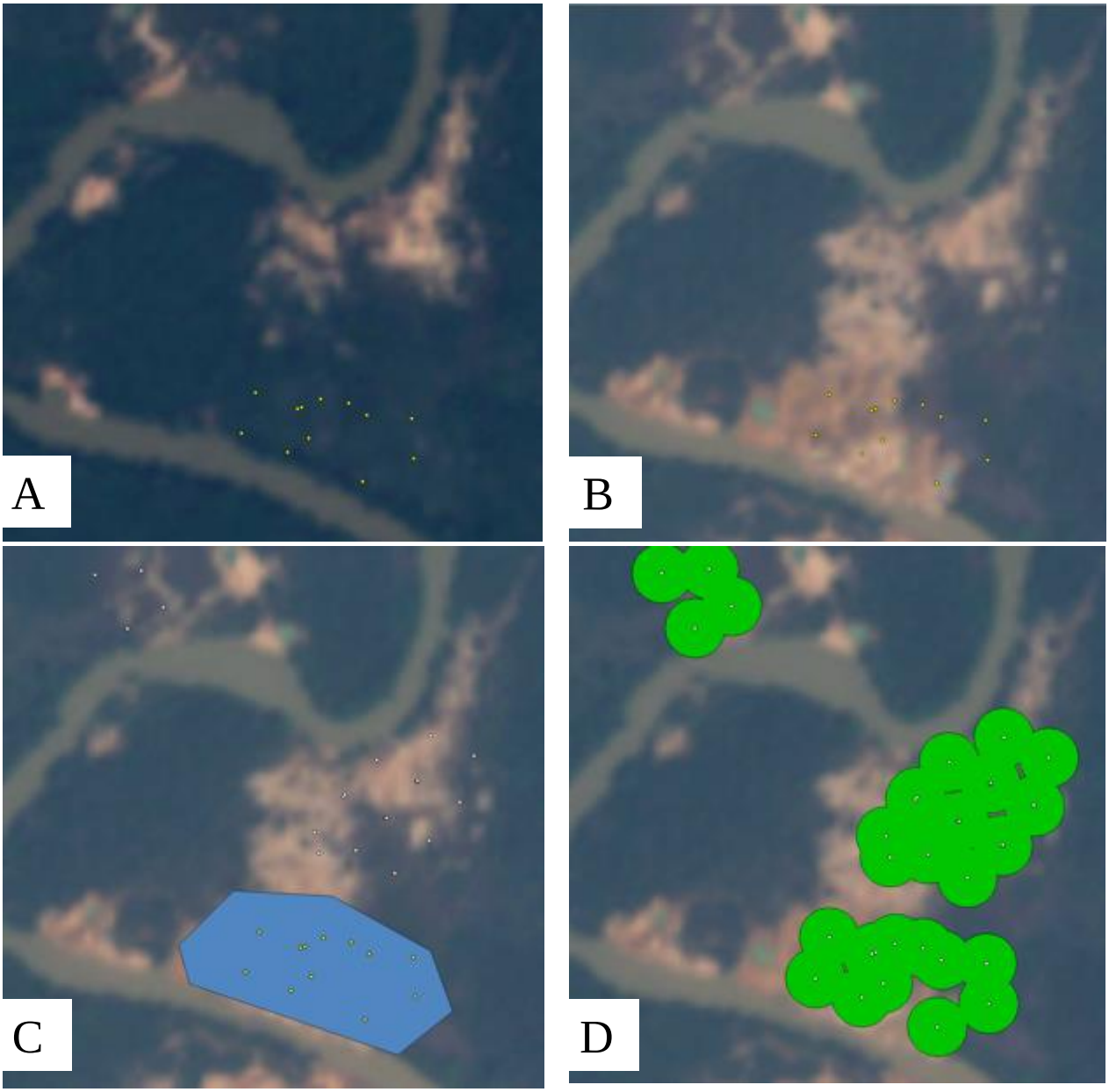
[172] For example, as area in Figure 8C, was manually classified being alluvial mining (AM), all areas in Figure 8D were also assigned with the same classification.

demarked by algorithmic demarcation process, serves as an indication of upper-end estimates on ASGM population and gold production for mining types AM, AMGB, HR and HRGB.

9.3.6 Demarcation of ASGM areas of by-production and river panning

Finally, a similar algorithmic method as described earlier revealed, 56 hectares of likely diamond mining areas on greenstone belt areas, where by-production of gold is assumed to occur. This was done by using recent (2017-2018) spatial records on diamond mining locations occurring on greenstone belts, where gold can be expected to be found along with diamonds.

Analysing high-resolution aerial photos taken in Baoma Station and Yele, revealed that approximately 48 gold panners and divers can be assumed to occupy one kilometre of river in the vicinity of mining area (Figure 51). There is approximately 11,000km of known rivers and streams[173] in Sierra Leone, and the likely areas for panning and diving were defined with a simple spatial method:



[173] Data: Open Street Map (https://www.openstreetmap.org).

Figure 52: A: Spatial data records seen on Sentinel-2 satellite image on 1 January 2017. B: Sentinel-2 satellite image on 28 February 2018. C: Active ASGM activity area demarked manually. D: Potential active ASGM areas demarked algorithmically using a GIS software. Scale: Diameter of a circle is 80 meters.

All 35,839 spatial records on artisanal mining between 2000-2018[174], were surrounded by a 500 m circular buffer (Figure 54) by disseminating overlapping circles. Then, river areas intersecting these buffers were detected and their overall length calculated. It was then concluded that a total of 691km of rivers can be expected to be occupied by artisanal miners, those areas being within a radius of 500 meters from known areas where mining is assumed to be happening. It was further concluded that a total of 33,168 ASGM workers can be expected to be occupied in panning and diving, producing approximately 300kg of gold (24K) annually.

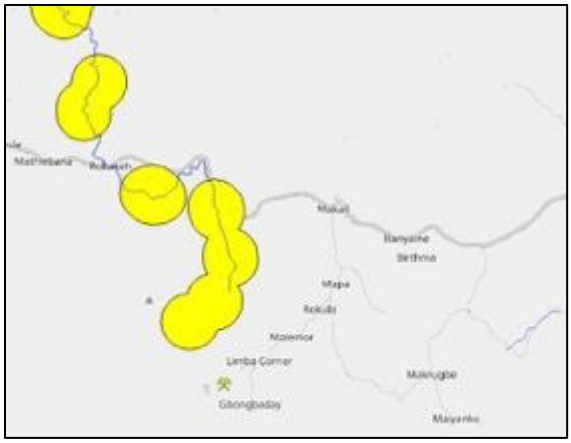


Figure 55: Disseminating 500m buffers revealing likely areas for gold panning and diving

9.3.7 The size of the ASGM sector: Final estimates

Based on the extrapolation, the final results can be summarized.

Table 20: Summary of ASGM statistics in Sierra Leone

Type	Area		Gold (24K) production		Workforce		Daily earnings (Le)	
	min	max	min	max	min	max	min	max
AM	343.21	687.4	384.46	770.03	12606.45	25248.90	33088.03	
AMGB	168.8	384.2	918.80	2091.26	11708.04	26648.28	50178.59	
HR	7.26	10.98	24.61	37.22	132.06	199.72	49085.59	
HRBG	31.26	64.55	105.96	218.80	568.61	1174.16	49085.59	
Mixed	46.09	46.09	336.31	336.31	4013.30	4013.30	42582.76	
SmallScale	n/a	n/a	185.26	185.26	15.00	15.00		
By-production	56.37	56.37			3909.85	3909.85		
Panning and diving	n/a	n/a	332.01	332.01	33168.00	33168.00	15000.00	
Average (column)	652.99	1249.59	2287.41	3970.88	66121.32	94377.22	25822.63 (weighted)	30817.45 (weighted)
Average (min/max)	951.29		3129.15		80249.27		28320.04	

[174] All artisanal records were taken into account, as it was recognized in Baoma Station that while men were busy mining diamonds, women occupied nearby riverbed to pan gold.

10 Annex 4: Countrywide Geological Report

National Artisanal and Small-scale Gold Mining (ASGM) Overview

Submitted to:

The Environmental Protection Agency, Sierra Leone
21 Old Railway Line
Brookfields
Freetown

Contact Person: Mr. Alie D. Jalloh,
Assistant Deputy Director, Policy Planning and Research

Research Dates: 22 January - 16 February 2018
Photos by: Kelvin F. E. Anderson
Cover Photos: Left to right, top to bottom; quartz vein (primary deposit), ironstone, soft rocks, swamp gravel, stream / river gold, terrace / mountain gold, tailings, mercury and sponge gold.

Prepared by:

Kelvin F. E. Anderson

National Consultant, ASGM Overview

12 March 2018

Table of Content

TABLE OF CONTENT II

TABLE OF FIGURES III

1. INTRODUCTION 1

2. METHODOLOGY 1

3. SUMMARY GEOLOGY OF GOLD IN SIERRA LEONE 1

4. MINING COMMUNITIES VISITED 3

4.1 SELLA LIMBA CHIEFDOM, KARENE DISTRICT 3
4.1.1 KATHANTHA 3
4.1.2 KASASSIE 4
4.2 SANDA LOKO CHIEFDOM, KARENE DISTRICT 4
4.2.1 LAMINAIA ..... **ERROR! BOOKMARK NOT DEFINED.**
4.2.2 KAMPALA 5
4.3 DIANG CHIEFDOM, KOINADUGU DISTRICT 6
4.3.1 YAMFARA 1, 2 AND 3 7
4.3.2 SITE WORKED MAINLY BY WOMEN 8
4.3.3 KUWAIT 9
4.3.4 DOJO RESOURCES (SL) LTD. 9
4.4 SIMIRIA CHIEFDOM, TONKOLILI DISTRICT 10
4.4.1 MASUMBIRI 11
4.4.1.1 Dayu Mining 12
4.4.2 BONGA TOWN 13
4.4.3 MARANDA 13
4.5 KUNIKE BARINA CHIEFDOM, TONKOLILI DISTRICT 15
4.5.1 MAKONG 15
4.6 YELE CHIEFDOM, TONKOLILI DISTRICT 15
4.6.1 ROSSINT 16
4.6.2 M & S VENTURES LTD. 16
4.7 VALUNIA CHIEFDOM, BO DISTRICT 17
4.7.1 BAOMAHUN 17
4.7.1.1 American Small-scale Mining company 18
4.8 BAOMA CHIEFDOM, BO DISTRICT 20
4.8.1 BAOMA STATION 20
4.9 NIMIKORO CHIEFDOM, KONO DISTRICT 20
4.9.1 KOMAHUN 21
4.9.1.1 New Site 21
4.9.1.2 Somalia 21
4.9.1.3 Israel, Libya, Iraq & Bethlehem 22
4.9.2 SMALL-SCALE MINING COMPANIES 23
4.9.2.1 Hongxing Mining Company Ltd. 23
4.10 SANDOR CHIEFDOM, KONO DISTRICT 25
4.10.1 TEFEYA AND WYDALLA 25

4.10.1.1 Pluto Mining Company 25

5. CONCLUSIONS 26

Table of Figures

Figure 1 Locations of mining communities and sites visited overlaid on a simplified geological map of Sierra Leone.....2
Figure 2 Mining swamp visited in the environs of Kathantha.....4
Figure 3 Terrace mining site in Laminaia.....5
Figure 4 The main mining site in Kampala.....6
Figure 5 The mining sites visited around Dalakuru.....7
Figure 6 Mining methods around Dalakuru......9
Figure 7 The main operations of the Chinese contractors in Makonie......10
Figure 8 The main rock types in Masumbiri.....11
Figure 9 Mining pits and processing of ores in Masumbiri......12
Figure 10 Entrance to the mining tunnel of Dayu Mining, Adit, Masumbiri.....13
Figure 11 Mining area in Bonga Town.....14
Figure 12 Mining up the hills in Maranda.....14
Figure 13 The mining site visited in Makong.....15
Figure 14 The mining site visited in Rossint.....16
Figure 15 Dredge working in the Taia River for M & S Ventures.....17
Figure 16 Gold mining in Baomahun......19
Figure 17 The processing plant of a small-scale company in the outskirts of Baomahun.....20
Figure 18 Deposits mined in Somalia......22
Figure 19 Mining in Libya and Iraq.....23
Figure 20 Two excavators in operation in the concession of the small-scale mining company.....24
Figure 21 Water pond where concentrates are paned using wooden Chinese pans.....24
Figure 22 Mechanised system designed to process gravels for both diamonds and gold.....26

1. Introduction

Sierra Leone has signed and ratified the Minamata Convention on Mercury which is designed to "protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds". The United Nations Institute for Training and Research (UNITAR) is therefore conducting a Global Environment Facility funded project on the "Development of the Minamata Initial Assessment (MIA) and the National Action Plan (NAP) for Artisanal and Small-scale Gold Mining (ASGM) in Sierra Leone".

A field research on the country's ASGM sector has been conducted by a team comprising consultants for the Environmental Protection Agency, Sierra Leone (EPA), UNITAR, the National Consultant and the Senior Environmental Officer, EPA. This report gives a geological overview of all the mining communities visited including the use of mercury in the sector.

2. Methodology

The mining communities visited were chosen by the EPA in consultation with the National Minerals Agency (NMA). Regional offices of the NMA and EPA were visited to get their perspective on the ASGM sector in terms of mining regulations, monitoring, the environment, challenges they face and recommendations on how to improve the sector and quality of the services they offer.

Permission to visit the mining communities were sought from the respective Paramount Chiefs. At each community, interviews were conducted with the town chiefs, elders and gold agents, dealers and miners. Some small-scale mining companies, active within the mining communities, were visited.

The geology of the mining sites was studied in terms of the ore being mined, the rock types present, and the mining and processing methods used.

3. Summary Geology of Gold in Sierra Leone

The main hosts of gold in Sierra Leone are the greenstone belts. These are mafic and ultramafic volcanic, intrusive and associated volcanosedimentary rocks metamorphosed to greenschist or amphibolite facies. These facies contain green minerals including amphiboles, chlorite, epidote and serpentine.

The following greenstone belts are known to contain gold; Gori Hills, Kambui Hills, Kangari Hills, Loko Hills, Nimini Hills and the Sula Mountains. Figure 1 shows the locations of the mining communities and sites visited overlain on a simplified geological map of Sierra Leone. It can be seen that most of the mining communities visited are located within the greenstone belts

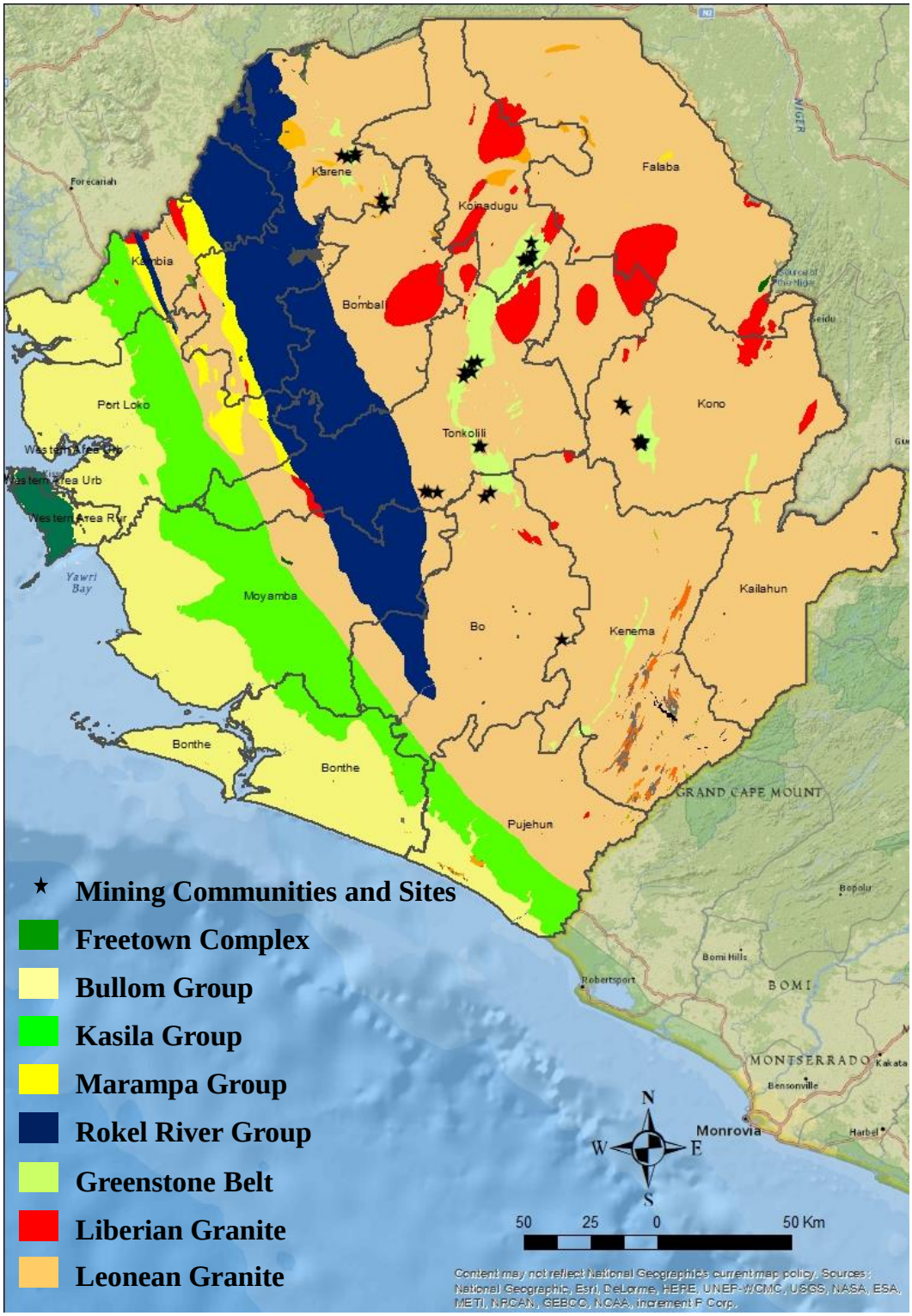


Figure 1 Locations of mining communities and sites visited overlaid on a simplified geological map of Sierra Leone

The primary deposits (lode gold) are usually high-grade quartz veins, gold associated with sulphides, gold associated with iron rich quartzites and ironstones. The secondary deposits occur in the form of alluvials / placers including residual (laterite and soft rock) deposits. The gold can also occur in free forms such as nuggets, flakes and grains. The main ore minerals are asenopyrite, chalcopyrite, pyrite and pyrrhotite. Several studies e.g. Barrie and Touret, 1999 and Warnsloh, 2011, have shown that

gold mineralization in Sierra Leone is structurally controlled occurring in shear zones and lineaments.

Open pit mining of alluvial and residual deposits is the dominant type of gold mining in Sierra Leone. These secondary gold deposits are found on the surface or near surface soft rocks, making them easy to mine. Reserves of these secondary deposits have been almost depleted in most of the gold mining areas. Primary deposit (hard rock / lode gold) mining is limited in the ASGM sector because of the costs involved and government regulations. Hard rock mining was being done in only two of the mining communities visited.

4. Mining Communities Visited

4.1. Sella Limba Chiefdom, Karene District

The mining towns visited in this chiefdom are Kathanta and Kassasie. The source of the gold in these communities is thought to be the Loko Hills with the main rock types being the basement granites, gneisses, amphibolites, migmatites and pegmatites. The gold is associated with quartz veins, quartzites and banded ironstones intercalated with granites and pegmatites. Alluvials are being mined in swamps, terraces and river channels and the gold occurs mainly as flakes. The mining areas are located within the mining and exploration concessions of AMR Gold (SL) Limited (AMR).

4.1.1. Kathantha

Mining in Kathantha is mainly done in swamps and terraces. The swamp mining area visited (Figure 2A) had greater than 200 pits and trends N - S, which is the general trend of gold deposits in Sierra Leone. Gold and coltan have been mined there but both are said to have been almost depleted. They however continue to mine gold there mainly on a subsistence basis. The number of workers per pit ranged from 3 to 5.

Gravels are met at depths of less than 2 m. Panning seems to be the main method used to process the gravels and the gold occurs in the form of flakes (Figure 2B). The miners said they rent sluices when needed but none were seen. There were also no water pumps present but the miners have developed a method of draining their pits using 5-gallon containers attached to strings (Figure 2C). All these indicate lack of investments in the area mainly due to the gradual depletion of the near surface gold resources.

Figure 2 Mining swamp visited in the environs of Kathantha (A), (B) gold flakes mixed with other concentrates in a pan, (C) miners draining a pit.

There was no evidence of mercury use as the gold flakes are big enough to be collected by panning with just water. During the rainy season, the majority of the miners go back to farming, the main occupation in the area, whereas others move from the swamps to the terraces.

4.1.2. Kasassie

The shallow soft rock gold deposits have been nearly exhausted, and this has led to a significant decrease in the mining population which is now made up of mainly migrants from nearby villages. No miner was seen on the swamp visited even though it was once considered to be the main mining site in the community. The future of artisanal mining in the community seems bleak as the miners can't afford to fund the deep mining which is now required.

4.2. Sanda Loko Chiefdom, Karene District

The mining communities visited in this chiefdom are Laminaya and Kampala. This area is also underlain by supercrustal rocks of the Loko group lying within Leonean granites and pre-Leonean migmatitic gneisses and granitoids. The greenstone lithologies consists of amphibolites, banded ironstones, hornblende schist, metagrewackies, quartz-biotite schist and quartzites. The trend of the major lineaments in the area is NE and ENE. Others are trending NNW. Gold is currently being mined in swamps and terraces, but no primary resource is being mined. Diamonds and coltan have also been mined in this chiefdom.

These communities also fall within AMR's concession and they stopped most of the artisanal mining that was going on. Even though they have not done any work since 2012, artisanal mining has not got back to how it was before the ban.

4.2.1. Laminaya

Laminaya has potential for both primary and secondary gold deposits. The primary resource is thought to be located up in the hills whereas the secondary deposits are found mainly in valleys. The main hard rock mining site is near a dam supplying water to the town and mining has been stopped there to avoid contamination. Only swamp and terrace material are now being mined.

Figure 3A shows a terrace site visited. The depth to gravel is about 3 m and Figure 3B shows a miner pointing to the start of the gravel layer within a pit. The gravel is about 1 m thick and consists of

various rock fragments. The main processing method used are sluices (Figure 3C) and panning the concentrates. Figure 3D shows gold grains from Laminaya mixed with magnetic concentrates. These can be easily separated using magnets.

Figure 3 Terrace mining site in Laminaya (A), (B) miner pointing to the gravel layer in a pit, (C) miners washing gravel using sluice box, (D) concentrates comprising gold and other magnetic minerals.

The miners do not use mercury, but the chiefdom elders claim a small-scale mining company active in the area between 2009 - 2017 used mercury. The mining population according to the village authorities was as high as 5000 people but now is about 1000.

4.2.2. Kampala

Almost every household in Kampala is involved in mining if even for subsistence reasons. Swamps and terrace deposits are being mined but no hard rock primary deposit. A swamp mining site was visited (Figure 4A.) and these have miners in groups of about 5 people. Depth to gravel is about 3 m. Figure 4B shows the carpets used in the sluice (Figure 4C). It is believed this type of carpet which is made in China, captures most of the gold. It occurs mainly in the form of flakes. Rock fragments removed during the washing process include weathered granite, quartzite and ironstones. Excavation of top soil to gravel depth can take a couple of days to a month. Washing period can be for just a few days.

Figure 4 The main mining site in Kampala (A), (B) carpets used in the sluice boxes, (C) 5 miners washing gravel using a sluice box. Note the mauve bowl where the carpets will be washed.

Mercury is not being used by the miners in Kampala, but the same small-scale mining company accused of using mercury in Laminaya was also active in Kampala.

4.3. Diang Chiefdom, Koinadugu District

The main mining towns visited in this chiefdom are Dalakuru, and Makonie. The artisanal mining sites visited were around Dalakuru and adjacent to the Yamfara River from which they got their names i.e., Yamfara 1, Yamfara 2 (Figure 5A) and Yamfara 3 (Figure 5B). This area is known to be one of the wealthiest and most productive in the country for alluvial gold. Other mining sites visited around Dalakuru are Kuwait (Figure 5C) and one along the Yamfara River worked mainly by women (Figure 5D).

Figure 5 The mining sites visited around Dalakuru (A) Yamfara 2, (B) Yamfara 3, (C) A pit in Kuwait - Note the competency of the laterite, (D) site on the banks of the Yamfara River predominantly worked by women.

This area is situated on the northern portions of the Sula mountains and the Kangari Hills. Intense laterization has led to the ground surface being covered by duricrust and boulders making it difficult to recognise the mineralisation at the surface. Outcrops of fresh rocks are rare, but the gold is known to be associated with quartz veins associated with sulphides and pegmatites veins showing sulphide mineralization. Non-sulphide minerals in the ore body include carbonates and tourmaline. The associated rock types include amphibolites, banded ironstones and granites. The mineralisation is structurally controlled with Dalakuru sitting at the intersection between two major shear zones. This area has potential for both alluvial and primary deposits.

Artisanal mining in these sites have declined in the past 3 years due to the gradual depletion of the near surface deposits. Deep mining is now necessary but expensive and requires small-scale mining licenses due to the heavy machinery required. A small-scale mining company is active in Makonie.

There has been no report of mercury use amongst artisanal mining in these communities mainly due to the high quality of gold being produced.

4.3.1. Yamfara 1, 2 and 3

Yamfara 1 and 2 are mining camps with mining ongoing in their environs. The depth to gravel is usually > 10 m and the gravel thickness is about 1 to 1.5 m. The size of the mining groups is between 3 and 8 people. A small portion of the gravel is washed at the start and the women are asked to wash the tailings to test the effectiveness of the sluice in capturing the gold. If a certain amount of gold is recovered, the angle of the box, flow rate of water and carpets are suitably adjusted. At the end of the washings, the carpets from the sluice are washed in large bowls and the women pan the concentrates to recover the gold.

Yamfara 3 is a mining site and not a camp as is the case of Yamfara 1 and 2. The area is swampy and has been mined before by a small-scale mining company. The mining method used here is different

from those discuss so far. Holes with diameter of 75 cm to 1 m are dug to depths of up to 12 m or more to get to the gravel. The holes are dug in soft rock and to prevent the walls from caving in, they are cased with a special type of stick which is flexible but tough (Figure 6A). Only one person referred to as the "diver" goes down the pit at a time. The gravel is removed using buckets attached to a pulley system (Figure 6B) The "diver" also follows the gravel underground, casing the hole with sticks as he proceeds. Draining the pits requires generators as water pumps are not effective due to the depths and structure of the pits. This makes this mining method a bit more expensive, but the gold produced is of high quality and in the form of flakes. (Figure 6C).

4.3.2. Site worked mainly by Women

This area has been mined before and is no longer attractive to the men due to low gold recoveries. Ironstone is the main rock mined here (Figure 6D). They first separate the iron rich rocks from others, breaks them down to smaller pieces using hammers and mill them in holes dug in hard lateritic rocks. The fine-grained material is then sieved and panned. Figure 6E shows a woman pounding these rocks in holes in a laterite rock whilst her daughter looks on. Note the pounded material and sieves being used and that the lateritic rock has several holes for multiple use. They work in groups of 2 to about 10 with the larger groups having a few men. The gold produced is in the form of powder (Figure 6F) and much finer than those produced in the area (Figure 6F).

Figure 6 Mining methods around Dalakuru. (A) cased holes dug in swamps, (B) gravel being brought to surface, (C) the swamp gold produced, (D) gold containing ironstone, (E) holes in lateritic rocks where ironstones are pounded, the materials produced and sieves.

4.3.3. Kuwait

This area has been worked before and was one of the most productive areas, hence the name. The pits are dug similar to those in Yamfara 3. In this case however, weathered hard rocks are dug into so no casings are used (Figure 5C) as the rocks are considered to be competent. The holes can be up to 10 m deep. When met, the gravel is then followed underground. Miners work in groups of 4 or 5 and the gold produced is in the form of flakes.

4.3.4. Dojo Resources (SL) Ltd.

Dojo Resources (SL) Ltd. operates in Makonie with Chinese and Russian contractors in separate areas. The Chinese contractors have been operating since February 2017, but the Russians were just getting started at the time of the field research. The Chinese are working on swamps and Figure 7 shows their main operations.

Figure 7 The main operations of the Chinese contractors in Makonie. (A) an overview (B) an excavator extracting and loading gravel in to a mechanised sluice with water hoses, (C) the tailings from the first sluice are sent to this second sluice.

They use a mechanised system (Figure 7) in which the excavator is used to load the sluice (Figure 7B). The first washing uses mechanical water hoses and carpets such as that shown in Figure 4B and these extracts about 70 % of the available gold. The tailings are sent to a second sluice (Figure 7C) which extracts most of the remaining 30 %. Washing of the carpets and panning for gold is done indoors and the team did not get access to that area. The workers met denied mercury was being used as part of their operations.

4.4. Simiria Chiefdom, Tonkolili District

The main mining communities visited in this chiefdom are Masumbiri, Maranda and Bonga Town. Primary and secondary deposits are being mined in Masumbiri in an area called "Adit", where several mining or exploration adits and tunnels have been dug under the hills. No fresh primary deposit was being mined in Maranda. Mining in Bonga town is mainly on a swamp and terraces close to the Pampana River.

The gold deposits can be found in the southern end of the Sula Mountains close to its boundary with the Kangari Hills. The primary gold is hosted within quartz veins associated with sulphides (pyrite, arsenopyrite and chalcopyrite) as in Figure 8A, which intrudes sheared and altered talc-chlorite-carbonate schists (Figure 8B) and associated rocks. The talc-chlorite-carbonate schists are easily recognised by their slipperiness and soapy feel. In competent rocks the veins are massive and can be up to 50 cm wide. In the Adit, the veins occur in contact zones between metavolcanics and metasedimentary rocks. In some cases, cupriferous gossans are seen in association with the gold mineralisation (Figure 8C).

Figure 8 The main rock types in Masumbiri (A) quartz vein with pyrite band. (B) talc-chlorite-carbonate schists, the country rock, (C) cupriferous gossans (blue) indicating association with copper.

The secondary deposits are mainly found along the drainage system of the area. The near surface deposits in all these types of deposits have been almost depleted according to the miners.

4.4.1. Masumbiri

The depth of the rock pits visited was about 6 m (Figure 9A) and miners mining the primary deposit go underground if necessary. There are about 7 members in a group and they use tools such as hammers, chisel, crowbars etc. to extract the rocks. The rocks are broken down to small sizes and packed into bags which are either taken to crushers or down to the village to be pounded in mortars. The miners first process some of the rocks to know the potential recovery before taking the rest to the crushers because the cost of crushing a bag of ore is significant. This process involves pounding the rocks in mortars (Figure 9B) using metal bars, sieving the crushed material (Figure 9C), with the sieved material washed and panned. The crushers are connected to sluices with water hose to wash the crushed material immediately (Figure 9D).

Figure 9 Mining pits and processing of ores in Masumbiri. (A) pit with quartz veins at the bottom, (B) pounding of quartz veins (C) sieving the crushed rocks, (D) crushing and grinding machine with sluice attached.

The swamp or river material are washed directly in sluices without crushing. At the time of visit there were about 3 groups of 3 persons washing gravels with rented water pumps. The migrants work mainly along stream channels whist the locals use their knowledge of the geology of the area to locate mineralised quartz veins and ironstones. No mercury use was recorded in Masumbiri amongst the artisanal miners.

The hard rock mountain ranges (Adit) falls within the exploration and mining licenses of Kingho Investment Company (SL) Ltd and they have contracted Dayu Mining to mine the deposit.

4.4.1.1. Dayu Mining

They started operations in December 2017 and envisage a 25-year mine life with the first gold pour expected in August 2018. They could however not elaborate on the processing methods they intend to employ. Figure 10 show the entrance to the mine.

Local mining in the Adit area is allowed for now but will be disrupted by the operations of Dayu Mining. They have suggested artisanal miners move out of a radius of 9.5 km from their operations at any point in time. At the time of visit they had about 100 locals working mainly in road construction and as labourers but none as geologists or engineers.

Figure 10 Entrance to the mining tunnel of Dayu Mining, Adit, Masumbiri

4.4.2. Bonga Town

This is a mining camp located next to the Pampana River. Alluvial mining is taking place on the river bed, banks and flood plains (Figure 11A). Some of the pits have continued underground as shown in Figure 11B. According to the locals, the river bed is being mined by diverting it rather than using divers. The well rounded quartzites (Figure 11C) and ironstones which are common in the area indicates they have been transported long distances and that the area may be a paleochannel.

4.4.3. Maranda

This forms parts of the Sula Mountains. Both alluvial and weathered rocks up the hills are been mined. The gold is found associated with quartz veins and ironstones. There was no evidence of fresh rocks being mined. The dominant rocks in the area are talc-chlorite-carbonate schists and weathered ones can be seen at the entrance of the pit shown in Figure 12A. The weathered rocks extracted (Figure 12B) are taken to a crusher (Figure 12C) situated up the hills where they are crushed and washed using sluice and panning. The gold occurs in the form of flakes (Figure 12D).

Figure 11 Mining area in Bonga Town (A) flood plain being mined, (B) pit showing entrance to underground tunnel, (C) well rounded quartzites indicating long distance travel and a possible paleochannel.

Figure 12 Mining up the hills in Maranda (A) pit showing weathered talc-chlorite-carbonate schists host rocks, (B) ironstones and quartz veins mined, (C) crusher with sluice box attached, (D) recovered gold.

Mercury is not being used by the miners. They however stated that a small-scale mining company from Burkina Faso operating in the area in the past, used mercury.

4.5. Kunike Barina Chiefdom, Tonkolili District

The gold mining town visited in this chiefdom is Makong and it forms part of the Kangari hills schist belts. Gold is usually contained in quartz veins / stringers and pyrite pegmatites, which are associated with the granites and tremolite schists rich in calcite. The quartz veins are mostly composed of sugary quartz which can contain pyrite crystals. Other rock types present are amphibolites, Banded Iron Formations (BIFs), chlorite talc schist and metasediments. As most of farming lands fall within the Kangari Hills Forest Reserve, mining is the main occupation. No heavy machinery were seen or reported to be active in the artisanal mining sites.

4.5.1. Makong

The mining site visited in the Makong area is called Mafai (Figure 13A). The locals are mining both hard weathered and soft rocks (Figure 13B). Pyrite crystals could be seen present in a sugary quartzite in Figure 13C. There were 4 crushers and sluices present and they were washing various horizons of the weathering profile (Figure 13D).

Figure 13 The mining site visited in Makong (A), (B) gold bearing quartz veins, (C) Pyrite crystals on sugary quartzite, (D) various gold bearing horizons of the weathered profile.

They work in groups of 4 - 8 people depending on the size of the pit. The gold produced is generally in the form of flakes but are thought to be finer than those from Dalakuru and Maranda. There was no evidence of mercury use.

4.6. Yele Chiefdom, Tonkolili District

Alluvial gold is being mined in this chiefdom with both artisanal and small-scale mining ongoing. The mining site visited is in the vicinity of Rossint Village and artisanal mining is mainly done along the banks of the Teye River. M & S Ventures Ltd., a small-scale mining company, employs Chinese contactors and uses a dredge to mine the Taia river bed.

4.6.1. Rossint

The mining area visited is shown in Figure 14A and is along the banks of the Teye River. Several pits were being dug and they use terraces (Figure 14B) to help prevent pit wall collapse. The depth to the gravel is estimated to be about 8 m and gold nuggets, flakes and fines have been reported. Mining can only be done during the dry season due to the proximity to the river. The miners work in groups of about 4 or 5 people.

Figure 14 The mining site visited in Rossint (A), (B) terraces to protect the pits from collapsing, (C) divers collecting and washing gravel from the river bed.

Artisanal mining is also taking place in the Teye River by divers who extract gravel from the river bed. (Figure 14C). The divers go down with buckets using long sticks attached to the river bed and fills the buckets with gravel. The buckets are then hurled by someone in the canoe. The divers are usually in teams of 4; 1 diver, 1 drawback and 2 people who do the washing (mainly women) using sluice and panning (Figure 14C).

4.6.2. M & S Ventures Ltd.

This company has employed Chinese contactors to mine the river bed using a dredge (Figure 15A). It is a bucket dredge and some of the component parts are shown in Figure 15B. It shows the sluices (left), buckets (top right) and the pond, bowl and pan used to wash the carpets and concentrates. The dredge was assembled in Sierra Leone with parts from China and started operations in the Pampana River. Their operations at the time of the field research was in the Teye River.

Figure 15 Dredge working in the Teye River for M & S Ventures (A), (B) the sluices (left), buckets (top right). Note the pond and bowl used for washing the carpets and panning (bottom right).

Seven men work on-board comprising 3 Chinese contractors and 4 Sierra Leoneans. It was not in operation when the team visited but questions were asked off the workers and villagers met on board. They work 24 hours shifts with 22 hours (10 am to 8 am) spent digging and washing gravels. Two hours are spent processing the concentrates. The carpets from the sluices are washed in a large bowl and the first set of gold collected by panning.

Mercury is added to the tailings to remove the fine gold grains. The amalgam is not burnt onboard the dredge but taken to their office in Magburaka.

4.7 Valunia Chiefdom, Bo District

The mining community visited in this chiefdom is Baomahun. Algom Resources Ltd's (Algom) exploration licenses covers most of the artisanal mining areas and as such their Baomahun camp was also visited. They have allowed artisanal mining to continue as long as no heavy machinery is used. The artisanal miners may have to work out of a predetermined safety radius when Algom starts mining.

The gold in this area is derived from the Kangari Hills schist belts and is associated with shearing along the BIFs, quartzites, granodiorites, garnet-cummingtonite schists and ferruginous quartzites. It occurs in folded and faulted series of steeply dipping beds of various types of schists, quartzites and amphibolites. Gold mineralisation is associated with disseminated arsenopyrite and other sulphides (mainly pyrite) which follows the contacts between magnetite-rich garnet-cummingtonite schist and cordierite schist. The gold is thus associated with strong arsenopyrite mineralisation.

The gold is bound to quartz rich zones in the schist where magnetite-rich veins are usually abundant. As such the schists are also worked for gold. As the gold is associated with the BIFs and other magnetic rocks, magnetism is being used to explore for gold. Artisanal miners also use BIFs to locate mineralised zones.

4.7.1 Baomahun

The main gold resource being mined is located in the hills around Baomahun (Figure 16A). Mining is also done in swamps and rivers. The ore material varies from hard weathered ironstone rocks (Figure 16B) to soft schists material (Figure 16C). No crusher was seen on site and the gravel is pounded with rods into powder form (Figure 16D) then sieved (Figure 16E) and washed using sluices. Sieving is an optional step in the procedure and is skipped by some of the miners. The concentrates are then panned using mercury (Figure 16F). At the end of the washing, the amalgam (Figure 16G) is collected and heated to evaporate the mercury (Figure 16H).

The average pit size is about 2 m^2 with depths of between 10 m - 12 m and there are usually between 8 to 15 workers per pit. The gold produced is of a lower quality compared to other parts of the country. Gold from the hills is mainly in the form of powder whilst those from the rivers and streams can be both flakes and powder. Silver is a by-product of the gold being mined in Baomahun. The population of miners has reduced significantly as most have gone to Komau which currently hosts the largest number of artisanal miners in the country.

According to the locals, mercury use started in 1980 when there was an influx of miners, dealers and supporters into Baomahun after a small-scale mining company left the area. It is alleged that the mercury comes mainly from Guinea and Liberia. The amalgam is most of the time burnt up the hills and sold to dealers stationed there or it can be taken down to the village and heated there.

4.7.1.1 American Small-scale Mining company

A company which the locals say is American, was setting up their processing plant by a river in the outskirts of Baomahun. Figure 17 shows the plant including its sieves and sluices (Figure 17B and C.

Figure 16 Gold mining in Baomahun. (A) Hill being mined, (B) ironstone being mined (C) schists being mined, (D) pounding gold bearing material, (E) sieving the pounded material, (F) mercury added to wash concentrates, (G) amalgam, (H) amalgam been heated to evaporate the mercury.

Only the security was met on site and he could not give any details about their operations including their mining or processing methods. They are expected to mine alluvials.

Figure 17 The processing plant of a small-scale company in the outskirts of Baomahun (A), (B) the sieves, (C) sluices.

4.8 Baoma Chiefdom, Bo District

The mining community visited in this community is Baoma Station. Gold in this chiefdom is mined as a by-product of diamond mining and is also done by women along the Sewa River. The women also pan the tailings from diamond mining. The chiefdom has about 47 miles of the Sewa River which joins the Bafi River in Kono.

The gold sector in the chiefdom is unregulated with the focus being on diamonds. The bulk of the recovered gold is sold to traders from or in Bo. It is not clear how much support they give to the miners, but these may include tools to ensure the gold is sold to them.

4.8.1 Baoma Station

Mining in this community has been going on since the 70's but picked up after the country's civil war. Almost all the women are involved in panning for gold on the banks of the Sewa River. Panning by the river happens mainly in the dry season and the gold is in the form of flakes and powder. They also work on diamond tailings. They credit tools from traders and pay when they sell their gold or sell it to the traders themselves.

4.9 Nimikoro Chiefdom, Kono District

The mining community visited in this chiefdom is Komau. It is by far, the largest gold mining community in Sierra Leone in terms of population and operations. Mining in this locality is thought to be illicit as the area is part of Nimini Mining Ltd's exploration concessions. Nimini Mining Ltd. are currently under care and maintenance.

The country rocks in the area are talc carbonate schist. Other rocks include amphibolites, BIFs, ultra-basic schist, pelites chert, and quartzo-feldspathic meta-sediments. The mineralization consists of quartz veins, veinlets and lenses which contain arsenopyrite, pyrite, chalcopyrite, sphalerite and galena. They can also occur as fine disseminations associated with arsenopyrite, pyrrhotite and occasionally magnetite. They usually occur within or close to the BIF horizons and gold could be found in the immediate wall rock. The deposit is known to have high sulphide and magnetite content in places. The metamorphic assemblages at Komau are characterised by chlorite, phlogopite (biotite), magnetite, garnet, epidote and tourmaline indicating a lower amphibolite / high greenschist facies

metamorphism. The deposit is structurally controlled being associated with prominent regional structures and stratigraphic contacts.

Alluvial mining is dominant in Komau but in at least one locality, primary hard rock deposit was being mined. Excavators are present in Komau as most areas require deep mining due to gradual depletion of the near surface resources.

4.9.1 Komau

There are thousands of active miners in Komau even though the population is said to have decreased due to the gradual depletion of the near surface deposits. The miners live on 3 camps away from Komau village i.e. Camp 1, 2 and 3.

Three main types of material are being mined; fresh rocks, hard weathered rocks and soft rocks. Most of the mining now seems like small scale operations as excavators and tractors are common. There are about 280 crushing and grinding machines registered in the Camps with about 120 - 130 being active. This reflects the sheer size of the mining community.

Mercury use is common in Komau and it is mainly used when washing tailings. Tailings are usually given to women who help in the processing of the ore. The miners are convinced that the only way to get the remaining gold in the tailings is by using mercury. Even though the women are given the tailings, they most of the time do not do the panning with mercury themselves. Tailings are panned by mainly men who specializes in panning with mercury. When very little material is left in pan, the amalgam and remaining mercury is poured into a cloth and squeeze to recover the free mercury and collect the amalgam. The amalgam is then vaporized to get rid of the remaining mercury and form sponge gold. It is so called because it looks like sponge with its coarse surface and honeycombed structure. The sponge gold are not mixed with the mercury free gold.

It is widely believed that the mercury is got from Liberia and Guinea but there are other claims that it is also got from hospitals and funeral homes where it is used to preserve the dead. Chiefdom authorities are aware of the harmfulness of the use of mercury, but it is still being used.

The main mining sites in Komau are given names of countries involved in conflicts e.g., Libya, Somalia, Israel and Iraq with the exception of Bethlehem which is the farthest of all the mining sites. A new mining site close to the camps was being worked at the time of the visit.

4.9.1.1 New Site

This site was opened in early January 2018 next to camp 2. The miners claim that this site now belongs to a Chinese small-scale mining company, but they are allowed to work there by hand for a fee paid to the local authorities. They were using excavators before mining was stopped by the authorities. Over 10 pits were counted, and the mined material is usually schist and ironstones.

4.9.1.2 Somalia

Somalia is the only site where the mining of primary quartz vein deposit (Figure 18A) was ongoing. The pit visited is at an elevation of 528 m with depth > 40 m and has high angled talc carbonate schist wall rocks associated with amphibolites. Work on the pit started in October 2017 and they now claim to get > 15 bags of fresh quartz veins a day. The ore is transported in sewn 50 kg rice bags to avoid spillage during transportation. The mineralised rocks are taken down the hills where they are broken down to sizes of about 3¼ cm before being fed into crushers with sluice attached.

Soft rocks are also mined in Somalia as was seen in a second pit being worked (Figure 18B). The material contains fragment of quartz veins, quartzite and other rock types.

There was a small-scale mining company working the primary ore in Somalia in addition to swamps down the hills.

Mercury is not used amongst this set of miners. The material is crushed and washed twice, and the tailings given to women who help with panning. There is the tendency for mercury to be used when panning the tailings.

Figure 18 Deposits mined in Somalia. (A) 20 cm thick quartz vein (right); note smaller veins in the centre and left, (B) soft rock deposit.

4.9.1.3 Israel, Libya, Iraq & Bethlehem

These mining sites are grouped together because only soft rocks are being mined in all of them. Excavators were in use in all of them except Libya where a bulldozer was in operation and Bethlehem where heavy machinery has not been used. The bulldozer (Figure 19A) was being used because of an earlier pit wall collapse. Libya seems prone to landslide due to high angle slopes in deeply weathered terrain and fatal accidents have occurred in the past. They were mining the talc carbonate schist in Libya.

Getting to the gravel layer is time consuming and expensive because of the depths of the pits required and depth of weathering in these mountainous regions. The soft rock layer they mine is not fixed and they always test the different layers to see which one is more productive. In Iraq, the gravel is being sought in the pits leading to deep holes with depth > 20 m (Figure 19B).

When the favourable layer has been met, extraction can be very fast with 50 to 100 bags of material extracted per day. Bethlehem at an elevation of about 535 m is the farthest by road but the highest is Iraq which is at an elevation of almost 600 m. A jeep has been contracted to help transport the bags of material from Bethlehem to the camps. The jeep can take about 17 bags at a time.

There were groups of about 10 to 15 men working in these sites and in the case of Israel, they have been working there since September 2017. Mining started in Bethlehem when former workers of Nimini Mining Ltd decided to pan material from old trenches they made whilst working for the company.

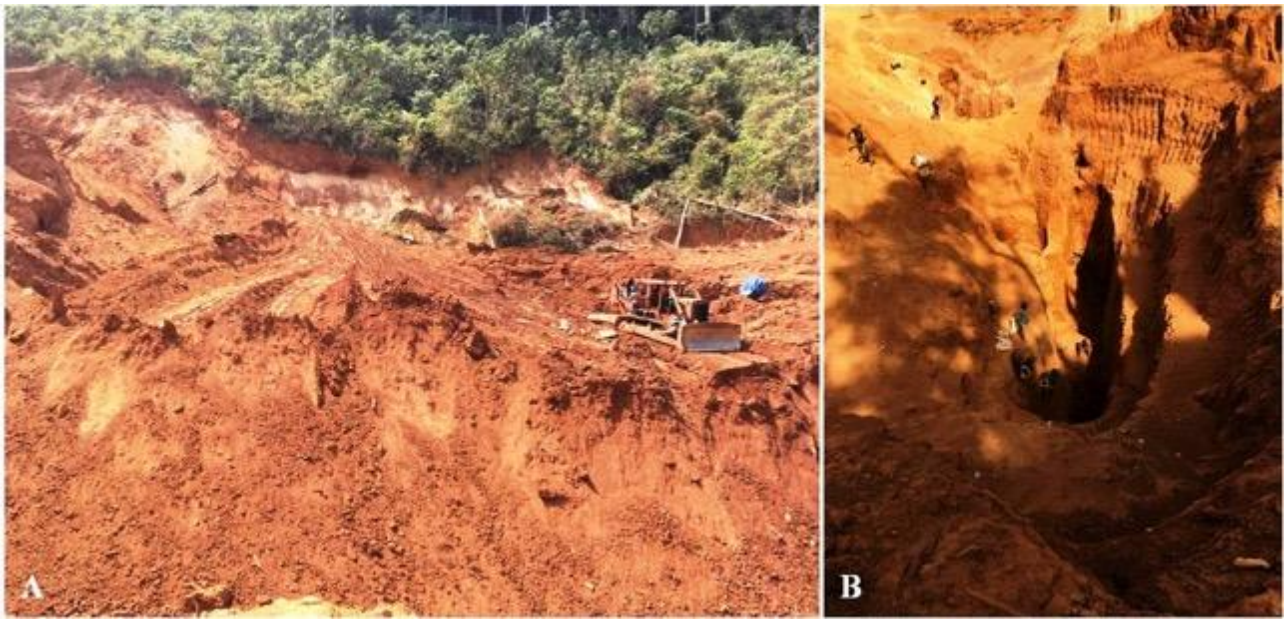


Figure 19 Mining in Libya and Iraq (A) bulldozer in operation in Libya, (B) deep (> 20 m) pit in Iraq.

4.9.2 Small-scale Mining Companies

It was reported that at least 3 small-scale mining companies with Chinese contractors were active in Komau at the time of the visit. The team was able to visit 2 of these.

The first company has been working on swamps and stream bed for 3 years on a 25-acre concessions within the Nimini Mining licenses. They had 15 workers of which 5 were Chinese (1 from Hong Kong) and the rest were Sierra Leoneans on daily wages. At the time of the visit, 2 excavators (Figure 20) were in operation but the workers met could not elaborate on their processing methods or gold production.

4.9.2.1 Hongxing Mining Company Ltd.

More technical details was got from the second company called Hongxing Mining Company Ltd. They have been in operation in Komau for more than 4 years and only work on soft rocks from the rivers and swamps. They have 6 excavators working in 3 sites i.e. 2 per site. One is used to load the sluice whilst the other continues to excavate for gravel.

They claim to only use water (no mercury) to wash their gravel. The water hose attached to the sluice is manually controlled by the workers. Panning is done in a pond using a wooden Chinese pan (Figure 21 A) which according to them has been in use for over 100 years in China. They recover both nuggets and flakes.

Figure 20 Two excavators in operation in the concession of the small-scale mining company

Acid is used to purify the gold which is then melted and poured into a mould to form bars. Cooking gas burners are used in the first purification process and acetylene gas (Figure 21B) is used in the final purification process which involves melting the gold and forming gold bars. There operations including camp site are protected by 4 members of the armed unit of the Sierra Leone Police known as the Operations Support Division, and they work by shift.

Figure 21 Water pond where concentrates are paned using wooden Chinese pans (A), (B), acetylene gas used to smelt gold to produce gold bars.

The small-scale mining companies do have frictions amongst themselves mainly over boundary issues. If they can't resolve the boundary dispute themselves, they refer the matter to the chiefdom elders to resolve the issue. The companies visited claimed not to use mercury.

The small-scale mining companies are dependent on the locals to finding new mining sites and if productive, they negotiate with the chiefdom elders to take it over and exclude the artisanal miners.

4.10 Sandor Chiefdom, Kono District

Diamonds, gold and coltan are been mined in this chiefdom. Gold is regarded as a by-product from the diamond mining as it is known that many of the diamond gravels and sands contain gold. Getting gold from diamond mining is quite common in diamond mining areas close to the greenstone belts. The former National Diamond Mining company conducted gold exploration on their leases in Kono, Lake Sonfon area of the Sula Mountains, the Gori Hills, 40 kilometres southeast of Koidu and Pampana in the southwest of the Sula Mountains. Only women pan for gold mainly on the banks of the Bafi River. Small-scale diamond mining companies are active in these areas with heavy machinery.

Gold is mined as a by-product of diamond mining mainly in the Bafi River and its environs. The Bafi River is thought to drain the diamond producing areas of Kono and hence it attraction to diamond miners. The gold is thought to come from the greenstone belt of the Nimini hills which is cut by the Bafi River and lies east of Tefeyah.

The gold mining site visited in Wydallah is a small-scale mining operation in the Bafi River and in Tefeyah, the area visited has been mined out by a small-scale mining company and locals.

4.10.1 Tefeyah and Wydallah

Mining and agriculture are the main occupations with most of the men involved in diamond mining on swamps and flats around the Bafi River. The women are mainly involved in gold panning on the Bafi River. According to the locals, excavators and dozers are been used in the artisanal licenses. Small-scale diamond mining companies do not report gold recoveries but have systems in place to mine gold. Such a system was seen when the team visited Pluto Mining company's processing plant in Wydallah.

4.10.1.1 Pluto Mining Company

Pluto Mining company are active in an area called Mexico where they are mining the Bafi River bed. They were not in operation at the time of the visit but are said to employ about 20 workers. They share boundary with another small-scale diamond mining company who it is alleged also have plants designed to process gold.

Pluto Mining Company has mechanised system (Figure 22A) designed to process gravels for both diamonds and gold. The river is banked to extract the gravel, and this is done mainly in the dry season. Gravel is brought in by the excavators and fed into a plant with sieves which vibrates and has holes at the base. Sand goes through the holes and into a sluice (Figure 22B) attached after the processing for diamonds has been completed.

Figure 22 Mechanised system designed to process gravels for both diamonds and gold (A), (B) sluice attached to diamond system.

5. Conclusions

The distinction between artisanal and small-scale mining is now blurred due to the gradual depletion of near surface deposits and the mining of deep seated ore bodies. Heavy machinery is now required to mine the deep-seated gold deposits, and this has led to a good number of artisanal miners quitting their job as they can't afford the costs involved. Unless these miners find alternative livelihoods, this situation can potentially lead to social unrests mainly but not exclusively in the mining communities.

The processing methods applied are quite satisfactory and some minor adjustments such as the type of carpet used in sluice, the angle of the box and the water flow rate can improve recovery. Sieving was not widely seen. Most of the time, they sluiced material which contained big rocks, which naturally lead to bad recovery as they will drag small gold flakes along with them while rolling down the sluice. Any major attempt to improve on processing methods will require capital investment into the sector to get equipment such as ball mills or efficient mechanised processing plants.

According to most dealers spoken to, Dalakuru has the best quality gold in Sierra Leone and Baomahun the least. There is not much difference in the quality of gold from the other producing areas. In general, swamp and river gold are of a higher quality than terrace or mountain (Adit) gold. Sponge gold is always sold for less no matter its origin.

Mercury has been proven to be used in 3 mining communities; Baomahun, Komau, and by the small-scale mining company, M $ S Ventures Ltd. at Yele on the Teye River. In the case of Baomahun, mercury is being used because the gold from the hills occurs mainly in powder form. In Komau, it is used to extract gold from tailings. The tailings are usually given to women but panning with mercury is usual done by men who specialises in this. Miners move from place to place taking their mining methods with them. This means that mercury users could introduce it to other areas they move to. Most village elders are aware of its harmfulness and will prevent its common usage, but sensitization should be made even in areas where its use has not been reported.

It is alleged that the bulk of gold produce in Sierra Leone is smuggled across the more than 800 border crossings into Guinea. This is also aided by the fact that export taxes are lower in both Guinea and Liberia. The mines monitors who are supposed to ensure compliance and sensitize locals about the mining codes are underpaid and lack vehicles and other logistics to effectively perform their duties.

The cost of gold in the country is relatively high compared to world prices. This indicates that it is not that profitable to be in the gold business if the intention is to sell in the international market. The persistent high prices indicate some buyers are using gold for other purposes.

The fact that the primary resource has not been mined in most areas means there is still a chance of an economically viable gold industry in Sierra Leone.

11. Annex 5: Calculation Sheets

The calculation sheets are available electronically at
https://www.dropbox.com/s/he9irywpohoj7hs/Annex5_SierraLeoneASGMOverview_Data_17042018.xlsx?dl=0
and contains the following color-coded sections:

Section	Colour	Referenced Chapter in the report
Summaries of visited communities	Yellow	3.2, Annex 2
MiningAreas- Manual Demarcation	Orange	3.1, Annex 3
MiningAreas - Algorithmic Demarcation	Orange	3.1, Annex 3
MiningAreas -Panning and Diving	Orange	3.1, Annex 3
MiningAreas - By production	Orange	3.1, Annex 3
Chiefdom Count	Orange	4.3, 4.4
ASGM in Chiefdoms	Orange	4.3, 4.4
ASGM in Districts	Orange	4.3, 4.4
Quantitative Data - Kathanta	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Laminaya	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Kampala	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Dalakuru	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Makonie	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Masumbirie	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Maranda	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Kumaru	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Makong	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Baomahun	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Yele	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - Panning and Diving	Blue	4.3, 4.4, 4.8, 4.9
Quantitative Data - By-production	Blue	4.3, 4.4, 4.8, 4.9
Official Gold Export	Grey	4.3
Gold Trade	Grey	4.3
RainFall 1991-2015	Grey	4.2