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WORLD BANK

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APPENDIX TO THE REPORT "MERCURY TRADE AND USE FOR ARTISANAL AND SMALL-SCALE GOLD MINING IN SUB-SAHARAN AFRICA"

FINAL REPORT

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FINAL REPORT

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1 Preface

This report is a supplement to a report on "Mercury trade and use for small-scale and artisanal gold mining in Sub-Saharan Africa" and is one of the outputs of the World Bank project "Development of mercury trade diagnostic for Sub-Saharan Africa". For further description of the aim of the study, reference is made to the said report.

This report summarizes the obtained information on mercury trade and use in use in ASGM in the countries as well as the experience with regard to site investigations and initial mercury baseline developments.

This report is intended for distribution to the participating countries, implementing and executing agencies for the national action plans (NAPs) in the countries and consultants involved in the development of NAPs. It is presumed that the reader is familiar with the methodologies and guidelines used. The report has not been written for publication to a wider audience.

Working group - The project has been implemented by COWI A/S Denmark and COWI Tanzania in cooperation with the following individuals and organizations:

- groundWork South Africa (input on regional trade and questionnaires)
- Alliance for Responsible Mining (local consultant in Senegal, Baptiste Hyacinthe Coué)
- Noël Thiombiano (local consultant in Burkina Faso, affiliated with the Centre for Studies, Documentation and Research in Economics and Social Sciences, University of Ouagadougou)
- Peter Appel (workshop and field training, affiliated with Geological Survey of Denmark and Greenland)
- Sara Geenen (coordinator of activities in DR Congo, affiliated with CEGEMI (Expertise Centre on Mining Governance at Universite Catholique de Bukavu, DR Congo) and Institute of Development Policy and Management (IOB) at the University of Antwerp, Belgium
- Bossissi Nkuba (local consultant in DR Congo, affiliated with Université Catholique de Bukavu)
- Rogers Nunurai Murinda (local consultant in Zimbabwe, affiliated with Geo-Global Environmental Solutions)

- Paul Yankson (Local consultant in Ghana, affiliated with University of Ghana)
- Dominique Bally Kpokro (local consultant in Côte d'Ivore, affiliated with World Alliance for Mercury-Free Dentistry)
- Stephen Turyahikayo (local consultant in Uganda, affiliated with earthbeat foundation).

Steering group - The project has been followed by a steering group with the following participants:

- Sanjay Srivastava, Ahmed Fall, Ruma Tavorath and Svetlana Khvostova, World Bank
- Carsten Lassen, COWI A/S (Project Director) and Jesper Jönsson, COWI Tanzania (Team Leader).

Country contact points - The activities in the eight participating countries have been coordinated by the following country contact points:

- Burkina Faso: Desire Yameogo Nonguema, Ministry of Environment and Sustainable Development
- Côte d'Ivoire: Kouame Georges Kouadio, Ministry of Environment and Sustainable Development
- DR Congo: Jean-Claude Emene Elenga, Ministry of Environment
- Ghana: Sam Adu-Kumi, Environmental Protection Agency
- Senegal: Aïta Sarr Seck, Ministry of Environment and Sustainable Development
- Tanzania: Magdalena John Mtenga, Vice President's Office
- Uganda: Christine Akello, National Environment Management Authority
- Zimbabwe: Petronella Rumbidzai Shoko, Environmental Management Agency.

2 Introduction

2.1 Overall methodology applied

The overall methodology applied for site investigations in this study is described in two existing guides:

- **Developing Baseline Estimates of Mercury Use in Artisanal and Small Scale Gold Mining Communities**: **A Practical Guide**, Version 1.0. Persaud, A., Telmer, K., Artisanal Gold Council. Victoria, BC, 2015.
- **Developing a National Action Plan to Reduce, and Where Feasible, Eliminate Mercury Use in Artisanal and Small Scale Gold Mining**. **Guidance Document.** Working Draft August 17, 2015. United Nations Environment Programme, 2015.

The methodology in these guides has been used to develop site investigations, forms and a reporting system and calculation tool. The methodology for site investigation has been applied for training in the participating countries and the methodology for developing national baseline inventories, using the reporting system, is illustrated in worksheets to be submitted to participating countries.

The lessons learned from the use of the methodology are summarized in chapter 11.2.

2.2 Requirements of the Minamata Convention

The methodology aims at producing key information for National Action Plan (NAP) evaluation, as per the requirement of the Minamata Convention (MC):

- Total mercury use for ASGM in the country
- Percentage of ASGM gold production based on mercury
- Total mercury emissions from mercury use in ASGM (Minamata Convention (MC), Annex C, paragraph 1 (d) Strategies for promoting the reduction of emissions and releases of, and exposure to, mercury in ASGM and processing, including mercury-free methods)
- Percentage of ASGM production based on whole ore amalgamation (MC Annex C, paragraph 1 (b). Actions to eliminate whole ore amalgamation)

- Percentage of sponge gold production using retort/fume hood (MC Annex C, paragraph 1 (b). Actions to eliminate open burning of amalgam or processed amalgam).

2.3 Tools and reporting system for site specific investigations and country baselines

Training in the methodology was undertaken during a two-and-a-half day sub-regional training workshop for all eight participating countries and 2-4 days' field training in six of the countries.

The training material consists of the following documents/files:

- **Workshop agenda** (provided electronically and in print at the workshop)
- **The two guides:**
  - Developing Baseline Estimates of Mercury Use in Artisanal and Small Scale Gold Mining Communities: A Practical Guide
  - Developing a National Action Plan to Reduce, and Where Feasible, Eliminate Mercury Use in Artisanal and Small Scale Gold Mining.
- **Workshop presentations** (provided electronically and in print at the workshop)
- Monitoring, reporting system and calculation tool:
  - **Excel workbook** for calculation and reporting of ASGM site investigations and development of national baseline estimates. Developed by COWI for this project (provided electronically)
  - **Reporting system documentation**. Developed by COWI for this project (provided electronically and in print at the workshop)
  - **Site investigation form**. Developed by COWI for this project (provided electronically and in print at the workshop with site example to be used for exercises).

2.3.1 Workshop

The workshop consisted of lectures, exercises and feedback from the participants. The lectures addressed:

- Minamata Convention requirements and linkage to related activities
- Basics on organization of ASGM sites, extraction methodologies and the use of mercury
- Value chain of mercury for ASGM and linkage with the value chain of gold
- Introduction to the reporting system and calculation tool (including showing how the tool works – this was documented in PPT slides).
- Developing ASGM site-specific baseline estimates
- Planning and developing country baselines for mercury use for ASGM
- Presentation of the preliminary assessment of regional mercury trade flows
- Lessons learned from other treaties.

- The **exercises** included hands-on training in the use of the reporting system and calculation tool for estimating gold production and mercury use on sample ASGM sites

› The workshop also served to stimulate **feedback** from the participants on the draft reporting system and the initial assessment of regional mercury trade flows. Furthermore, **information exchange** between participants served to build up regional cooperation between the participating countries and international organizations.

2.3.2 Reporting system and calculation tool

The Excel workbook

A calculation tool and a reporting system based on an Excel workbook has been developed. The workbook was developed to supplement the UNEP Toolkit for mercury inventories and can be operated by users with limited Excel skills. The workbook is available in English and French. The workbook is open for further editing and development by the experienced user and is documented in a separate note.

The workbook is:

› To be used for calculations and reporting of site investigations as part of the training.

› To be used for development of initial national baseline estimates for this project (one workbook developed for each country)

› To be used as a reporting system for the countries' further development of baseline estimates and monitoring of mercury use for ASGM (for participating countries, further development will be based on the workbook developed under this project).

Based on the entered data, the calculation tool combines automatic calculations of various output parameters with manual selections and/or estimates of some parameters by triangulation. For the latter estimates, expert assessments were needed for assessing quality differences in estimates based on different input parameters and calculation methods (e.g. differences between extraction based and income based gold production estimates).

The core of the system is a worksheet containing site-specific data. The data in this worksheet are organized in a way that facilitates the import of data into a database program such as MS Access in case some countries favor this option later on. Each column represents a record with all relevant data for one site.

The results of all site investigations are automatically summarized in order to provide an overview of the results of all site investigations and form the basis for extrapolation at a national level.

The workbook is protected so cells calculating the various output parameters cannot be changed by the user. The experienced user can unprotect cells and sheets and further develop the system, if required.

Estimation principle - The applied estimation principle is basically as follows:

› Site investigations using the methodology of the guidelines developed by Artisanal Gold Council

› On basis of investigated sites, parameters for the country baseline estimate are established:

  › Number of miners per site

  › Mercury to gold ratios

- Gold production and mercury consumption per miner
- Mercury recovery rates

- Results from investigated sites are extrapolated to the whole country on the basis of information on:
  - Total miner population and/or total number of sites in the country
  - Total gold production from ASGM (if available)
- Estimates are assessed with a view to other available information:
  - Trade of gold (industrial and ASGM)
  - Trade of mercury (e.g. national statistics)
  - Information from other countries with similar ASGM sector

Developed workbooks - A workbook with data from the site investigations was developed for the further use of each of the countries.

Reporting system documentation

The system is documented by a 20-page note available in English and French (English version attached in Appendix 1). The note is intended for experienced users of spreadsheets and workbooks and describes in detail how the various output parameters are calculated and how the workbook basically works. Furthermore, the note can be used for review and further development of the system.

The note is not intended to be a step-by-step introduction to the user of the workbook. This kind of information was provided in the training workshop presentations.

Site investigation form

The reporting system is supplemented with a site investigation form which contains all information to be collected on investigated ASGM sites. This form can be filled in by investigators without any experience in the use of Excel workbooks, and the collected information can subsequently be entered into the reporting system by a user with some basic skills in the use of spreadsheets.

The site inspection form to be used for site investigation consists of two parts:

- A part with key information used for estimating gold production, mercury use and releases at the investigated site. The entries are almost identical to the information to be entered into the reporting system.
- A part with supplementary information which may be collected for deeper analyses of the ASGM sites, e.g. production methods and organization, social and demographics information, living costs on site, and hygiene & safety. This information is not necessary to estimate the gold production and mercury use at the site, but may be relevant for a deeper analysis of the sector.

The intention is that the form is filled in by use of a pencil in the field and later filled in electronically on the basis of the field notes. For many parameters, the form applies tick boxes for easy and consistent reporting. The information is manually entered (or copied) into the reporting system.

2.3.3 Reporting system summaries

The reporting system provides summaries of the investigated sites by mining type. The objective of the summaries is that data can be extracted from the summaries and used for the national inventories. The summaries for each of the countries is provided in the country chapters of this report.

2.4 Field training

Field training was undertaken in six of the countries. In DR Congo the training was not undertaken for security reasons; in Burkina Faso the training was cancelled because the mining sites were closed due to the rainy season. The results of the field training are reported for each country.

3 Senegal

3.1 The ASGM sector in Senegal

The artisanal and small scale gold mining (ASGM) sector in Senegal has recently been described in a diagnostic assessment of artisanal and small-scale gold mining in Senegal commissioned by the World Bank (Fall, 2015) and reference is made to this assessment.

ASGM is practiced mainly in the southeastern area of Senegal, located in the Birimian Greenstones Gold Belt. The ASGM activities mainly take place in two regions: Kedougou (main) and Tambacounda.

There are two types of gold occurrences: placer gold deposits (alluvial and elluvial) and gold-bearing quartz veins (exploited by hard rock mining).

Although it is difficult to establish reliable statistics on this largely informal and occasional activity, it is likely now that at least 30,000 to 60,000 people are directly and regularly involved in gold mining. This activity is currently carried out on more than 95 sites, providing income to thousands of people living mainly in rural areas or from neighboring countries. Artisanal miners have organized themselves into more than 25 economic interest groups (EIGs); as well, some associations of EIGs have been established as a federation of EIGs.

Further data on the sector are provided in section 3.5 with the initial national baseline estimates of mercury use in ASGM.

3.2 Trade statistics for mercury and gold

Comtrade statistics on import/export of mercury

Data on import of mercury to Senegal, and export to Senegal as reported by partner countries from the UN Comtrade database, are shown below. For the period 2011 to 2015, no import was reported, while for 2011 an export of 11 kg mercury to Senegal was reported by Mexico.

The recorded import is well below the estimated consumption of mercury for ASGM of 2.6-7.7 t/year. Information from miners and miners' organizations indicates that the majority of mercury used in ASGM is smuggled in from neighboring countries. This circumstance is likely the explanation for the missing registered import of mercury.

Detailed statistics on mercury import have been obtained from the customs authorities for the period 2005-2011. The data are confidential and consequently not included here. During this period, seven shipments were recorded. The quantities ranged from 3 to 367 kg. The importers are mainly dentists or suppliers to dentists and medical institutions. The Comtrade data for 2010 shown below are identical to the detailed customs data, but for 2011 one shipment of 367 kg is not indicated in the Comtrade statistics. It cannot be excluded that some of the legally imported mercury has been sold for use in ASGM; legally imported mercury for dentists and laboratories does not appear to be a major source of mercury for ASGM in the country.

Table 3.1 Import of mercury (28 05 40) 2010-2015 in kg to Senegal by country (Comtrade database)

	2010	2011	2012	2013	2014	2015
Czech Rep.	3					
Spain	345					
Turkey	24					
Total	372	no data	no data	no data	no data	no data

Table 3.2 Export of mercury (28 05 40) 2010-2015 in kg to Senegal by country (Comtrade database)

	2010	2011	2012	2013	2014	2015
Mexico			11			
Spain	14					
Total	14	no data	11	no data	no data	no data

Statistics on gold production and trade

According to the data from USGS Minerals Yearbook from 2013, the total production of gold in industrial gold mines increased from 4.4 tonnes in 2010 to 6.7 tonnes in 2013. During this period the reported export of gold was on average about 3 t/y higher than the reported production, possibly reflecting gold production of that amount by ASGM.

According to the yearbook, in 2008 the government reported production from ASGM at 600 kg/year.

Table 3.3 Production of gold 2010-2013 in Senegal (USGS, 2015)

	Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year	Note by USGS
	2010	2011	2012	2013			
Senegal	4,380	4,089	6,666	not yet available	no	600	"Gold, mine output, Au content"; In 2008, the government estimated an unreported production of artisanal gold of 600 kg. Since then, no artisanal mining has been reported.

Table 3.4 Net export of gold (Commodity code 7108) 2010-2015 from Senegal (Comtrade database)

Net export, kg/year					
2010	2011	2012	2013	2014	2015
8,258	7,611	7,861	9,072	10,116	7,784

3.3 Informal information on mercury use and trade flows

Trade routes

The available information suggests that mercury is imported from Mali and other neighboring countries. Informants for this study have reported that the mercury mainly comes from Mali. The president of Kedougou's Regional Federation of Artisanal Miners states that the mercury comes from Ghana, Belgium, Burkina Faso, and Mali. There are no data available on mercury imported from Belgium; because of the EU mercury export ban, it is unlikely that mercury would currently originate from EU countries.

No information indicating that the mercury is imported from countries outside the Sub-Saharan region via the port in Dakar has been identified.

Persaud (2015) states that mercury likely enters Senegal through clandestine supply chains, typically by gold buyers entering mainly from Mali, with whom it is believed that the majority of gold also exits.

The Ministry of Environment also assumes that all entry of illegal chemicals occurs through Senegal's eastern and southern “porous frontiers”, with Mali specifically, and brought in illegally by Malians and Burkinabe.

The information obtained confirms official trade data which do not indicate direct import from countries outside the region. The regional assessment indicates that a major entry point for mercury import to Western Africa is the port of Lomé in Togo; however, the officially reported import to Western Sahara is significantly lower than the expected consumption for ASGM in the sub-region, perhaps indicating some significant illegal import to the sub-region, possibly to Mali or Burkina Faso.

Actors in the mercury value chain

According to interviewed woman artisanal miners, there are two ways of obtaining mercury:

- 1) through the buyer of gold who provides mercury and reduces the price, corresponding to mercury used, when buying the gold,
- 2) through mercury sellers who practice door-to-door selling advising they have some “product” for sale. The door-to-door sellers would sell only mercury and nothing else.

These two types of actors are the same as identified in other Sub-Saharan African countries. The small scale miners organization informed the study that it is most often provided by the gold buyers.

Some miners have informed the study that they do not know of any Senegalese selling mercury, only Guinean and Malian, whereas others assert that mercury is also sold by Senegalese.

A gold buyer on an ASGM site states that the mercury trade is covert, with no consistent sellers and no certainty about when next delivery will be. The buyer informs the study that the people selling mercury are

not trading other articles such as food, materials, etc. and sometimes it is not possible to get mercury for 2 or 3 months.

As mercury is not informally imported, the mercury is probably not imported by general import and trading companies (as e.g. is the situation in Ghana and South Africa) but rather brought across the borders by small traders. Before 2011 some dentists and dental suppliers applied for permits for import of smaller amounts of mercury. Even though no import has been notified for the last 5 years, it is likely that these actors would still import some mercury.

Small amounts of mercury are reported to be imported by laboratories using mercury. One laboratory reported they imported 5-10 bottles of 1kg of mercury per order (not notified to the authorities). One informant from a small mechanized mining company reported that, some years before, the company frequently bought mercury at a laboratory with headquarters in Dakar. The example demonstrates that, to some extent, mercury imported for use in laboratories is in fact used for ASGM.

Quantities traded and prices

A mercury retailer and local gold buyer at a mining site in Senegal reported that he buys the mercury from unofficial sellers, at a price of CFA 500 per 10 g (USD 0.83/kg). Mercury is sold in plastic bags, in a fluid state. The mercury is sold to the miners from whom he buys gold, at a price of CFA 1,000 (USD 1.65/kg).

Socioenvironmental investigations done as part of a recently finished project in Senegal confirm that the mercury is also sold in 10-g bags, at prices varying from 1.000 to 2.000 CFA (USD 1.65 - 3.30/kg).

A laboratory & import company in Dakar informed the study that the price of a bottle of 1 kg of mercury has increased from EUR 100 to EUR 283 (USD 315/kg). It should be noted that this mercury may be of higher quality than the mercury used for ASGM.

Persaud (2015) reports that on every site he visited in Senegal in 2014, the cost of mercury for a 10 gram plastic bag was between CFA 1,500 and 2,000 (USD 2.50-3.40/kg).

The available data indicate that prices have been decreasing over the last year, reflecting the trend in price on the world market.

According to available information, mercury is highly available, easily purchased, and very low cost for miners in Senegal. Persaud (2015) notes that when *"compared with the average price received by miners in the field for 1 gram of gold ($30 USD), and when factoring in a mercury amalgamation ratio of 1.3 Hg: 1 Au, the purchasing ratio of mercury used to gold produced makes it highly economical for the miners to use mercury as a processing tool. Essentially for every $30 that the miners make, they need to spend approximately 50 cents on mercury – a purchasing power ratio of 60:1."*

Sources of liquid mercury other than import

No sources of liquid mercury in Senegal other than import have been identified. Some recycling of mercury may take place in some of the small-scale mining companies, but this mercury would be re-used within the companies themselves.

3.4 Results of ASGM sample sites investigations

The site investigation took place from May 22nd to 30th 2016 in the Kedougou area with the participation of one international expert, one local expert and three trainees.

The aim of the field work was to train the three government employees to interview small-scale miners and fill out ASGM site investigation forms and get some experience in undertaking the inventories. The forms were delivered in French and English languages.

Four sites were visited. The obtained data are reported in specific site forms and the Excel reporting system where the data have been further processed. The following sites were investigated:

Site	location	Key characteristics
Diakha	Samecouta (village), department and region of Kédougou, Senegal	The gold ore exploited here is in alluvial deposits. The miners dig down a few meters; locally down to more than 5 meters. The ore is generally very soft. When a bucket of ore is hoisted to the surface a high quality metal detector scans the mined ore. The detector can reportedly detect gold grains down to a few mm in size. If the detector finds gold grains of that size, the ore is collected and brought to a processing site. If, however, no large gold grains are detected then the pit is abandoned. The mining area bears evidence of many shallow and deep pits which have been abandoned. The auriferous ores are trucked down to a processing site near to a river with ample water supply. The ore is then crushed and the crushed ore is let down a sluice where a coating captures the heavy minerals. Next step is making a gold concentrate in a pan. The miners claimed that they do not use mercury. Inspection of a panned concentrate did indeed reveal rather coarse gold (> 3 mm), but also large amounts of very fine grained gold.
Tomboronkoto (Woundoudou)	Commune de Tomboronkoto, village de Tomboronkoto, region de Kédougou UTM 1416621.4 28N 793836.5	Alluvial mining in shafts down to 7 meters. Locally tunnels are mined. The mined ore is trucked to a common processing site. The produced gold concentrate is then processed with amalgamation. This is done individually by the miners back in the villages. In the same area genuine placer mining is carried out where miners stand in the river, dig up sand and gravel and extract gold. Some miners mine the huge tailing dumps and extract small amounts of gold.
Woundoundou	Village de Ngari, commune de Tomboronkoto, region de Kédougou UTM 1398313.2 28 N 798989.9	Genuine hard rock mining site where the processed gold concentrates are treated with mercury.
Bantako	Village of Bantako, municipality of Tomboronkoto, region of Kédougou UTM 1413207.3 28N 801915.6	Hard rock gold deposit with auriferous quartz vein systems. The ore is mined in deep shafts and tunnels. There are two processing system. 1) UNIDO has recently installed a modern system comprising a Chinese wheel to grind the crushed gold ore and the ground ore is flushed down over a set of sluices coated with fiber material to capture the heavy minerals. The large amounts of heavy minerals are then treated in a huge shaking table. The high grade gold concentrate from the shaking table is then treated with mercury to recover the gold. This processing plant is used by a small group of miners mainly the leaders of the small-scale mining. 2) The other processing system is traditional. The miners truck the gold ore to a processing system as the one described above e.g. at Tomboronkoto.

Data for each site are provided to the Ministry of Environment in the form of an Excel reporting system with the site data and national summaries and the site investigation forms.

The summery of the results are shown in the table below.

Site **1. Sites étudiés**	**Type de site**		**Roche dure**	**Alluvion**	**Total**
- mineurs	Nombre de sites avec des informations sur la population de mineurs ainsi que les informations initiales sur le site		3	1	4
	Nombre de sites avec une enquête détaillée du site (Niveau 1 - 3)		3	1	4
	Nombre de mineurs (arroundi, distribution mathématique)	Min	1,891	240	2,249
		Max	3,395	500	3,777

Site **1. Sites étudiés**	**Type de site**		**Roche dure**	**Alluvion**	**Total**
	Nombre de mineurs	Min	1,696	240	1,936
		Max	3,590	500	4,090
	Moyenne du nombre de mineurs par site		881	370	753
- Production d'or	Production totale d'or, kg/an (meilleure estimation pour chaque site)		755	29	784
	Production totale d'or à partir du mercure, kg/an (meilleure estimation pour chaque site)		755	-	755
	Pourcentage d'or produit à partir de l'amalgamation au mercure		100%	0%	96%
	Production totale d'or à partir de l'amalgamation totale du minerai, kg/an		-	-	-
	Pourcentage d'or produit en utilisant l'amalgamation totale du minerai (de la production totale d'or à partir du mercure)		0%		0%
	Pourcentage d'or produit en utilisant l'amalgamation total du minerai (de la production totale d'or)		0%	0%	0%
	Production totale d'or par amalgamation du concentré, kg/an		646	-	646
	Pourcentage d'or produit à partir du concentré (de la production totale d'or à partir du mercure)		86%		86%
- Consommation de mercure	Consommation totale de mercure (mercure recyclé est soustrait)		1,042	-	1,042
	Consommation totale du mercure pour l'amalgamation du minerai (mercure recyclé non soustrait)		-	-	-
	Consommation totale par l'amalgamation du concentré (Mercure recyclé non soustrait)		923	772	1,695
- recupération du mercure	Quantité totale du mercure récupéré des amalgames et de l'or spongieux, kg/an		0		0
	Taux de recyclage total (% de l'usage total pour l'extraction) (excl. Récupération des boues)		0%		0%
	Mercure récupéré des boues et autres déchets, kg/an		0	0	0
- rejets de mercure	mercure total émis dans l'air, kg/an		755	0	755
	rejets totaux de mercure dans l'eau et le sol (incl. Les boues)		287	0	287
- Ratio mercure - or	Ratio mercure composé - or (moyenne de tous les procédés)		1.4	-	1.3
	Ratio mercure - or, amalgamation du minerai				
- statistique sur le site	Ratio mercure - or, amalgamation du concentré		1.4		2.6
	Nombre de sites où le mercure est utilisé (totalement ou partiellement)		3	0	3
	Pourcentage de sites où le mercure est utilisé (totalement ou partiellement)		100%	0%	75%
	Nombre de sites où l'amalgamation du minerai brut est pratiquée (totalement ou partiellement)		0	0	0
	Pourcentage de sites où l'amalgamation du minerai brut est pratiquée (tous les sites avec les enquêtes détaillées)		0%	0%	0%
	Nombre de sites où les retors / hotte à fumée sont régulièrement utiliés pour la production d'or spongieux (totalement ou partiellement)		0	0	0

Site **1. Sites étudiés**	**Type de site**		**Roche dure**	**Alluvion**	**Total**
	Nombre de sites où les retors / hotte à fumée sont régulièrement utiliés pour la production d'or doré (totalement ou partiellement)		0	0	0
	Pourcentage de sites où les retors / hotte à fumée sont régulièrement utiliés (totalement ou partiellement)		0%	0%	0%
	Nombre de sites où le mercure est récupéré des boues et autres déchets		0	0	0
	Nombre de sites avec estimation de la production basée sur l'extraction d'or		0	0	0
	Nombre de sites avec estimation de la production basée sur le revenu		0	0	0
	Nombre de sites avec d'autres méthodes d'estimation de la production d'or		0	0	0
	Nombre de sites avec des informations sur le nombre de puits		3	1	4
	Moyenne du nombre de puits par site (pour les sites avec des données sur les puits)		71	40	63
	Production d'or moyenne par puits (pour sites avec des données sur les puits), kg/an		11	0.7	12.4
	Consommation moyenne de mercure par puits (pour sites avec données sur les puits), kg/an		5.0	0.0	3.7
- par mineur	Production moyenne d'or par mineur, g/an		286	78	260
	Production moyenne d'or produit avec du mercure par mineur, g/an		286	0	264
	Consommation moyenne de mercure par mineur, g/an (incl mineurs n'utilisant pas de mercure)		394	0	346
	Moyenne du nombre de mineur par site		881	370	753
	Revenu annuel moyen par mineur, /an		-	-	-
	Nombre de sites où les données sur les revenus sont disponibles		0	0	0
- Genre et Âge	Pourcentage de femmes parmi les mineurs (du nombre total de mineurs)		-	-	-
	Pourcentage d'enfants parmi (du nombre total de mineurs)		-	-	-

3.5 Initial national baseline estimates of mercury use in ASGM

Establishing a national baseline based on investigation of four sites is not possible, but the following illustrates the use of available data to be used for establishing a baseline by using the "National summary" sheet of the reporting system. Likely, more than half the ASGM sites would have to be investigated to arrive at better estimates than those provided below.

Basic national data for baseline estimates

Total number of sites - Based on an inventory undertaken as part of the PASMI project, and later updated, Fall et al. (2015) lists 95 named sites (“dioura”) in 74 villages. The sites are divided among different mining sectors. For each site, the type of mining activities is indicated. The inventory distinguishes between four types and combinations of these:

- Placer deposits: Alluvial and elluvial ("Alluvionnaire" and "Eluvionnaire"
- Hard rock formation ("Filons" and "Primaire")

According to the list of sites (Fall, 2015) the number of the different types is as follows:

- Placer deposits (in the Excel spreadsheet indicated as "alluvial"): 69
- Hard rock: 8
- Mixture of hard rock and alluvial: 18

The list does not indicate the number of miners; furthermore, the distribution between the different types does not necessarily indicate the distribution in terms of number of miners. Many of the placer deposits in particular are relatively small.

Furthermore, the indication of mining type in this list is not identical to the indication used by Persaud (2015). As an example, the sites Sambrambougou and Douta are both indicated as primary hard rock mining by Persaud (2015), whereas the same sites are indicated as alluvial in the list provided in Fall (2015).

According to Persaud (2015), the majority of the sites were small and sparsely populated, and the greater part of the ASGM working population (approximately 68%) could be found on 7 major primary sites identified as Karakena, Diabougou, Sambrambougou, Tenkoto, Bantakho, Douta and Gondala.

The quality of data as regards number of sites is considered to be high, and the existing list may be used as a reference for a clear identification of sites. But the contradictory information indicates a high uncertainty as to the gold mining type applied at each site.

Total number of ASM miners (all types of artisanal and small-scale mining) - Data for the total number of ASM miners have not been identified.

Total number of ASGM miners (only gold ASM) - No recent detailed assessment of the number of ASGM miners in Senegal is available. According to the PASMI project (reported in 2009) approximately 30,000 to 60,000 persons were involved in ASGM activities at that time spread across several villages in Eastern Senegal (as cited by Niane et al., 2014). Sixty-one percent of the sector was believed to be composed of Senegalese, 28% Guinean, and 13% Malian (as cited by Persaud, 2015).

Persaud (2015) reach an estimate of the miner population of 34,000 - 99,000 (mean value 67,000). The total estimate for sites visited by Persaud is 23,300-29,650, indicated to account for 53% of the estimated miner population in Senegal. However, the 53% estimate is uncertain; this uncertainty leads to the wide range of 34,000 - 99,000 (although not specifically indicated). In the absence of any data on some small and medium sized mining sites, population factors were applied, where small mines were given a 225 person mean population factor and medium mines a 675 mean population factor. This illustrates the difficulties in estimating the total, even though a relatively certain estimate was available for a significant part of the population because some uncertainty will still exist as to the representation of the investigated sites.

The President of Kedougou's Regional Federation of Artisanal Miners estimates the total number of miners as being much lower: at around 10,000 miners with about 60% working full-time. The difference between this estimate and the estimates above may depend on the definition of "miners".

For a first estimate it is assumed that the miner population is distributed as follows: 65% involved in hard rock mining, 20% alluvial and 15% a mixture of the two.

Total gold production from ASGM - According to the data from USGS Minerals Yearbook from 2013, the total production of gold in industrial gold mines in Senegal increased from 4.4 tonnes in 2010 to 6.7 tonnes in 2013. During this period, the reported export of gold was on average about 3 t/y higher than the reported industrial gold production. To this should be added gold from ASGM illegally exported to neighboring countries.

According to Fall (2015), quoting UNIDO, the annual production of gold by ASGM in 2014 was around 2.5 t/y and is expected to reach 4 t/year.

Persaud (2015) estimates, considering their own results and previous studies, the total gold production at 4,5 tonnes with an uncertainty of +/- 49%, in the range of 2.3 - 6.7 t/year. For the estimates here, this range is applied and expected to be distributed between mining types using the same distribution as the number of miners. The quality of the estimate is defined as level 2.

Total mercury-based gold production from ASGM (based on national statistics or similar if available) - No data indicating the share of the gold production produced by mercury-free methods have been identified. According to a recent, unpublished study, around two thirds of the 20 sites investigated used mercury. In one third of sites where mercury was used, only a few miners used mercury, and in the remaining two thirds, most of the miners used it (Baptiste Coué, personal communication).

The president of Kedougou's Regional Federation of Artisanal Miners estimated that 85% of the gold extracted is separated using mercury.

Mercury-free methods are mainly used at alluvial sites. For the national estimate, Persaud (2015) assumed that 50% of the gold at alluvial sites is produced without mercury. This assumption will be used here as a best estimate; it is further assumed that 25% of the gold at mixed sites is produced without mercury. This results in an estimate of 86% of gold being produced using mercury.

Compound mercury to gold ratio - All available information indicates that only amalgamation from concentrate is used in Senegal, but it cannot be ruled out that whole ore amalgamation takes place at some sites. Physical measurements carried out on three different hard rock mining sites by Persaud (2015) gave ratios ranging between 1:1 and 1.6:1 with an average of 1.3:1. The ratio of 1.3:1 is indicated as typical for hard rock mining in Western Africa where amalgamation from concentrate is applied.

For alluvial sites (in this case colluvial), a ratio of 0.65:1 was applied to reflect gold nugget processing which requires no mercury to be used, but as emphasized by the author, this reduction was applied based solely on the author's observations and through information derived from anecdotal evidence by colluvial miners.

The compound mercury to gold ratio of the four sites investigated in this survey was 1.3 (three sites using mercury and one not).

Net import of mercury - The net import of mercury has been 0 tonnes in recent years and cannot be used for estimating the consumption of mercury for ASGM.

Consumption of mercury, estimate from official statistics and informal sources, t/year (expert estimate) - No estimate of mercury consumption is available from official statistics. Persaud (2015) estimates total mercury consumption in 2015 at 2.6-7.7 t/year (mean 5.2 t/year) on the basis described above**.**

Gold production per miner - The annual gold production per miner varies between sites. In the investigation of eight sites by Persaud (2015), the estimated annual production varied between 19 and 148 g/miner/year. The 90 % confidence level based on the dataset can be estimated at 25-110 g/miner/year. The average for all investigated sites was 54 g/miner/year, whereas an average of 67 g/miner/year was obtained from the estimated total national miner population and ASGM gold production.

The president of Kedougou's Regional Federation of Artisanal Miners estimates that miners can typically produce around 100 g/miner/year. Some miners can obtain 1 kg/year, but this is unusual.

In the current survey, the estimated annual gold production per miner ranged from 36 g/miner/year in Bantako to 533 g/miner/year in Tomboronkoto**.** This range clearly demonstrates the difficulties in estimating miner populations and gold production at the sites and the need for further training and investigation of the most appropriate methods to determine the parameters and avoid bias in the data. The production data may in fact be correct for the days the sites were visited; however, they may not accurately reflect the average annual production.

With a higher number of investigated sites, the uncertainties reflecting fluctuations in number of miners and production, however, would be reduced in terms of the totals for the investigated sites.

Extrapolation on the basis of sample sites results

With four sample sites representing about 5% of the total population, and only extraction based gold production estimates, the database remains too limited for meaningful extrapolation to the national level. In principle, the data of Persaud (2015) for 8 sites may be inserted into the database, thus providing an improved statistical basis for estimates.

However, the Excel sheet reporting system illustrates how the extrapolation is done and is ready for further extrapolation as more data arrives.

Triangulation and discussion

So far the data from sample sites have been too limited for triangulation at national level and the estimates from Persaud (2015), as that study represents a significantly higher percentage of the total miner population of Senegal than this survey.

4 Tanzania

4.1 The ASGM sector in Tanzania

Organization of the sector

The vast majority of Artisanal and Small-Scale Gold Mining (ASGM) establishments in Tanzania adopt an organizational structure consisting of claim holders, pit owners, mine workers, transporters, ore processing teams, brokers and service providers. Claim title holders are proprietors who acquire Primary Mining Licenses (PMLs), which entitle them to operationalize mining sites. Claim owners typically sub-contract mining work to pit owners and visit the claims periodically to keep track of developments, though spending more time on site during periods of high production. Pit owners engage in the day-to-day operations, overseeing primary activities such as ore processing and the provision of supplies. Pit owners employ a multitude of mineworkers, including mine inspectors, drillers, blasters, ore hoisting teams, ore processing teams and security guards. Ore processing teams labor in a range of operations, from crushing and sluicing, to amalgamation and the burning of amalgam. These teams are paid by unit or on a daily basis, payments often being commensurate with processed quantities. Other actors include gold brokers – many of whom operate informally as a result of being uninterested or unable to afford the requisite license – as well as miscellaneous service providers such as food vendors, shop keepers, technicians and vehicle drivers.

Number of mining sites and geographical distribution

ASGM activities in Tanzania are concentrated around the Lake Victoria gold fields (in the regions of Mara, Simiyu, Mwanza, Geita, Kagera, Shinyanga, Tabora and Singida) and southwards to Katavi and Mbeya regions. However, there are smaller operations taking place in most of the country's regions including Arusha, Tanga, Morogoro, Njombe, and Ruvuma. Figure 4.1 provides an overview (though incomplete) of ASM sites in Tanzania.

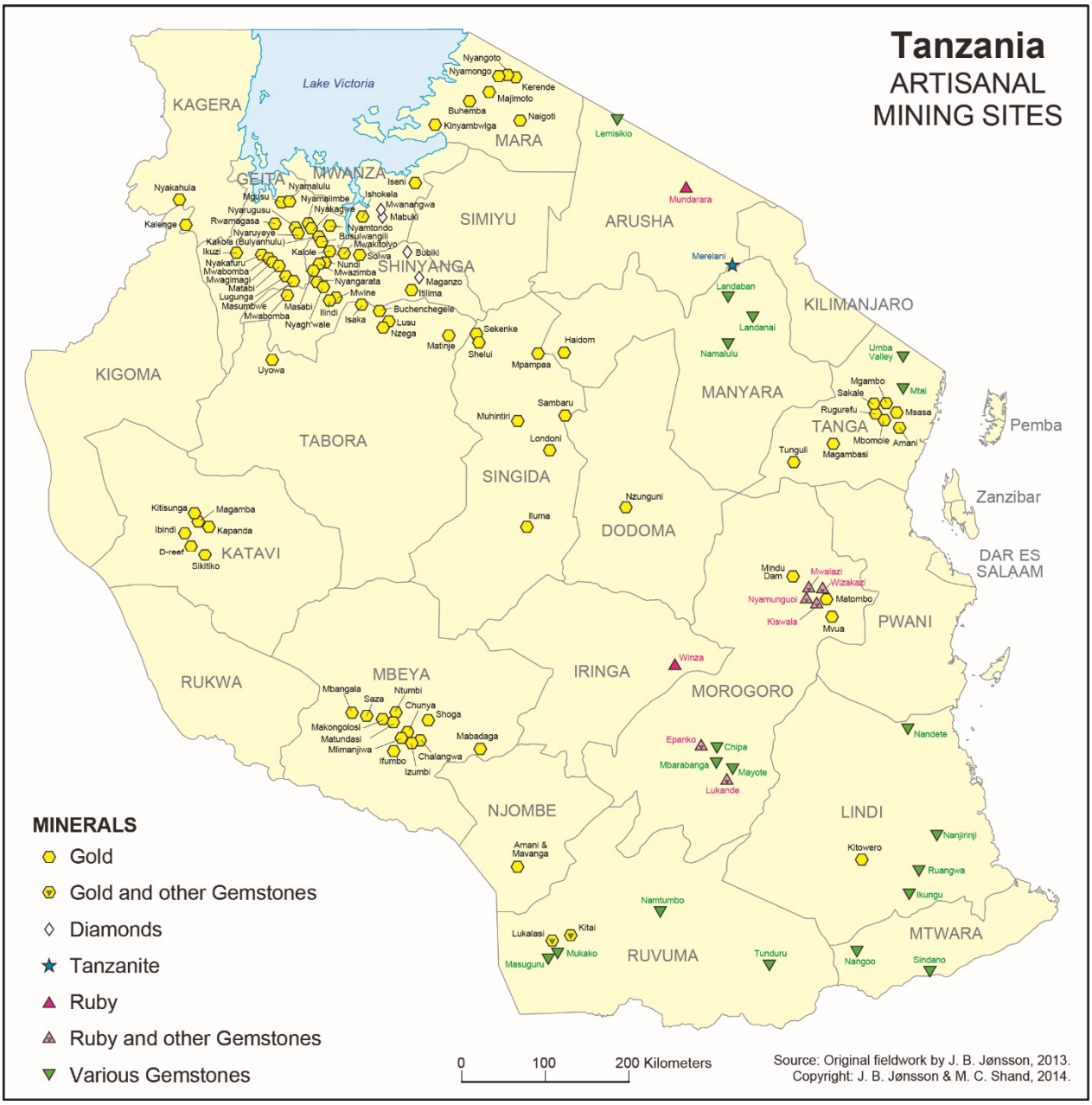

Figure 4.1 Overview of ASGM sites in Tanzania.

ASM and ASGM population

According to a recent baseline study by Tanzania's Ministry of Energy and Minerals, ASGM accounts for over 50% of the population of the country's diversified ASGM sector of about 680,000 (MTL, draft). By 2011, a total of 396,310 artisanal and small-scale gold miners were enumerated, of whom 293,362 were male and 102,948 were female.

Applied extraction methods

Although there have been initiatives to reduce the usage of mercury in ASGM, especially the Global Mercury Project around 2006-08, a limited number of people use retorts or other mercury-reducing methods and mercury is still widely used and available throughout Tanzania's ASGM sites. The dominant extraction method is through concentration, with whole ore amalgamation being either rare or non-existent. During the last ten years, between 100 and 200 cyanidation leaching plants have been established throughout

Tanzania's ASGM sites. While these pose an environmental and health threat if not managed properly, they are likely to have reduced the usage of mercury in certain areas.

Legislation

The Industrial and Consumer Chemicals (Management & Control) Act No. 3 of 2003 through the Government Chemist Laboratory Agency (GCLA) regulates the production, importation, exportation, transportation, storage and dealing of mercury and other chemicals in Tanzania. As per Section 9 of the Act, the Chief Government Chemist is the Registrar of Industrial and Consumer Chemical in Mainland Tanzania. In order to ensure control of production, importation, exportation, transportation, storage and dealing of mercury or any other chemical, an application for registration of chemicals needs to be made to the Chief Government Chemist in the prescribed manner and form and accompanied by prescribed fees as set out in the Act. The registration procedures are clearly set out in Section 11 to 29 of the Act. After an application is submitted, the Registrar will conduct necessary investigation before approval by the board of the GCLA. As such, every chemical (including mercury) which is imported, distributed, manufactured, transported, sold, or stored shall bear on its container a label with words, amongst others, "Approved by the board", Chemical Abstracts Service (CAS) and registration number, batch number and dates of manufacture, expiry, trade and chemical name, etc. The registration period for a chemical shall be five years with two years for provisional registration. The Mining Act of 2010 allows for the use of mercury subject to the use of retort when burning amalgams.

National mercury inventory

An inventory of mercury releases in Tanzania was developed in 2012 using the UNEP Toolkit, Level 1 (Vice Presidents Office, 2012). The report does not present mercury trade data, but estimates the potential releases of mercury using default input and output distributions factors and national activity rates. According to the inventory, mercury was not used in the country in industrial processes or for industrial production of mercury-added products. The total use of mercury for ASGM was estimated at 1,056 kg based on gold production by ASGM of 528 kg. Total mercury content of consumed thermometers was estimated at 61 g, whereas mercury content of dental amalgams and other mercury-added product was not estimated.

4.2 Trade statistics of mercury, mercury-added products and gold

Data on mercury import to Tanzania and export to Tanzania reported by partner countries from the UN Comtrade database are shown below. There is no reported export. The import data indicates highly diversified trade in import of mercury from numerous countries. Some import from EU countries is reported for 2013 and 2014 in spite of the EU export ban. The same countries have not reported export to Tanzania; Switzerland is the only country recording significant mercury export to Tanzania.

The recorded import is well below the estimated consumption of mercury for ASGM of 31.5-58.5 t/year, indicating significant informal import of mercury.

Table 4.1 Import of mercury to Tanzania by country in kg 2010-2015 (Comtrade database)

	2010	2011	2012	2013	2014	2015
Australia		3				
Brazil			1,190			
China					7,382	
China, Hong			981		1,035	

	2010	2011	2012	2013	2014	2015
Kong SAR						
Germany		1,289		1,128	1,163	
India					600	2
Japan				902		
Mexico				1,190		
Netherlands					4,200	
Singapore				1,117		
South Africa		20				
Switzerland						1,201
USA				7		
Total		1,312	2,171	4,344	14,380	1,203

Table 4.2 Export of mercury in kg to Tanzania by country 2010-2015 (Comtrade database)

	2010	2011	2012	2013	2014	2015
India		1			276	208
Kenya	448					
Netherlands				50		
South Africa		5	126		11	
Switzerland					2,070	
Total	448	6	126	50	2,357	208

Statistics on gold production and trade

According to data from USGS Minerals Yearbook from 2014, the total industrial production of gold increased from 39 to 43 t/year in the period 2010-2013. Gold production by ASGM is not reported. No statistics on gold production by ASGM have been identified.

The registered export of gold from Tanzania varied considerably during the period 2010-2015 with an average of 240 t/year during the period. For all the years, some of the data appears flawed as the values of the exports are out of range. Consequently the data cannot be considered reliable. Data as reported by importing countries are added to the table. The main export countries were United Arabic Emirates, South Africa, Switzerland and India.

Table 4.3 Production of gold 2010-2013 in Tanzania (USGS, 2014)

	Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year
	2010	2011	2012	2013		
Tanzania	39,448	42,300	40,650	43,390	no	not assessed

Table 4.4 Net export of gold (Commodity code 7108) 2010-2015 from Tanzania (Comtrade database)

	Net export, kg/year

	2010	2011	2012	2013	2014	2015
As reported by Tanzania	318,423	41,081	317,255	139,694	279,988	347,773
As reported by import countries	15,909	20,783	44,415	45,224	40,951*	25,109

* Import to India corrected as the quantity was a factor of 100 too high.

4.3 Informal information on mercury use and trade flows

Trade of mercury

The usage of mercury in artisanal and small-scale gold mining has been the subject of extensive literature, albeit its trade across Sub-Saharan Africa is scantly documented. While official trade statistics indicate a steady level of mercury importation, informal in-country trade flows are gaining increased attention, having been reported off-the-record among recipient actors on the ground. With the exception of Kenya, all of the export countries for which importation into Tanzania has been recorded are non-African, the major exporters being China and The Netherlands. Given that non-extractive consumption accounts for the majority of the inventoried imports, the stable availability of mercury within the local ASGM sector is suggestive of a prevailing informal market. Hinging on multiple cross-border channels, the informal trade of mercury within the sector is extensive and complex, with intricate supply networks serving ASGM sites around the country, as shown by the findings presented below.

Informal trade routes

A study was carried out locally with a view to elucidating, as precisely as feasible, the origin and routes of informal mercury trade in Tanzania. This study was based on semi-structured interviews with stakeholders and on participatory investigations in active ASGM sites within the goldfields of Geita and Chunya districts.

A series of semi-structured interviews was also convened with experts from the institutions involved in the national ASGM sector. Premising on their research in the districts of Chunya and Tarime, two representatives from the National Institute for Medical Research (NIMH) believe that a large proportion of mercury used in ASGM originates from Nairobi, and that it is supplied by local gold-brokers to operators, often on credit, with the dues settled upon the subsequent sale of gold by the loan recipients. In another consultation, the Principal Environmental Scientist of Tanzania Minerals Audit Agency (TMAA) cited anecdotes from Chunya District which allege that the trade is dominated by Dar es Salaam-based goldsmiths, who afford mercury to ASGM operators as part of their purchase arrangements with the gold sellers. He stated that only a few grams of mercury are typically sighted during audits, recalling only one incident when a 1-kg mercury bottle was found. When inquired about his knowledge of the source countries for the local market, he alluded to anomalous accounts of mercury inflows from Algeria. A number of officials from the Government Chemist Laboratory Agency and the Tanzania Bureau of Standards were also interviewed as these institutions, aside from the Ministry of Energy and Minerals and TMAA, comprise the country's de facto regulatory framework for mercury. On this end, however, very little has been established regarding informal trading channels for mercury, though the authorities expressed interest in the matter, in view of the regulatory instruments being enacted.

The managing director of MTL Consulting asserted that the ASGM sector sources mercury informally from the bordering countries of Kenya and Zimbabwe, as well as from the DRC whereby stocks are trafficked into the country to the mining and trading town of Katoro in Geita Region. In addition, he posited that the

Port of Dar es Salaam represents a key entry-point for smuggled mercury, upon which local goldsmiths and, to a lesser extent, pharmaceutical operators are especially reliant. One program officer from AGENDA, a local NGO, stated that mercury is smuggled into Tanzania chiefly from Zimbabwe and Kenya, with inflows from the former supplying the northern regions of the country and those from the latter providing for the southern reaches. As averred by this informant, Zambia is a transit country for the bulk of mercury sourced from Zimbabwe, with supplies smuggled across the town of Tunduma where border checkpoints are less thorough; forested hideaway routes represent another ingress for the smuggled mercury.

Curechem, a private company specialized in the supply of mining chemicals to clientele across Sub-Saharan Africa and Asia, was approached for further inputs in view of its involvement with ASGM in Tanzania. According to the company's sales manager, Curechem abolished its mercury supply operations in 2014 in Zimbabwe and has never sold mercury in Tanzania. The manager was aware of one Zimbabwean national, who had travelled around Tanzania selling large quantities of mercury to middlemen and ASGM operators. He also affirmed that both mercury and cyanide are smuggled across the borders between Zimbabwe and Tanzania, through either Malawi or Zambia, by means of buses and other vehicles. The manager further pointed out that mercury middlemen are concentrated in mining towns around the gold fields, examples of which include the townships of Katoro, Kahama and Geita. One shop-owner at the main market in Kariakoo, Dar es Salaam, gave an account of his sale of mercury to Mozambican businesspersons, who supply the commodity to ASGM areas in northern Mozambique.

A number of investigations were undertaken in several active ASGM sites and goldsmith shops situated within the district of Geita in Geita Region. The Acting Assistant Commissioner for the Lake Zone and the Acting Resident Mines Officer in Geita District both identified Nairobi as the principal source of mercury for the local ASGM sector, and local gold-buyers as the major distributors of the resource. The former chairman of the Mgusu Miners Cooperative Society revealed that mercury used at the site is sourced mostly from local gold brokers. According to the chairman, although little is known about its primary source, mercury is readily available in Geita and is believed to originate from Nairobi, mainly via the Sirari border. The site manager of the Blue Reef Mining Site in Rwamagasa Village was fairly certain that Nairobi, being a prominent transit point for mercury, is a major source of mercury in the area. In addition, he affirmed that a parallel supply chain routes through Dar es Salaam. "In reality, mercury is readily provided by local distributors, thus users at the mining level have little interest in supply segments beyond immediate links and are seldom knowledgeable about sources outside their localities", he emphasized, adding that gold buyers purchase mercury from local dealers who are primarily employed in this business. Further to these acknowledgements, the mine inspector of the Rwamagasa Gold Mining Savings and Credit Cooperative Society attested to the influx of mercury supplies from Nairobi, noting that other sources have been reported in other regions including Mbeya, where there are anecdotal accounts of mercury inflows coming from Malawi and Zambia (likely to come from South Africa, via Zimbabwe). According to the inspector, mercury is traded somewhat openly in the village of Rwamagasa. Another ASGM operator based in Geita District alleged that mercury sold for ASGM in regions around Lake Victoria is brought in from Nairobi, packaged in 34.5 kg canisters. He stated that such importations are often run by specialized distributors who purchase it from goldsmith shops in the Kenyan capital.

The site manager of Sangano Mining Site of Mawemeru Village alleged that mercury sold in the area is imported from Nairobi, maintaining that while ASGM is relatively limited in Kenya, Nairobi has become a hub of mercury trade in East Africa, as it is probably regarded a conducive business center (by foreign suppliers) for the regional market. In recollection of his own procurement follow-ups, the Site Director reiterated that local supplies (distributed in 34.5kg canisters) stream mainly from Nairobi, although it is known that some brokers order mercury from Dar es Salaam. The informants were of the opinion that mercury trade in Geita district is generally covert and that it is practiced under-the-counter in goldsmith shops where mercury containers are stored on a restrictive basis rather than conventionally shelved.

The Secretary of the Geita Women Miners Association (GWOMA) based in Nyarugusu confirmed that mercury used in Nyarugusu is sourced mainly from Nairobi, highlighting that it is locally distributed by middlemen whose network is quite established, with well-connected dealers becoming inter-dependent in times of short supply. She maintained that the commodity is smuggled from Kenya across the border town of Sirari, where mercury containers are loaded onto bicycles and motorbikes, which are exempt from rigorous border-checkpoint inspections. "Back in 2014, I travelled to Nairobi where I was able to purchase 5 kilos of mercury from a supermarket, where mercury was sold in plastic bottles at a price of around TZS 50,000 per kilo". She further narrated, "I sold all of the stock to local ASG miners at a final price of TZS 200,000 per kilogram".

Several gold brokers in Geita, known to sell mercury to ASGM operators, were elicited as to the source of their supplies. One local jeweler disclosed "Supposedly sourcing from Kenya, middlemen purchase mercury in full 34.5-kg-capacity canisters costing about TZS 7,000,000, which we buy and re-sell to miners in plastic, 2-kg-capacity bottles at an average price of roughly TZS 250,000 per kilo". He elaborated that mercury is not used by goldsmiths at the workshop, but is purchased, stocked in a cache, and sold off to local ASGM operators. In another engagement, a broker based in Nyarugusu displayed a plastic bottle containing 500 grams of mercury, which he had purchased for TZS 100,000 at a jewelry store in Geita. He indicated that the mercury is brought from Kenya and that it is readily available in most jewelry stores in Geita Town.

Figure 4.2 *Mercury canisters (34.5 kg capacity) displayed at a gold broker's workshop in Geita (Left) and bottle that typically is sold containing 1 kg of mercury (right). Photo: COWI*

One small-scale miner recounted his employment in ASGM activities during the period 2009 to 2015 in the gold mining sites of Kakola, Ikuzi, Nyakagwe, Nyarugusu, Nyakarata, Kakola, Mwazimba, Rwamgasa, Nyamahuna, Buziba and Matabe. Alongside his partner, he launched a mercury selling business in 2011, with a capital injection totaling TZS 3,000,000 at which time the commodity cost TZS 380,000/kg. His partner was responsible for purchasing mercury from upstream suppliers in Mwanza City, and transporting it to Kakola Town, which was the center of mercury distribution to all surrounding ASGM sites. These suppliers stipulated a minimum purchase of one kg at a time, such that the mercury was packaged into medical containers and weighed at the point of sale. He stressed that the mercury dealers do not sell mercury to unfamiliar buyers. "To be able to buy from them, you would have to be physically introduced to the dealers by an insider, and they should be convinced that you are a genuine buyer from a gold processing facility in a known site," he explained.

He revealed that the mercury chain courses through Nairobi, wherefrom it enters the country through the border town of Sirari, before being transported to Mwanza and ultimately to Kakola. The dealers are aware that mercury is channeled through Kenya but have no information on the supply stream(s) feeding into the Kenyan value chain. He sold his mercury mostly in the villages of Nyakagwe, Nyakarata and Nyarugusu where the demand was high due to both the extent of the gold mining processes and the size of the mining sites. He was also able to sell in other areas, particularly in gold rush sites where high profit margins

were attainable on account of continual supply shortages. By the year 2013, there were only four mercury dealers in Kakola, who were well-connected with other dealers located in Kahama, Katoro and Geita. "This business, being illicit, is conducted in a highly secretive manner such that an outsider could spot mercury only in gold processing sites," he shared, adding, "It is also sensitive in that it can be stolen by miners and resold with good profit given the high demand in ASG mining areas". He identified the challenges of the business as the availability of the resource, transportation to the site as well as security, considering the constant police surveillance. Another challenge is quality, as boiled mercury sold by some suppliers is less functional. Of lesser challenge is the need to carry out accurate measurements during retail sales, as continuous mismeasurements are bound to result in considerable loss. He withdrew from the business when his partner was arrested following a purchase of fake mercury from police-assigned dealers in Mwanza. He now plans to restart the business on a diversified basis, that is, selling mercury, being a gold broker and leasing out gold-processing equipment (such as crushers and ball mills) concurrently, as this seems to work well for other dealers. He remarked that in cases where gold-sellers cannot afford mercury, it can be provided in exchange for gold.

A round of interviews was also held with ASG operators and brokers in the goldfields of Mbeya region. One miner in Itumbi Village, a former Ward Councilor, told of how he used to sell gold to a large goldsmith in the city centre of Dar es Salaam. He would supply them with gold and they would provide him with up to 5kg of mercury in return. "Brokers distributing mercury in Itumbi source it from upstream suppliers, who in most cases, are dealers of Asian-origin based in Dar es Salaam," he mentioned. The miner, though uninformed about suppliers furnishing the dealers in Dar es Salaam, disclosed that he buys mercury from a company that imports mining chemicals including cyanide and mercury. A mine chemicals trader based in Chunya stated that he imports a number of products from Korea, China and India. Although he denied any involvement in the distribution of mercury, he acknowledged that this business is quite lucrative in the area, remarking "I know of dealers who buy mercury at TZS 70,000 per kilo and sell it locally for TZS 300,000 per kilo to brokers and ASG miners". Contrary to his claims, however, several miners admitted to purchasing mercury from his outlet.

A gold broker interviewed in Itumbi divulged that mercury sold in the area is smuggled from Zimbabwe, through Zambia, and into Tanzania across the border town of Tunduma. He described Itumbi's mercury middlemen as young men who frequent the locality, carrying packages in backpacks. In further reference to the local market, he recalled a supply shortage in 2010, when the price of one bottle cap surged to TZS 75,000. Another broker in the area asserted that he does not deal in the sale of mercury, but gave an interesting account of an established supply chain sourcing directly from China. "One of the workers at a medium-scale Chinese-run mine sells mercury to local brokers and ASG miners, and it is known that Chinese operators at the site import the commodity from China on a direct basis," he alleged. From the account of one mine equipment seller in Chunya, mercury in the area is smuggled in from Zimbabwe across Tunduma border post, mostly by Zimbabwean traders who are part of an extensive supply network. Another interviewed gold broker, who has operated in Matundasi Village for over fourteen years, shared that he purchases mercury locally from suppliers who visit the area. With convenient access to 60g packages of mercury (full water-bottle caps) at a price of TZS 30,000, he rarely seeks supplies in Chunya Town.

According to a PML owner in Chunya District, mercury is readily available in retail shops in Zimbabwe, where he was able to buy and bring home 6 kg sometime in the past. Quoting his own experience, he accounted this being the case for other well-off miners in the area, who venture out to Zimbabwe to dispatch various mining-related issues and purchase of mercury in such outlets. Another informant based in Chunya district further divulged that suppliers, allegedly from Zambia and Malawi, but more likely to be Zimbabwean, furnish mercury to local shops where the commodity is sold off under-the-counter to small-scale gold brokers and ASGM operators. Two brothers in the area, who have been working as brokers for over a decade, speculate that Zimbabwean traders bring mercury into Chunya town, which they deem to be evidenced by the relatively high population of Zimbabwean residents in the area. "These purveyors can be

seen transacting with local brokers, with mercury bottles pocketed in their coats," one of the brothers shared. They explained that Zimbabwean dealers were initially based in Mwanza, where they supplied mercury to a multitude of processing sites, but later extended their network to Chunya. According to the brokers, mercury is currently priced at TZS 200,000/kg on account of the stable supply streams secured by Zimbabwean dealers in the area. Five to six years ago, the local price of mercury soared to TZS 1,000,000/kg as a result of a prolonged supply shortage. Prior to Zimbabwean traders dominating the local mercury market, the resource streamed from South Africa through Tunduma Town. Indian dealers based in Dar es Salaam networked with their associates in South Africa to channel mercury into Tanzania through the border town. The dealers would provide mercury to local brokers in exchange for gold, which they would later sell off in Dubai. Upon the sale of 34.5kg mercury canisters in Dar es Salaam, the dealers would issue brokers with a copy of a document certifying import from South Africa, which they were to present to the police in the event of an inspection along their journey. In a final remark, the brothers stated that the Indian dealers have been out-competed by the Zimbabwean purveyors who offer much more affordable supplies.

Another interviewed broker in Chunya holds that locally traded mercury comes from China and Zimbabwe. "A Chinese dealer, previously employed in a Chinese mining company which closed down a few years ago, is known for selling mercury in the town," he claimed. The informant denied any dealings in mercury supply, but acknowledged the employment of the resource in his mining operations. During the interview, however, a gold broker who had been approached a day before visited the premises to purify some gold and was seen leaving with what appeared to be a mercury-filled container wrapped in a black plastic bag. Following the meeting, a local miner situated nearby confirmed that the broker in fact sells mercury, sometimes in rectangular containers such as that which was sighted in the course of the interview.

In order to better understand the mercury source referred to by numerous informants, the Consultant went to Nairobi Kenya to inquire to identify mercury outlets in Dar es Salaam Street (Nairobi), which was referenced in a detailed account from an informant in Geita. The search proved unsuccessful, until support was sought from a local contact who visited a number of shops. In three of these, mercury was found to be sold at a price of KES 3,500/kg (USD 35). This experience indicates the difficulties of mapping the mercury flows from key urban suppliers without an introduction by trusted dealers with whom the sellers are familiar.

Drawing from the information provided by the different groups of informants, it can be deduced that local mercury supply chains in Tanzania rest on three major transboundary trade routes. The trading channel from Kenya dominates supply into the country's northern goldfields, having been consistently cited by key informants in the region of Geita. Local agents purchase bulk, low-cost supplies in Nairobi and smuggle these into the country, mainly through the border town of Sirari (though the Namanga border was also mentioned), for sale into the multitude of mining and trading towns and ASGM sites in the northern regions. Contrastingly, mercury inflows from Zimbabwe, routed chiefly through the Tunduma border post, provide for the goldfields in the country's southern reaches. This trade course partly comprises Zimbabwean traders who operate locally. The city of Dar es Salaam represents another key source for the country's informal mercury trade flows, into which mercury enters, most likely, via the Port of Dar es Salaam. This supply point is regarded as feeding into the rest of the trading networks.

Actors in the mercury value chain

The actors in the country's mercury supply chain can be grouped as follows:

- Bulk traders – who sell smuggled mercury to large-scale gold buyers (in bulk quantities) who sell it further downstream on the gold-buying chain;

- Gold buyers – who provide mercury to ASGM miners under different arrangements i.e. on credit, in exchange for gold, subsidized or free of charge; Indian goldsmiths in Dar es Salaam sell mercury to smaller gold-brokers and middlemen who distribute the commodity in ASGM sites.

- Middlemen – with localized operations, these specialized dealers sell mercury to miners in ASGM areas;

- Chinese traders – who are alleged to sell mercury in ASGM sites, which is believed to be sourced directly from China.

Quantities and prices

The market price of mercury in Tanzania ranges from TZS 200,000 (USD 92) to 300,000 (USD 137.4) per kg. Shortage-driven prices as high as TZS 1,000,000 (USD 459) per kg have been reported for the town of Chunya around the period 2010-11. Along the domestic supply chain, mercury is imported in either 1 or 2 kg bottles or 34.5 kg canisters and refilled into smaller bottles depending on the market. Below this level of supply, bottled portions are measured into soda bottle caps (using 5 mm^3 syringes), which are priced at TZS 30,000 (USD 14).

Other sources of mercury

With reference to accounts by experts consulted from the NIMH, TMAA and AGENDA, medical centers, including hospitals and laboratories, are likely to feed into the informal mercury supply chain. It is believed that medical personnel engage in the malpractice of deliberately damaging mercury-containing equipment in order to access mercury for clandestine sale to users in ASGM. These speculations are substantiated by inputs provided by some respondents interviewed in Geita. One ASGM operator divulged that staff at the major hospitals in the regions around Lake Victoria take part in the illicit sale of mercury. In line with these claims, a statement from a gold broker based in one gold mining district alleges that district medical doctors sell out mercury in soda bottle caps. In addition, another informant disclosed that Nairobi Enterprise Ltd, a large supplier of medical equipment, deals in the formal sale of mercury, at relatively high prices.

Of other sources or routes, only mentioned by one informant, a senior geology lecturer at the University of Dar es Salaam narrated that, formerly, mercury was smuggled through Tanzania's borders with Burundi and Rwanda due to border-control disruptions that arose in the course of prolonged civil unrests in these states. By his account, a sizeable fraction of informally imported mercury streams from the DRC, as Congolese traders have been reported to smuggle mercury into the country and return with loads of food, amongst other purchases.

4.4 Results of ASGM sample sites investigations

Site investigations took place from 28-20 June 2016 in the Geita area with the participation of one international expert, one local expert and three trainees. The following sites were investigated:

Site	location	Coordinates	Key characteristics
Mgusu Miners Cooperative Society Ltd. including the whole site of Mgusu	Mgusu Mtaa, Geita District	UTM 9685260 36M 0395733	An ASGM sites with numerous pits. Ore processed predominantly through ball mills and concentrated through sluices with heavy-duty sacks, amalgamation, and burning. Mercury used for concentrate amalgamation.
Blue Reef Mining Site	Rwamagasa Village, Geita District	UTM 9655253 36M 0394538	One of many Primary Mining Licenses (PMLs) in the village of Rwamagasa. The PML has a cyanidation plant and claim that mercury is not used, though observers questioned this.

Rwamagasa Gold Mining Savings and Credit Cooperative Society	Rwamagasa Village, Geita District	UTM 9655101 36M 0394848	One of many PMLs in the village of Rwamagasa. The PML is owned by a society with several members. Ore is processed in ball mills, concentrated, amalgamated and burned in the open
Sangano Mine	Mawemeru Village, Geita District	UTM 9656699 36M 0413481	One of the PMLs in and around Mawemeru village. Ore is processed in ball mils, concentrated in sluices, amalgamated and burned in the open
Nyambale Gold Mine	Nyarugusu Village, Geita District	UTM 9652236 36M 0414852	A small-scale mine in the village of Nyarugusu. Ore is processed in ball mills, concentrated in sluices, amalgamated and burned in the open
Nyarugusu Village	Nyarugusu Village, Geita District	UTM 9656236 36M 0414852	In the rest of the ASGM sites in Nyarugusu Village, ore is crushed in ball mills, concentrated in sluices, following which amalgam is burned (often openly). Tailings are sold off to a nearby leaching plant an locally manufactured retorts used at certain sites in the village
Mawemeru Village	Mawemeru Village, Geita District	UTM 9656699 36M 0413481	In the majority of the ASGM sites in Mawemeru Village, ore is crushed in ball mills and concentrated in sluices, after which amalgam is burned in the open

Data for each site are provided to the Ministry of Environment in the form of an Excel reporting system with the site data and national summaries and the site investigation forms.

The summary of the results is shown in the table below.

1. Investigated sites			**Hard rock**
- miners	Number of sites with information on population of miners and basic site information		5
	Number of sites with detailed site investigation (level 1-3)		5
	Number of miners (distribution mathematics)	Min	1,245
		Max	1,969
	Number of miners (simple sum)	Min	1,000
		Max	2,214
	Average number of miners per site		321
- gold production	Total gold production, kg/year (best estimate from each site)		199
	Total mercury-based gold production, kg/year (best estimate from each site)		199
	Percentage of gold production based on mercury amalgamation		100%
	Total gold production by whole ore amalgamation, kg/year		-
	Percentage of gold produced using whole ore amalgamation (of total mercury-based gold production)		0%
	Percentage of gold produced using whole ore amalgamation (of total gold production)		0%
	Total gold production by amalgamation from concentrate, kg/year		199
	Percentage of gold produced from concentrate (of total mercury-based)		100%
- mercury consumption	Total consumption of mercury (recycled mercury subtracted),		209
	Total consumption for whole ore amalgamation (recycled mercury is not subtracted)		-

	Total consumption for amalgamation from concentrate (recycled mercury is not subtracted)		250
- mercury recovery	Total quantity of mercury recovered from amalgams and sponge gold, kg/year		35
	Total recycling rate (% of total used for extraction) (excl. recovery from tailings)		14%
	Mercury recovered from tailings and other waste, kg/year		0
- mercury releases	Total releases of mercury to air, kg/year		164
	Total releases to water and land (incl. tailings)		45
- mercury to gold ratio	Compound mercury to gold ratio (average of all processes) (not accounting for recycling)		1.2
	Mercury to gold ratio, whole ore amalgamation		
	Mercury to gold ratio, amalgamation from concentrate		1.3
- site statistics	Number of sites where mercury is used (fully or partly)		5
	Percentage of sites where mercury is used (fully or partly)		100%
	Number of sites where whole ore amalgamation is applied (partly or fully)		0
	Percentage of sites where whole ore amalgamation is applied (all sites with detailed investigation)		0%
	Number of sites where retorts/fume hoods are regularly used for sponge gold production (fully or partly)		2
	Number of sites where retorts/fume hoods are regularly used for gold doré production (fully or partly)		1
	Percentage of sites with detailed site investigation where retorts/fume hoods are used (fully or party)		40%
	Number of sites where mercury is recovered from tailings and other waste		0
	Number of sites with extraction based gold estimate		5
	Number of sites with income based gold estimate		5
	Number of sites with alternative gold estimate		0
	Number of sites with information on number of shafts/pit		5
	Average number of shafts/pits per site (for sites with shaft data)		19
	Average gold production per shaft/pit (for sites with shaft/pit data), kg/year		10.5
	Average mercury consumption per shaft/pit (for sites with shaft/pit data), kg/year		3.9
- per miner	Average gold production per miner, g/year		124
	Average mercury-based gold production per miner, g/year		124
	Average mercury consumption per miner, g/year (incl. recycling and miners not using mercury)		130
	Average number of miners per site		321
	Average annual income per miner, TZS/year		2,613,566
	Number of sites where income data are available		5
- gender and age	Percentage women among miners (of total number of miners)		17%
	Percentage children among miners (of total number of miners)		0%

4.5 Initial national baseline estimates of mercury use in ASGM

Basic national data for baseline estimates

No full inventory of ASGM sites in Tanzania has been identified. The number of sites is probably in the range of 300-600 sites i.e. the sample sites represent about 1% of the total number of sites.

A draft baseline survey of ASGM activities in Tanzania estimates a total of 680,000 ASM miners in the country; of these, 391,000 are involved in ASGM (MTL, unpublished draft).

No data on the production of gold by ASGM in the country are available.

Extrapolation on the basis of sample sites results

If the total number of 350.000 - 430,000 is multiplied with the average gold production per miner of the sample sites at 124 g/y (taking recycling by use of retorts into account), the total gold production in the country by ASGM may be estimated at 43-53 tonnes. Using the average mercury consumption per miner of 130 g/year (taking mercury recycling into account), the total mercury consumption can be estimated at 45-56 tonnes per year (mean 50 t/year). With only 1% of the sites covered, the uncertainty on the average mercury consumption per miner would still be high and the actual ranges wider than indicated here.

The Global Mercury Assessment (AMAP/UNEP, 2013) estimates, on a limited data basis (indicated as an educated guess at the MercuryWatch database), the total consumption in 2009 at 31.5 - 58.5 t/year (mean: 45 t/year).

Both estimates are uncertain but are of the same magnitude. On this basis, the total mercury consumption in Tanzania for ASGM is estimated at 30 - 55 t/year.

5 Côte d'Ivoire

5.1 The ASGM sector in Côte d'Ivoire

Until 2002 little to no mercury was used by small scale gold miners in Côte d'Ivoire. However, when the country was split up during the rebellion in 2002, a massive influx of small-scale gold miners from neighboring countries, primarily Burkina Faso, was observed in the northern part of the country; these miners introduced amalgamation in gold extraction.

Number of mining sites and number of miner

No official data on the number of mining sites and number of miners have been identified. The artisanal Miners Association has been requested to provide information on the number of ASGM miners in the country. The association does not hold information on numbers of miners as the sector is still not well organized, but did inform the study that in just one cooperative, the number of workers is about 10,000. The Ministry of Mines also does not have any information on number of miners. According to answers from NGOs in Côte d'Ivoire to a survey undertaken for UNEP Chemicals by Fritz (2014a), the number of miners in 2014 was 30,000-50,000.

According to the Artisanal Miners Association, about 95% of workers in the sector come from foreign countries (Mali, Burkina Faso, Guinea, Ghana and China).

Applied extraction methods

According to the Artisanal Miners Association, the majority of the gold is mined from alluvial deposits. Mercury in ASGM is essentially applied in concentrate, whereas no use of whole ore amalgamation is reported. The mercury to gold ratio is reported to be typically 2:1, relatively high compared to other countries in the region. In accordance with this, studies from two sites, Hire and Kokoumbo, found mercury to gold ratios ranging from 1.7 to 2.3 (unpublished results).

It was reported by the Artisanal Miners Association that large amounts of mercury are used in ASGM, but no dependable figures for these quantities exist, since there is no control of artisanal miners.

In general, limited information on the ASGM sector in Côte d'Ivoire is available. UNIDO has recently been implementing some projects to assess working methods and use of mercury and other chemicals for ASGM, but the results are not yet published.

Formalization

Since 2013, the government through the Ministry of Mines has decided to remove artisanal miners from the sites they illegally occupy. The Artisanal Miners Union was created in 2013 based on the participation of cooperatives, associations and others groups. The creation of the Union was consecutive to the decision by government to remove all artisanal miners from the sites they occupied illegally because of the environmental, agricultural and health impacts of this activity.

On 31st March 2014, the government initiated a new program of artisanal mining rationalization. Under this program, artisanal mining is divided into two categories:

- The artisanal mines for which the license is delivered for a square, 25-hectare maximum piece of land and the shaft may not be sunk deeper than 15 meters.
- The semi industrial or medium size mine for which the license is delivered for a square, 100-hectare maximum piece of land and the shaft may not be sunk deeper than 30 meters.

For artisanal mines, no chemicals are allowed for use. Medium size mines are, however, allowed to use mercury or cyanide. But for that purpose, the company or the mine owner needs to present their management plan for destruction or treatment of wastes generated by chemicals use. This plan needs to be accepted both by ministries in charge of environment and in charge of mines. After the license is signed by the Ministry of Mines, the company is allowed to buy mercury or chemicals needed for its activities. The intention is that the government is aware of the chemicals sellers and will control and track the mercury used in medium size mines.

In 2016 the Ministry of Mines started issuing licenses for medium size mines. Ten licenses have been issued for gold medium size exploitation. No licenses for mercury trade to thee mines have been issued.

5.2 Trade statistics of mercury, mercury-added products and gold

Comtrade statistics on import/export of mercury

Data on import to Côte d'Ivoire from the UN Comtrade database is shown below. No import data are available for 2011-2015. No partner countries have reported exports to Côte d'Ivoire.

Detailed data for 2014 and 2015 were obtained from the customs services in Abidjan. The data were identical to the data in the Comtrade database and no import of liquid mercury was registered. Apart from a few shipments of mercury chemicals for laboratories, the registrations concerned mercury batteries and lamps.

Table 5.1 Import of mercury (28 05 40) 2010-2015 in kg to Côte d'Ivoire by country (Comtrade database)

	2010	2011	2012	2013	2014	2015
France	7	nd	nd	nd	nd	nd
Total	7	nd	nd	nd	nd	nd

Statistics on gold production and trade

According to the data from USGS Minerals Yearbook from 2013, the total production of gold from industrial mines doubled from 5 tonnes in 2010 to 10 tonnes in 2012. No data are available for ASGM, but it is indicated in the yearbook that gold was also produced throughout the country by artisanal miners. For the period 2010 to 2012, the reported export of gold was about 2 t/year higher than the mine output. A steep increase is reported for 2013 - 2015 but no data on mine output is available as yet. The majority of the gold was exported to Switzerland and South Africa in 2015.

Table 5.2 Production of gold 2010-2015 to Côte d'Ivoire(USGS, 2015)

	Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year	Note by USGS
	2010	2011	2012	2013			
Cote d'Ivoire	5,310	9,870	10,420	not yet published	no		"Gold, mine output, Au content"; Does not include production from artisanal mining.

Table 5.3 Net export of gold (Commodity code 7108) 2010-2015 from Côte d'Ivoire (Comtrade database)

Net export, kg/year					
2010	2011	2012	2013	2014	2015
5,419	13,114	13,120	14,157	19,136	22,275

5.3 Informal information on mercury use and trade flows

Trade routes

The routes by which mercury enters Côte d'Ivoire depend on the regions in which it is used. The President of UNOMICI (National Union of Mining Operators in Côte d'Ivoire) carried out investigations in different artisanal mining sites in 2014. The identified routes by which mercury enters Côte d'Ivoire were:

- In Northern region: Mercury stems from Burkina Faso and Mali
- In Western region: Mercury stems from Guinea
- In Centre – North region: Mercury stems from Mali and Burkina Faso.

In a survey carried out by Dominique Bally Kpokro from the NGO Jeunes Volontaires pour l'Environnement in 2013, it was shown that in some regions of Côte d'Ivoire, mercury routes are comprised of the following:

- In the Central region: Mercury come from Burkina Faso,
- In Centre-West region: Mercury come from Burkina Faso and Mali.

It has been confirmed in this study that the majority of the mercury used in Côte d'Ivoire comes from Ghana and Togo through Burkina Faso. The mercury routes from Mali and Guinea have not been further investigated as these countries have not participated in the project and data from the countries have not been available.

Notably, the mercury does not appear to be imported from Ghana/Togo or directly imported to Côte d'Ivoire from countries outside the region (confirmed by official trade data which do not indicate import). The total quantities of mercury used in Côte d'Ivoire are small compared to the neighboring countries Ghana and Burkina Faso; this trade therefore has limited influence on the overall trade pattern in the sub-region. As explained elsewhere, there has historically been a link between miners and gold traders from Burkina Faso living in Ghana and miners and gold dealers in Burkina Faso; people from Burkina Faso are involved in the mercury trade in major parts of Western Africa. Mercury-based ASGM was introduced relatively late in Côte d'Ivoire, mainly by miners from Burkina Faso and other neighboring countries.

Information from several interviewees in Northern Côte d'Ivore indicated that the main route for mercury entering the northern mining sites in Côte d'Ivore is from Ghana via Burkina Faso. In one specific example, the traffic was organized by the site owners, the gold buyers and their supplier based in Burkina Faso. The suppler in Burkina Faso had its wholesaler in Ghana. The site owner in Côte d'Ivore could not purchase the mercury directly from the wholesaler in Ghana.

Another site owner in Northern Côte d'Ivore confirmed that the mercury to extract gold comes from Burkina Faso where it is imported from Ghana. According to the site owner, in Ghana, mercury is removed from ships during their cleaning and packed in bottles or 5-liter containers. This mercury is mixed with wastes; once wastes are evacuated from the harbor to dumping sites, mercury containers are removed from the wastes and sent to some wholesalers. Hereafter, the mercury is sent to Burkina Faso using unpaved roads where less control by police or customs occurs (information in accordance with the information from the Burkina Faso informants above). If the information is correct, it indicates that the mercury may also be illegally shipped from the exporting country, as the mercury is hidden within the ship. Mercury is sold at a price of CFA 40,000 or 50,000 kg (USD 69- 86) by suppliers in Burkina Faso. If artisanal miners and site owners based in Côte d'Ivoire want to buy mercury in Ghana, the price goes up to around CFA 70,000 and 90,000/kg (USD 120-154/kg). This is in accordance with information from other informants indicating that suppliers from Burkina Faso have control of mercury trade in this part of Western Africa.

Actors in the mercury value chain

As indicated above, there is no officially reported import of mercury to the country. In accordance with this fact, no importers of mercury from outside the region have been identified.

According to the obtained information, generally it is the site owner or financier who supplies miners with mercury. The mercury appears to be supplied to the site owners mainly by gold buyers with cross boundary networks in the region.

A site owner in Northern Côte d'Ivoire informed the study that the supply of mercury to the ASGM site is organized by the site owner, the gold buyers and their supplier based in Burkina Faso. These suppliers have their wholesaler in Ghana. The ASGM site's owner is not allowed to purchase mercury from the wholesaler in Ghana. When he tried to identify other mercury suppliers in Ghana, the cost of mercury increased by 60%.

One journalist noted that sometimes, industrial miners supply artisanal miners with mercury in order to purchase the gold they produce.

According to the president of the Dental Surgeons Order, no free liquid mercury is used for mixing dental amalgam in the clinics. Currently, only the encapsulated form is used. This information was confirmed by other informants from the sector. The capsules are typically imported from France, Eastern Europe, India and China. According to a lecturer at the Department of Conservative Odontology, trafficking of liquid mercury from dentists to the black market occurs but is difficult to track because no one knows the main organizer of this market. As amalgam capsules are relatively expensive, it is assumed by the authors of this report to be unlikely that this source of mercury would be sold and used for ASGM. There is no registered, legal import of mercury for dentistry in the country. Consequently, it is difficult to identify any driver for illegal import of mercury for dentistry which is afterwards sold on a black market for ASGM.

Quantities and prices

The ASM organization has informed the study that mercury is sold to artisanal miners at a price of CFA 500 for 10 g (corresponding to USD 0.85/kg). According to other informants, the mercury is sold by suppliers from Burkina Faso at a price of CFA 40,000 to 50,000 per kg (USD 68 to 85/kg). If mercury is bought directly from suppliers in Ghana, the prices are reported to be higher. Compared to prices in Eastern Africa, the price of mercury in Côte d'Ivoire is relatively low.

Sources of liquid mercury other than import

No sources of liquid mercury other than import have been identified.

5.4 Results of ASGM sample sites investigations and initial national baseline estimates

Training was carried out during the period June 6th to 10th 2016 with the participation of an international expert, a national expert and one representative of the ASGM Association of Côte d'Ivoire. Two representatives of the Ministry of Environment cancelled their participation one day before the field training. Field investigations were carried out at three small-scale gold mining sites.

The following sites were investigated:

Site	location	Key characteristics
Doka	Gabia Village in the Department of Oumé in Centre-West Côte d'Ivoire UTM 703533.8 30N 240821.2	 One large pit (photo) and several smaller pits. Hard rock mining and a mixture of alluvial and hard rock. The miners do use mercury. Retorts are not used. Amalgamation from concentrate. Photo: COWI
Godiefla	Gnanoufla Village in the Department of Oumé	Alluvial mining site. The miners do use mercury. Retorts are not used.Amalgamation from concentrate.

	centre-West Côte d'Ivoire UTM 703535.5 30N 237608.8	
Loukoukro	Gnanoufla Village in the Department of Oumé in Centre-West Côte d'Ivoire UTM 705937.3 30N 243014.4	Miners use a metal detector which is so sensitive that it can detect gold grains down to a few mm in size. The grains are collected. No use of mercury occurs.

Data for each site are provided to the Ministry of Environment in the form of an Excel reporting system with the site data and national summaries and the site investigation forms.

The summery of the results are shown in the table below.

Site **1. Sites étudiés**	**Type de site**		**Alluvion**	**Mélange roche dure/alluvion**	**Total**
- mineurs	Nombre de sites avec des informations sur la population de mineurs ainsi que les informations initiales sur le site		2	1	3
	Nombre de sites avec une enquête détaillée du site (Niveau 1 - 3)		2	1	3
	Nombre de mineurs (arroundi, distribution mathématique)	Min	212	800	1,432
		Max	1,278	3,200	4,058
	Nombre de mineurs	Min	80	800	880
		Max	1,410	3,200	4,610
	Moyenne du nombre de mineurs par site		373	2,000	915
- Production d'or	Production totale d'or, kg/an (meilleure estimation pour chaque site)		8	255	263
	Production totale d'or à partir du mercure, kg/an (meilleure estimation pour chaque site)		1	255	257
	Pourcentage d'or produit à partir de l'amalgamation au mercure		17%	100%	98%
	Production totale d'or à partir de l'amalgamation totale du minerai, kg/an		-	-	-
	Pourcentage d'or produit en utilisant l'amalgamation totale du minerai (de la production totale d'or à partir du mercure)		0%	0%	0%
	Pourcentage d'or produit en utilisant l'amalgamation total du minerai (de la production totale d'or)		0%	0%	0%
	Production totale d'or par amalgamation du concentré, kg/an		-	255	255
	Pourcentage d'or produit à partir du concentré (de la production totale d'or à partir du mercure)		0%	100%	100%
- Consommation de mercure	Consommation totale de mercure (mercure recyclé est soustrait)		2	332	334
	Consommation totale du mercure pour l'amalgamation du minerai (mercure recyclé non soustrait)		-	-	-
	Consommation totale par l'amalgamation du concen-		332	-	332

Site **1. Sites étudiés**	**Type de site**		**Alluvion**	**Mélange roche dure/alluvion**	**Total**
	tré (Mercure recyclé non soustrait)				
- recupération du mercure	Quantité totale du mercure récupéré des amalgames et de l'or spongieux, kg/an				0
	Taux de recyclage total (% de l'usage total pour l'extraction) (excl. Récupération des boues)		0%	0%	0%
	Mercure récupéré des boues et autres déchets, kg/an		0	0	0
- rejets de mercure	mercure total émis dans l'air, kg/an		1	255	257
	rejets totaux de mercure dans l'eau et le sol (incl. Les boues)		0	77	77
- Ratio mercure - or	Ratio mercure composé - or (moyenne de tous les procédés)		0.2	1.3	1.3
	Ratio mercure - or, amalgamation du minerai				
- statistique sur le site	Ratio mercure - or, amalgamation du concentré			0.0	1.3
	Nombre de sites où le mercure est utilisé (totalement ou partiellement)		1	1	2
	Pourcentage de sites où le mercure est utilisé (totalement ou partiellement)		50%	100%	67%
	Nombre de sites où l'amalgamation du minerai brut est pratiquée (totalement ou partiellement)		0	0	0
	Pourcentage de sites où l'amalgamation du minerai brut est pratiquée (tous les sites avec les enquêtes détaillées)		0%	0%	0%
	Nombre de sites où les retors / hotte à fumée sont régulièrement utilisé pour la production d'or spongieux (totalement ou partiellement)		0	0	0
	Nombre de sites où les retors / hotte à fumée sont régulièrement utilisé pour la production d'or doré (totalement ou partiellement)		0	0	0
	Pourcentage de sites où les retors / hotte à fumée sont régulièrement utilisé (totalement ou partiellement)		0%	0%	0%
	Nombre de sites où le mercure est récupéré des boues et autres déchets		0	0	0
	Nombre de sites avec estimation de la production basée sur l'extraction d'or		0	0	0
	Nombre de sites avec estimation de la production basée sur le revenu		0	0	0
	Nombre de sites avec d'autres méthodes d'estimation de la production d'or		0	0	0
	Nombre de sites avec des informations sur le nombre de puits		2	1	3
	Moyenne du nombre de puits par site (pour les sites avec des données sur les puits)		75	120	90
	Production d'or moyenne par puits (pour sites avec des données sur les puits), kg/an		0.1	2.1	2.9
	Consommation moyenne de mercure par puits (pour sites avec données sur les puits), kg/an		0.0	2.8	0.9
- par mineur	Production moyenne d'or par mineur, g/an		10	128	96
	Production moyenne d'or produit avec du mercure par mineur, g/an		2	128	94

Site **1. Sites étudiés**	**Type de site**		**Alluvion**	**Mélange roche dure/alluvion**	**Total**
	Consommation moyenne de mercure par mineur, g/an (incl. mineurs n'utilisant pas de mercure)		2	166	122
	Moyenne du nombre de mineur par site		373	2,000	915
	Revenu annuel moyen par mineur, /an		-	-	-
	Nombre de sites où les données sur les revenus sont disponibles		0	0	0
- Genre et Âge	Pourcentage de femmes parmi les mineurs (du nombre total de mineurs)		65%	15%	29%
	Pourcentage d'enfants parmi (du nombre total de mineurs)		0%	1%	1%

Establishing a national baseline on the basis of investigation of five sites is not possible, but the Excel workbook illustrates the use of available data for establishing a baseline by using the "National summary" sheet of the reporting system.

National baseline estimate

As mentioned above, no official data on the number of mining sites and number of miners have been identified. The Artisanal Miners Association has been requested to provide information on the number of ASGM miners in the country. The association does not hold information on numbers of miners as the sector is still not well organized. The Ministry of Mines also does not have any information on numbers of miners.

The Global Mercury Assessment estimated consumption in 2010 at 0.1 - 0.5 t/year, the default range applied in the assessment for countries for which no information was available, but ASGM was known to occur.

According to answers from NGOs in Côte d'Ivoire to a survey undertaken for UNEP Chemicals by Fritz (2014a), the number of miners in 2014 was 30,000-50,000.

If this estimate is correct, mercury consumption would likely be significantly higher than the estimated 0.1 - 0.5 t/year. On this basis, the actual consumption is estimated at some 0.5-5.0 t/year.

6 Ghana

6.1 The ASGM sector in Ghana

Number of mining sites and geographical distribution

Ghana is the second largest gold producer in Africa, after South Africa. The country's ASGM sector has a long history and is well developed, though covering a wide span of approaches, from artisanal miners engaging in rudimentary gold panning, to sophisticated and highly mechanized small-scale mining operations engaging in both hard rock and alluvial mining. The ASGM sector has a total of 1,355 small-scale mining claims distributed in eight mining districts.

ASM and ASGM population

The estimated number of artisanal and small-scale miners is close to a million. Mercury is widely used and available in and around mining sites.

According to Wilson et al. (2015), while ASGM represents a relatively small proportion (~10%) of Ghana's annual gold production, it is a sector that affects the livelihood of increasing numbers of people each year. In 2011, approximately 245,000 ounces of gold (6.9 tons) extracted by ASGM activities were purchased by and then sold through two Ghana-based gold buying entities (Precious Minerals and Marketing Corporation (PMMC) and Asap Vasa). This does not include an unknown - but estimated to be substantial - revenue from sales through informal markets and non-traditional means. The following year, registered ASGM production rose by 43% to 357,493 ounces (10 t).

Applied extraction methods

While there are many hard rock sites, Ghana is one of the countries in Sub-Saharan Africa with the most developed alluvial mining sectors, in some cases involving gold washing plants constituting significant investments. Mercury is widely used in both hard rock and alluvial mining, predominantly with concentrate amalgamation, though some alluvial sites visited use mercury only for some ore types. Whole ore amalgamation was not encountered during fieldwork, though it is likely to take place, not least considering the large Chinese community involved in ASGM as investors and providers of equipment. In contrast to other large ASGM countries like Zimbabwe and Tanzania, cyanidation plants are strictly illegal in Ghana.

Legislation

The Mercury Act, 1989, mandates the Ministry of Trade and Industry to regulate mercury within Ghana. Upon receiving applications and endorsements from the Environmental Protection Agency (EPA), applicants can be granted an license to import, buy, possess, sell, and deal in mercury subject to the specific

conditions stipulated in the license. The Act further states that licensed small-scale miners may purchase from licensed mercury dealers a reasonable quantity of mercury that may be shown to be necessary for the purposes of their mining operations subject to the mining operations demonstrating good mining practices in the use of mercury.

6.2 Trade statistics of mercury, mercury-added products and gold

Comtrade statistics on import/export of mercury

Data on import to Ghana and export to Ghana reported by partner countries from the UN Comtrade database are shown below. The recorded import as well as the export to Ghana has decreased significantly since 2010, probably due to misreporting. Until 2011, when the EU export ban went into force, a significant amount of mercury was imported from the EU.

India and Singapore registered significant exports of mercury to Ghana in 2015.

The recorded import is well below the estimated consumption of mercury for ASGM purposes of 49-91 t/year (Global Mercury Assessment).

Table 6.1 Import of mercury in kg to Ghana by country 2010-2014 (Comtrade database)

	2010	2011	2012	2013	2014	2015
Belgium	19,450	7,340		3		
China		652	3,706	44		
Germany		59				
India		1,506	4			
Lebanon				1,122		
Singapore			8,625			
South Africa	35	11,230				
Spain	390	3,712				
United Kingdom	72	3				
Total	19,947	24,502	12,335	1,169	n.d.	n.d

Table 6.2 Export of mercury in kg to Ghana by country 2010-2014 (Comtrade database)

	2010	2011	2012	2013	2014	2015
Belgium	3,450					
China, Hong Kong SAR		5,175				
India		99	9	2		2,505
Mexico	173					
The Netherlands	17,250	3,450				
Singapore		863			518	7,728

	2010	2011	2012	2013	2014	2015
Spain	2,277					
United Kingdom		21				
Total	23,150	9,608	9	2	518	10,233

As mentioned below, data on import licenses for the period 2006 to 2015 was obtained from the licensing authorities.

Statistics on gold production and trade

According to data from USGS Minerals Yearbook of 2013, the total production of gold from larger mines increased from 76 to 87 t/year in the period 2010 to 2012. On top of this amount is an estimated production of >5 t/year from ASGM. The net export of gold during 2010-2014 averaged 135 t/year which may indicate that the production by ASGM is well above 25 t/year.

Table 6.3 Production of gold in Ghana in 2010-2014 (USGS, 2013)

	Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year	Note by USGS
	2010	2011	2012	2013			
Ghana	76,330	82,920	86,700	88,376	no	>25,000	"Gold, mine output, Au content"; Does not include artisanal mining output, which in 2010 and 2011 was estimated to be more than 25,000 kilograms, respectively."

Table 6.4 Net export of gold from Ghana in 2010-2014 (Comtrade database)

Net export, kg/year					
2010	2011	2012	2013	2014	2015
96,012	117,767	224,622	139,888	96,012	not available yet

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6.3 Informal information on mercury use and trade flows

Trade of mercury

In reference to COMTRADE mercury statistics for Ghana, in 2015 exports from Singapore and India accounted for the bulk of official mercury inflows into the country, whereas no import of mercury to the country is reported.

For this project, data on import licenses for the period 2006-2016 were received from the licensing authorities. A reported 18 shipments – ranging from 5 kilos to 20 tons in quantity – were requisitioned by 27 licensed companies in the period 2011 to 2016. The variety of importers include chemical suppliers, mining

equipment dealers, gold mining companies and general trading enterprises (specialized in wood, agricultural products, etc.). In 2015, the total import by the licensed companies was 0.9 tonnes.

Trade routes

An in-depth study focusing on the identification of the origin and routes of informal mercury trade was undertaken in Ghana, grounded in semi-structured interviews with stakeholders both in Accra and in active ASGM sites located within the goldfields of the Eastern Region.

According to the Assisting Director of the Focal Point for Minamata Convention of the Environmental Protection Agency (EPA), declining mercury imports are reflective of ongoing smuggling and of the pervasive black market upon which Ghana's vast ASGM sector hinges. He asserted that mercury enters the country across its borders with Burkina Faso and Togo, and through the Port of Tema. These entry points were also raised by the Head of the Small Scale Mining Department of the Minerals Commission in his narration of recent anecdotes. The Director gathered that mercury is readily available in ASGM sites, where traders supply the resource to local gold buyers who in turn distribute it to smaller brokers and miners. The Director of Trade Facilitation from the Ministry of Trade and Industry remarked that ASGM partly accounts for formally imported mercury, though informal trade flows are regarded as significant in view of the consistently meager registered imports.

By the account of a doctoral candidate from the Institute of Statistical, Social and Economic Research (ISSER), large-scale gold buyers in Kumasi furnish mercury to middle-scale buyers based in Bole, Tinga and Techiman, who then supply it to small-scale brokers in ASGM sites, the latter of whom purchase small quantities of gold on a daily basis. Referring to a recent interview, he noted that small gold brokers afford mercury free of charge to miners who arrange to sell their gold to them, as an incentive to continued business with existing and potential gold-sellers. Under such arrangements, the miners commit to selling their gold to the brokers, who in turn sell off the merchandize to large-scale gold buyers. An associate Professor from the University of Ghana (Department of Earth Sciences) affirmed the widespread availability and usage of mercury in ASGM, emphasizing that the Knelson Concentrator – misinterpreted by some as an alternative gold extraction technology – is in actuality a concentration apparatus, which all the same entails amalgamation with mercury. According to the National Administrator of the Ghana National Association of Small-Scale Miners, mercury is still used by the majority of ASGM operations and is easily accessible in mining areas where it is covertly sold and distributed. He averred that mercury trade within the sector is practiced by dealers specialized in the business, adding, "Such dealers sell mercury to gold buyers who distribute it in ASGM areas by means of their established gold buying networks, though mercury middlemen based in such sites also take part in the trade". He speculates that mercury smugglers, while still very active along Ghana's border with Togo, operate mainly in Tema Port.

One mine owner of a licensed mining operation disclosed that he purchased a 34.5 kilo mercury canister from a staff from PMMC within PMMC's office in 2014, at a price of GHS 10,000 (USD 2,500). Several informants from another local ASGM site stated that mercury is sold in 36 g eye-drop bottles. They revealed that mercury is sold at the mining site, and in neighboring towns including Anyinam, but claimed to have no knowledge of sources further upstream. One interviewed gold broker acknowledged buying a quarter to five bags of gold per day, from ASG operators, at a price of GHS 140 per gram (USD 35), and to providing mercury in return. He divulged that he buys pre-packaged parcels of mercury encased in small plastic bags from larger gold-buyers in adjacent towns. "I purchase the parcels mainly from brokers in Akwatia, at a price of GHS 30 [USD 7.5], and they source it from Accra at a cost of GHS 25 [USD 6.3]," he shared. In his belief, this supply stream flows from China, with Chinese traders selling mercury in mining areas. PMMC, the national gold buying agency, was approached for enquiry, following leads on its

involvement in the supply of mercury. According the answer from PMMC, however, the organization is only involved with buying, purification, and processing of gold with no involvement in mercury business.

Notably, the information provided by the local stakeholders is in line with the accounts elicited from informants during parallel field surveys in Ivory Coast and Burkina Faso. In Ivory Coast, one site owner in Sanguinari Village revealed that gold-buyers distributing mercury in the area purchase the commodity from suppliers based in Burkina Faso, who source it from wholesalers operating in Ghana. Elaborating on a known supply route in Ghana, he described how smuggled mercury – concealed in ship waste – is transported to dumpsites, from where it is recovered and delivered to wholesalers in 5 liter containers. This trading channel was also cited by several site managers in the village of Varale. A number of ASGM actors interviewed in Burkina Faso shed more light on the nexus. One site manager quoted the Port of Lome and the ports of Tema and Takoradi as key entry points for informally traded mercury in the source countries of Togo and Ghana, respectively, and referred to port-based associates who unload and repackage mercury shipments into 5 kg, 25 kg and 50 kg containers. In clarification of Burkina Faso's mercury trade linkages with Ghana, the President of the National Corporation of Artisanal and Small-Scale Miners (CONAPEM) made known that the Ghanaian traders networking with mercury suppliers in the country are in fact emigrants of local origin, who settled in Ghana several decades ago, to specialize in ASGM.

In sum of these informative inputs, informal mercury supply chains in Ghana are believed to depend on multiple entry points, including the Port of Tema and Takoradi Harbor, and lesser known passages along the country's porous borders with Togo. While a few of the local informants alluded to inflows across the Ghana-Burkina Faso border, it is rather plausible that this trans-border traffic flows in reverse, marking the elucidation by the interviewed ASGM actors in the land-locked state of Burkina Faso.

Actors in the mercury value chain

Mercury supply networks in Ghana comprise the following categories of actors:

- Bulk traders – who sell mercury informally (or sometimes formally) to large-scale gold buyers (in bulk quantities) for subsequent sale further downstream in the gold-buying chain;
- Gold buyers – large-scale gold buyers supply mercury to the middle-scale buyers who distribute it to significant ASGM operations and small-scale brokers, from whom it is provided to ASGM miners under different arrangements;
- Middlemen – with localized operations, such as specialized dealers, sell mercury to miners in ASGM areas;
- Chinese traders – who are alleged to sell mercury in ASGM sites; and
- PCCM staff selling mercury from the PCCM office.

Quantities and prices[1]

Upstream in the supply chain, mercury is sold in 34.5 kg canisters costing GHS 10,000 (USD 2516) (2014 price). Midstream, it is sold in 750 ml beer bottles at GHS 3,000 (USD 755). In the downstream segment, mercury is distributed in eye-drop, ear-drop and penicillin bottles (collectively referred to by locals as Po-

[1] The exchange rate as at October 3, 2016.

hu) priced at GHS 20 to 30 (USD 5 to USD 8). Equally small quantities are also available in small plastic bags, in the GHS 25 to 30 price range. These contain around 30 grams of mercury.

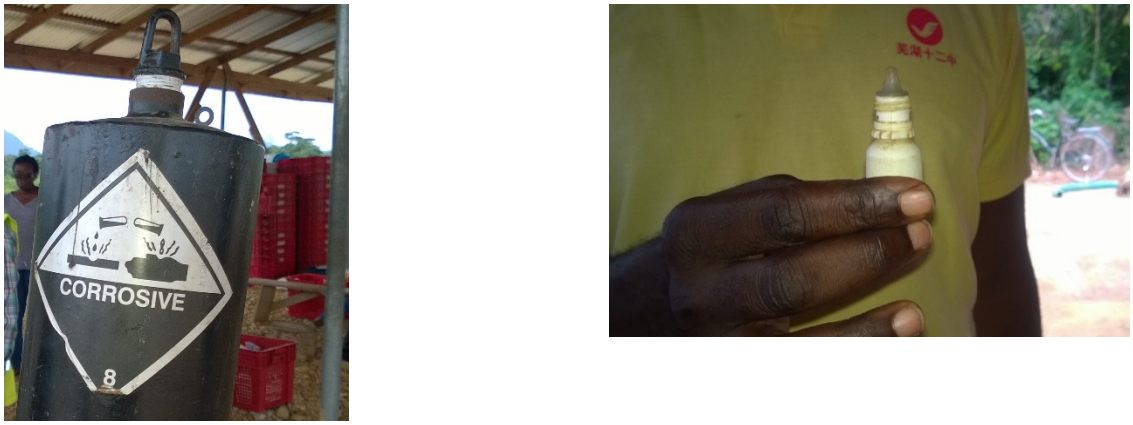

Figure 6.1 Mercury flask (34.5 kg) in mining site in Ghana (left) and ear-drop bottle use by a miner (right). Photo. COWI.

6.4 Results of ASGM sample site investigations and initial national baseline estimates

Site investigations took place on 3-5 August 2016 with the participation of one international expert, one local expert and three trainees. The following sites were investigated:

Site	location	Coordinates	Key characteristics
Osompa Mining Group	Fanteakwa District, Eastern Region	30N 0777496 0704247	Alluvial small to medium scale operation with large washing/processing machinery with mercury used for only 5-10 per cent of ore
Plaza Mining	Atiwa District, Anyinam, Eastern Region	30N 0771679 0706328	Informal galamsay site with alluvial mining involving miners and a washing/processing plant.
Kakoase Extraction Venture (KEV)	Moseaso Kwarreng, Atiwa District, Eastern Region	30N 0770649 0704045	Small-scale alluvial mining operation with multiple teams processing gold through feeding small washing/processing machines, after which the concentrate is amalgamated and burned. The site is surrounded by galamsey operations
Osompa Mining Group	Fanteakwa District, Eastern Region	30N 0777496 0704247	Alluvial small to medium scale operation with large washing/processing machinery with mercury used for only 5-10 per cent of ore

Data for each site are provided to the Ministry of Environment in the form of an Excel reporting system with the site data and national summaries and the site investigation forms.

The summary of the results are shown in the table below (all investigated sites were alluvial).

Site type		Alluvial
Number of sites with information on population of miners and basic site information		3
Number of sites with detailed site investigation (level 1-3)		2
Number of miners (rounded, distribution mathematics)	Min	240

Site type		Alluvial
	Max	280
Number of miners (simple sum)	Min	240
	Max	280
Average number of miners per site		87
Total gold production, kg/year (best estimate from each site)		237
Total mercury-based gold production, kg/year (best estimate from each site)		76
Percentage of gold production based on mercury amalgamation		32%
Total gold production by whole ore amalgamation, kg/year		-
Percentage of gold produced using whole ore amalgamation (of total mercury-based gold production)		0%
Percentage of gold produced using whole ore amalgamation (of total gold production)		0%
Total gold production by amalgamation from concentrate, kg/year		76
Percentage of gold produced from concentrate (of total mercury-based)		100%
Total consumption of mercury (recycled mercury subtracted), kg/year		98
Total consumption for whole ore amalgamation (recycled mercury is not subtracted), kg/year		-
Total consumption for amalgamation from concentrate (recycled mercury is not subtracted), kg/year		98
Total quantity of mercury recovered from amalgams and sponge gold, kg/year		0
Total recycling rate (% of total used for extraction) (excl. recovery from tailings)		0%
Mercury recovered from tailings and other waste, kg/year		0
Total releases of mercury to air, kg/year		76
Total releases to water and land (incl. tailings), kg/year		23
Compound mercury to gold ratio (average of all processes) (not accounting for recycling)		0.4
Mercury to gold ratio, whole ore amalgamation		
Mercury to gold ratio, amalgamation from concentrate		1.3
Number of sites where mercury is used (fully or partly)		3
Percentage of sites where mercury is used (fully or partly)		100%
Number of sites where whole ore amalgamation is applied (partly or fully)		0
Percentage of sites where whole ore amalgamation is applied (all sites with detailed investigation)		0%
Number of sites where retorts/fume hoods are regularly used for sponge gold production (fully or partly)		0
Number of sites where retorts/fume hoods are regularly used for gold doré production (fully or partly)		0
Percentage of sites with detailed site investigation where retorts/fume hoods are used (fully or party)		0%
Number of sites where mercury is recovered from tailings and other waste		0
Number of sites with extraction based gold estimate		2
Number of sites with income based gold estimate		2
Number of sites with alternative gold estimate		2
Number of sites with information on number of shafts/pit		3
Average number of shafts/pits per site (for sites with shaft data)		1

Site type		Alluvial
Average gold production per shaft/pit (for sites with shaft/pit data), kg/year		237
Average mercury consumption per shaft/pit (for sites with shaft/pit data), kg/year		49.2
Average gold production per miner, g/year		910
Average mercury-based gold production per miner, g/year		291
Average mercury consumption per miner, g/year (incl. miners not using mercury)		378
Average number of miners per site		87
Average annual income per miner, UGX/year		7,380
Number of sites where income data are available		2
Percentage women among miners (of total number of miners)		1%
Percentage children among miners (of total number of miners)		0%

Establishing a national baseline upon investigation of three sites is not possible, but the Excel workbook illustrates the use of available data for establishing a baseline by using the "National summary" sheet of the reporting system.

Initial national baseline

As mentioned above, the ASGM population is approximately 1,000,000. Using an average mercury consumption per miner from the investigated sites (only two sites with detailed data) of 378 g mercury/miner/year would result in an unrealistically high average mercury consumption in the country. More site investigations are needed for a robust estimate and, furthermore, some adjustments in the methodology may be needed in order not to systematically overestimate the mercury consumption per miner.

The Global Mercury Assessment (AMAP/UNEP, 2013) estimated the consumption of mercury for ASGM in Ghana in 2010 at 49-91 t/year (mean: 70 t/year), the highest consumption in any country in Sub-Saharan Africa at that time. Considering the size of the population of miners and data from Sudan and other countries, this estimate is maintained as the best estimate for 2015.

7 Uganda

7.1 The ASGM sector in Uganda

Number of mining sites and geographical distribution

The ASGM sector in Uganda, while growing, is still relatively definable. The table below presents a contemporary estimate of the size and nature of the sector.

Region	Description of mining sites
Eastern Region	Busia District (near the Kenyan border): old traditional ASGM site, use of mercury in hard rock mining. Currently around 1,000 miners, as many have moved on to recent rush sites Namayingo District (near Busia), east Uganda, gold rush around 2014-15, 3000-5000 miners engaging predominantly in hard rock mining and using mercury Bugiri District, gold discovered around 2013 – around 500 miners doing hard rock mining with mercury Mayuge District, gold discovered around 2013, around 500 miners doing hard rock mining with mercury
Central Region	Mubende District, 4 counties, gold discovered in 2013 with a subsequent significant rush, estimated 10,000 miners doing hard rock mining and using mercury
Western Region	Bushenyi District, ca 1000 miners Buhweju District, ca 1000 miners Ibanda District, ca 1000 miners Kanungu District, ca 500 miners In all these areas, it is predominantly alluvial mining with little or no use of mercury
Northern Region (Karamoja)	Districts of Abim, Kaabong, Moroto, Nakapiripirit, Amudat Miners scattered across these districts, highly poverty-driven and predominantly alluvial with no or little mercury usage – there are an estimated 5000 miners Mining has taken place for many years, though in Nakapiripirit, where there is the most mining activity, gold was discovered in 2013

ASM and ASGM population

The Ugandan ASM sector may be as big as 200,000 including mining of aggregates, lime, salt, sand, etc. However, the ASGM population is estimated to be around 40,000, a number that has increased significantly since a number of new gold discoveries and subsequent rushes took place in the period 2013-2015. The use of mercury was not widespread around the millennium, and was probably only used regularly in Busia.

ASGM is, for the most part, informal and not well regulated in the Mining Act, 2003. Licenses for ASM (i.e. a so-called Location License) are obtainable at an application fee of UGS 500,000 (annual renewal fee, UGS 250,000). There are only 50 Location Licenses in Uganda, which indicates the high degree of informality. A Location License requires a licensee has a license expenditure below USH 10 million, equivalent to around USD 3,000, an amount that constraints the license holder from any type of significant investment in mining and processing equipment. The legislation, however, is currently being revised.

Applied extraction methods

Mercury use has grown over the years and is now used in most hard rock operations. It is predominantly applied during final concentration, with an estimated mercury-gold ratio of 1:1 to 2:1, though one informant mentioned that some recent operations engage in whole ore amalgamation, where the ratio may be 4:1 or higher. Recently, miners from Tanzania have introduced cyanidation plants, which in under five years have led to the establishment of around 50 plants in Uganda.

Legislation

Mercury is not mentioned in recent mining and environment legislation. However, there is new legislation soon to be published and the revised Environmental Act is likely to present legislation related to mercury.

7.2 Trade statistics of mercury, mercury-added products and gold

Comtrade statistics on import/export of mercury

Data on import to Uganda and export to Uganda as reported by partner countries from the UN Comtrade database are shown below. There is no reported export. Total recorded import is below 100 kg/year on average, while for 2010 and 2011 Kenya and South Africa, respectively, reported exports of about 300 kg/year to Uganda. In the Global Mercury Assessment, mercury consumption in 2008 is estimated at 0.4 - 1.2 t/year i.e. somewhat higher than the reported export to Uganda in 2010 and 2011. As the ASGM miner population has been increasing in recent years, mercury consumption is likely higher at present, but this increase is not reflected in the statistics.

Data similar to the data reported in the Comtrade database have been obtained from the customs authorities in Uganda.

Table 7.1 Import of mercury in kg to Uganda by country in 2010-2015 (Comtrade database except for 2015, where the data are from the customs authorities)

	2010	2011	2012	2013	2014	2015
Australia			1			
India			45			
Kenya			1			
Malaysia					128	155
United Kingdom		100				
USA				4		
Total		100	47	4	128	155

Table 7.2 Export of mercury in kg to Uganda by country in 2010-2015 (Comtrade database)

	2010	2011	2012	2013	2014	2015
Kenya	344					
South Africa		282				
India						2
Total	344	282				2

Statistics on gold production and trade

According to data from USGS Minerals Yearbook of 2013, total production of gold in Uganda was very small at a few kg/year. Of this, 1 kg is estimated to be produced from ASGM. These data indicate that significant ASGM in Uganda is recent, though it must be assumed that gold from ASGM both previously and currently is predominantly smuggled out of the country. According to the yearbook, gold exports were re-exports of gold refined in Uganda. The reported amount of refined gold decreased from 450 kg in 2010 to 50 kg in 2013. A similar decrease in reported gold export is shown for the period 2010-2013 but with a steep increase in 2014.

Table 7.3 Production of gold 2010-2013 in Uganda (USGS, 2013)

	Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year	Note by USGS
	2010	2011	2012	2013			
Uganda, Mine	4	1	1	--	yes	1	
Uganda, Refined	450	150	200	50			Estimated data, rounded to no more than three significant digits.

The registered net export of gold from Uganda has increased in recent years.

Table 7.4 Net export of gold from Uganda 2010-2015 (Comtrade database)

Net export, kg/year					
2010	2011	2012	2013	2014	2015
797	215	329	84	1,939	996

7.3 Informal information on mercury use and trade flows

Trade of mercury

Mercury importation in Uganda is ongoing, with informal in-country trade flows becoming increasingly evident. COMTRADE mercury trade statistics indicate that South Africa and Kenya are the principal source countries, although Malaysia appears to have dominated official mercury imports over the past two years. According to the Uganda Revenue Authority (URA), eight consignments totaling 615 kg entered the country between January 2013 and February 2016, mostly from Kenya, as stated in official records. A representative of the URA emphasized that smuggling is likely to be rampant given the apparent lack of logistical and regulatory constraints.

Trade routes

A study purposed to lay the groundwork for the identification of the origin and routes of informal mercury trade in Uganda was carried out locally. This study was based on semi-structured interviews with key stakeholders and on participatory investigations in active ASGM sites located within the goldfields of Busia and Mubende districts.

A number of semi-structured consultations were convened with a range of stakeholders within the national ASGM sector. According to officials from the Ministry of Energy and Mineral Development (Geological Survey and Mines Directorate), there is a high level of certainty as to the smuggling although the tracing of these trading channels has proven difficult. Nonetheless, the Malaba border post is widely accounted as one of the country's leading entry points for smuggled mercury, other known conduits including the border towns of Busia and Mutukula. The chairperson of the Uganda National Artisanal and Small-Scale Miners Association asserted that while some mercury is traded in from Tanzania, more of it is sourced from Kenya and transported by both private and public vehicles across a number of border posts along the Kenya – Uganda border. Most traders (often Kenyan) deliver the mercury directly to mine sites, although the resource is as readily available in Kampala, where it is sold under-the-counter, among others, in jewelry stores. Whereas the ports of Mombasa and Nairobi are closer to Uganda than the Port of Dar es Salaam, Tanzania's northern goldfields are proximately situated around Lake Victoria, prompting Tanzanian dealers to supply mercury to Ugandan markets for good profits. Uganda has also been reported to be a transit country for a mercury trade route feeding into the Democratic Republic of Congo (DRC).

One ASM specialist from Auranda Minerals remarked that the usage of mercury was very limited up to the year 2005, and that it was largely prevalent in the Eastern town of Busia, where hundreds of ASG miners applied the resource in hard rock mining. "Numerous gold rushes have occurred since then, which has led to the substantial growth of mercury usage within the sector, although several goldfields north and west of the country employ alternative extraction technologies at present," she explained. As expressed by a Programme Officer from the Environmental Women in Action for Development (EWAD), local miners are unforthcoming as to the existing sources of mercury. She noted, "Some claim that the suppliers are gold buyers – of Indian origin – who, in some instances, trade mercury in exchange for gold". In another consultation, three representatives from the Pro-Biodiversity Conservationists in Uganda (PROBICOU) affirmed that mercury supplies stream in from Kenya, bypassing designated custom entry points. The respondents also averred that the major smuggling routes course through the border points of Malaba and Busia, emphasizing that gold buyers of Kenyan and Congolese origin have been alleged to supply mercury to ASG miners in the mining areas of Mubende. One claim owner narrated that some Chinese companies smuggle mercury by concealing small stocks in cavities of imported mining equipment.

Actors in the mercury value chain

In view of the information obtained, the country's mercury supply chains are comprised of the following actors:

- Foreign traders – specialized dealers of Kenyan, Tanzanian and Congolese origins who bring in and sell mercury to other mercury traders, gold buyers, and ASGM operators;
- Local traders who sell mercury in the ASGM sites. These are predominantly gold buyers who also engage in mercury supply in order to attract gold selling customers;
- Jewelry shops in Kampala, allegedly owned by people with Asian origins;
- Chinese mining companies – allegedly smuggling mercury into the country by concealing it in imported mining equipment.

Quantities and prices

A number of informants quoted the price of mercury per kilogram in Uganda as UGS 500,000-600,000 (USD 148-178/kg). The consultations revealed that mercury is typically distributed in 1 kg plastic bottles and portioned into small plastic bags or soda bottle caps further down the supply chain, selling for around UGS 1000 per gram though some respondents mentioned UGS 2,000 (corresponding to USD 300 - 600/kg).

Figure 7.1
Mercury is transported and sold in small un-labelled plastic bottles. This bottle is sold by a small gold buyer in a mining site in Mubende. Photo: COWI

Sources of liquid mercury other than import

By the account elicited from the country's Ministry of Health, there is no indication that mercury-containing equipment is vandalized by medical staff for illicit sale to the ASGM sector. Mercury is acquired and used in the dental sector; however, its involvement in the informal supply chain has not been reported hitherto.

7.4 Results of ASGM sample sites investigations and initial national baseline estimates

Site investigations took place on 6-9 September 2016 in the Busia and Mubende districts with the participation of one international expert, one local expert and three trainees. The following sites were investigated:

Site	location	Coordinates	Key characteristics
Rubali artisanal mining site	Kayonza Village, Kitumbi Subcounty, Mubende District	UTM 84050 36N 358852	Rush site (rush in 2013-14). Mainly informal, hard-rock mining, but some alluvial in the riverbed. Mainly concentrate amalgamation, but one incidence of whole-ore amalgamation. Ore is crushed in ball mills, concentrated in sluices and panned, after which amalgam is burned in the open. Tailings are sold off to a cyanidation plant.
Kagaba artisanal mining site	Kamusenene Village, Kitumbi Subcounty, Mubende District	UTM 364208 36N 77075	Rush site (rush in 2013-14). Hard rock mining takes place with ore crushed in ball mills and concentrated in sluices before being amalgamated and burned in the open.
Busia United Small-Scale Mining Association	Tiira Village, Busitema Subcounty, Busia District	UTM 56718 36N 620086	Both hard-rock and alluvial mining practiced, with ore crushed in ball-mills and concentrated in sluices, after which amalgam is formed in washing pans and burned openly, though allegedly sometimes with retorts
Syanyonja Mining Group	Syanyonja Village, Busitema Subcounty, Busia District	UTM 60648 36N 617118	Only hard-rock mining practiced, with concentrate amalgamation done in washing pans. Amalgam is burned in the open
Rubali artisanal mining	Kayonza Village, Kitumbi Subcounty,		Rush site (rush in 2013-14). Mainly informal, hard-rock mining, but some alluvial in the riverbed. Mainly concen-

Site	location	Coordinates	Key characteristics
site	Mubende District		trate amalgamation, but one incidence of whole-ore amalgamation. Ore is crushed in ball mills, concentrated in sluices and panned, after which amalgam is burned in the open. Tailings are sold off to a cyanidation plant.

Data for each site are provided to the Ministry of Environment in the form of an Excel reporting system with the site data and national summaries and the site investigation forms.

The summary of the results are shown in the table below (none of the investigated sites were alluvial).

Site type		Hard rock	Mix hard rock/alluvial	Total
Number of sites with information on population of miners and basic site information		3	1	4
Number of sites with detailed site investigation (level 1-3)		3	1	4
Number of miners (rounded, distribution mathematics)	Min	990	350	1,373
	Max	1,494	420	1,881
Number of miners (simple sum)	Min	864	350	1,214
	Max	1,620	420	2,040
Average number of miners per site		414	385	407
Total gold production, kg/year (best estimate from each site)		485	20	505
Total mercury-based gold production, kg/year (best estimate from each site)		453	19	472
Percentage of gold production based on mercury amalgamation		93%	95%	94%
Total gold production by whole ore amalgamation, kg/year		210	-	210
Percentage of gold produced using whole ore amalgamation (of total mercury-based gold production)		46%	0%	45%
Percentage of gold produced using whole ore amalgamation (of total gold production)		43%	0%	42%
Total gold production by amalgamation from concentrate, kg/year		243	19	262
Percentage of gold produced from concentrate (of total mercury-based)		54%	100%	55%
Total consumption of mercury (recycled mercury subtracted), kg/year		1,363	12	1,375
Total consumption for whole ore amalgamation (recycled mercury is not subtracted), kg/year		1,051	-	1,051
Total consumption for amalgamation from concentrate (recycled mercury is not subtracted), kg/year		316	25	341
Total quantity of mercury recovered from amalgams and sponge gold, kg/year		4	13	17
Total recycling rate (% of total used for extraction) (excl. recovery from tailings)		0%	53%	1%
Mercury recovered from tailings and other waste, kg/year		0	0	0
Total releases of mercury to air, kg/year		449	7	456
Total releases to water and land (incl. tailings), kg/year		914	5	919
Compound mercury to gold ratio (average of all processes) (not accounting for recycling)		2.8	1.2	2.8

Site type		Hard rock	Mix hard rock/alluvial	Total
Mercury to gold ratio, whole ore amalgamation		5		5.0
Mercury to gold ratio, amalgamation from concentrate		1.3	1.3	1.3
Number of sites where mercury is used (fully or partly)		3	1	4
Percentage of sites where mercury is used (fully or partly)		100%	100%	100%
Number of sites where whole ore amalgamation is applied (partly or fully)		1	0	1
Percentage of sites where whole ore amalgamation is applied (all sites with detailed investigation)		33%	0%	25%
Number of sites where retorts/fume hoods are regularly used for sponge gold production (fully or partly)		1	1	2
Number of sites where retorts/fume hoods are regularly used for gold doré production (fully or partly)		0	0	0
Percentage of sites with detailed site investigation where retorts/fume hoods are used (fully or party)		33%	100%	50%
Number of sites where mercury is recovered from tailings and other waste		0	0	0
Number of sites with extraction based gold estimate		2	1	3
Number of sites with income based gold estimate		3	1	4
Number of sites with alternative gold estimate		0	0	0
Number of sites with information on number of shafts/pit		3	1	4
Average number of shafts/pits per site (for sites with shaft data)		42	7	33
Average gold production per shaft/pit (for sites with shaft/pit data), kg/year		12	3	15
Average mercury consumption per shaft/pit (for sites with shaft/pit data), kg/year		8.3	3.6	7.1
Average gold production per miner, g/year		390	52	310
Average mercury-based gold production per miner, g/year		365	50	290
Average mercury consumption per miner, g/year (incl. miners not using mercury)		1098	31	845
Average number of miners per site		414	385	407
Average annual income per miner, UGX/year		5,571,097	2,750,000	4,903,535
Number of sites where income data are available		3	1	4
Percentage women among miners (of total number of miners)		17%	33.0%	21%
Percentage children among miners (of total number of miners)		5%	0%	4%

Establishing a national baseline upon investigation of five sites is not possible, but the Excel workbook illustrates the use of available data for establishing a baseline by using the "National summary" sheet of the reporting system.

The data from the four sites are not considered to be representative as one of the sites used whole ore amalgamation, uncommon in Uganda. Furthermore, the gold production per miner at that site was remarkably high (which may be correct due to a gold rush). As much higher mercury to gold ratios are used for whole ore amalgamation, the site using whole ore amalgamation represents by far the highest total

mercury use of the four sites and results in very high average mercury consumption per miner, which most likely is not representative of the ASGM sites in Uganda. More site investigations are necessary before more robust estimates can be made.

Initial national baseline

The ASGM population in Uganda is estimated to be around 40,000, a number that has increased significantly since a number of new gold discoveries and subsequent rushes took place in 2013-2015. Mercury use has grown in recent years and mercury is now used in most hard rock operations in the country. It is predominantly applied to concentrate, with an estimated mercury-gold ratio of 1:1 to 2:1. On at least one site, whole ore amalgamation is used with an expected higher mercury to gold ratio.

No data on gold production from ASGM is available. The majority of the gold produced using ASGM appears to be smuggled out of the country; national statistics are not available for this gold.

No recent estimates on the use of mercury for ASGM in Uganda exist.

If the average mercury consumption per miner from the investigated sites is applied (845 g/year) the resulting mercury consumption may be estimated at 33-48 t/year, but as mentioned above, this estimate is considered unrealistically high and more site investigations are needed (the average for sites with amalgamation from concentrate is 106 g/year). If the more likely average figure for Tanzania of 130 g/year (still high) is applied, the mercury consumption in Uganda would be some 5.2 t/year.

Considering the number of miners, and comparing to the situation in Tanzania with operations quite similar to those in Uganda, it is estimated that the total mercury consumption for ASGM in Uganda in 2015 would likely be in the range of 2 - 6 t/year (mean 4 t/year). If it turns out that whole ore amalgamation is more widespread than expected, the figure may be significantly higher.

8 Zimbabwe

8.1 The ASGM sector in Zimbabwe

The ASGM sector in Zimbabwe is not only significant, but also advanced, as compared to those of other countries in Sub-Saharan Africa. The sector covers a broad spectrum of mining establishments, from informal labor-intensive mines employing artisanal miners (locally known as Makorokozas) to highly mechanized small-scale mining operations.

Organization of sector

The sector is organized around 450 privately owned “custom milling” centers, which transport (in some cases; other times the miners do the transport), crush, concentrate and amalgamate the ore using mercury for limited funds, after which they make their money from cyanidation. While some custom mills (stamp mills) only engage in concentrate amalgamation with mercury to gold ratios in the range of 1 and 1.5 grams of mercury per gram of gold, others use copper plates containing mercury to capture the gold, which constitutes whole ore amalgamation with significantly higher mercury to gold ratios. Much of the gold is also extracted outside the milling centers, predominantly using mercury as few mercury-free initiatives exist. However, an increasing number of hammer mills have emerged in recent years.

ASM and ASGM population

The ASM population is estimated at 500,000. Some estimates are higher than this; most observers agree that the number is at least 500,000 miners. The number of people who have been involved with ASM during the last decade number in the millions, as people move in and out of the sector and, in many cases, engage in ASM as part of a diversified livelihood strategy that also includes agriculture and other activities. The number of Certificates of Registration (the term for ASM licenses) is approximately 40,000; of these, 8,000 have had an Environmental Impact Assessment (EIA) conducted.

8.2 Trade statistics of mercury, mercury-added products and gold

Import and export of liquid mercury

Data on import to Zimbabwe and export to Zimbabwe as reported by partner countries from the UN Comtrade database are shown below. There is no reported export.

Furthermore, some information was obtained directly from Customs in Zimbabwe. According to information obtained from customs, 94 kg mercury was imported from South Africa in 2014, in accordance with the Comtrade data, while in 2015 the import was only 9 kg (see below Table).

The steep decrease in import from 2012 to 2013 likely does not reflect the actual trend in import, but rather a change from formal to informal import. As shown in *Table 8.2*, export from South Africa, reported as export from South Africa to Zimbabwe, continued during 2013 and 2014.

As mentioned in the previous section, the restriction of mercury sales to one company may have resulted in increased smuggling of the substance into Zimbabwe, as buyers have fewer outlets in which they can formally buy mercury. This restriction may explain the apparent decrease in the formal import of mercury. The lack of import from the United Kingdom as of 2013 is a consequence of the EU mercury export ban.

The average for the period 2010 to 2012 of approximately 12 t/year is, however, low compared with the Global Mercury Inventory estimate on mercury use in Zimbabwe for ASGM of 12.5 - 37.5 t/year.

*Table 8.1 Import of mercury in kg to Zimbabwe by country in 2010-2014**

	2010	2011	2012	2013	2014	2015
China	120		865	5		
China, Hong Kong SAR			45			
India				16		
Italy			27			
South Africa	2,659	4,175	4,426	100	94	9
Switzerland	3,450					
United Arab Emirates		1,725	5,278			
United Kingdom	3,732	4,502	7,276			
Total	9,961	10,402	17,917	121	94	9

** Source: Comtrade database*

*Table 8.2 Export of mercury in kg to Zimbabwe by country in 2010-2014**

	2010	2011	2012	2013	2014	2015
The Netherlands	4,570					
South Africa	2	240	1,802	1,688	1,359	
Total	4,572	240	1,802	1,688	1,359	

** Source: Comtrade database*

The only significant trade within Sub-Saharan Africa of amalgams (mercury alloys) is between South Africa and Zimbabwe. The import of the two commodities to Zimbabwe from South Africa could indicate that imported mercury is registered to some extent as import of amalgam (Figure 8.1). From 2008 to 2015, as discussed elsewhere, the registered import of mercury to Zimbabwe from South Africa decreased from 9

tonnes in 2008 to a few hundred kg during the period 2013-2015. During the same period the import of amalgam increased. However, the registered import, even if the amalgam is assumed to be mercury, remains far below the estimated actual import from South Africa.

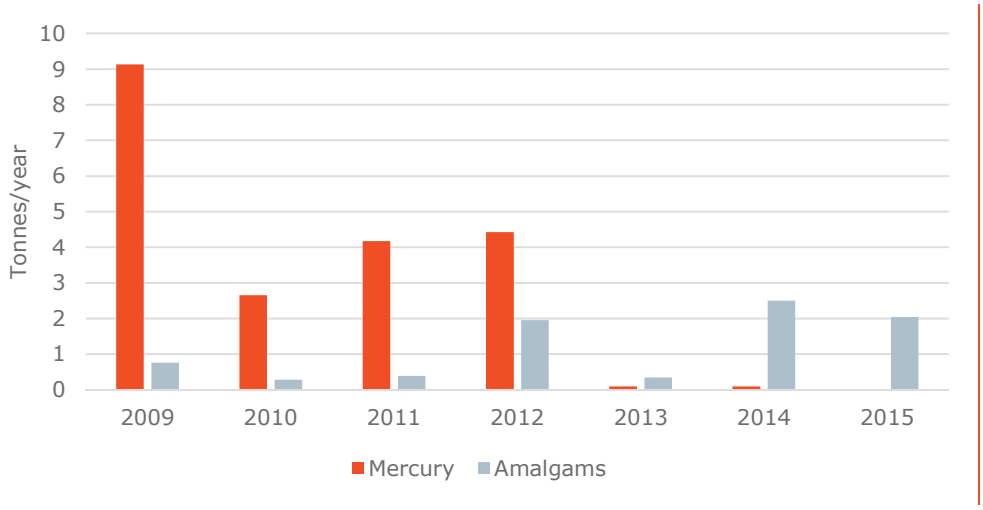

Figure 8.1 Registered import of mercury and amalgam to Zimbabwe from South Africa

Statistics on gold production and trade

According to the data from USGS Minerals Yearbook, the total production of gold in Zimbabwe increased from 9,100 kg in 2010 to 14,065 in 2013. It is not specifically mentioned whether this includes gold production from ASGM, but in many country reports this is specifically indicated. The reported exports in the Comtrade database for the years 2011, 2012 and 2014 are in the same order of magnitude, but reported exports in 2010 and 2013 are much higher, likely an effect of misreporting. The value in USD of the export in these two years is close to the values in the other years (where the USD/t was close to the gold spot price) indicating that the tonnage of the import in 2010 and 2013 was at the same magnitude as in the three other years. All gold export was to South Africa .The available data indicates an increasing trend in the production and export of gold.

Table 8.3 Production of gold 2010-2014 in Zimbabwe (USGS, 2015)

	Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year
	2010	2011	2012	2013		
Zimbabwe	9,100	12,824	14,742	14,065	?	2013: 3,000

Table 8.4 Net export of gold in Zimbabwe in 2010-2014 (Comtrade database)

Net export, kg/year **					
2010	2011	2012	2013	2014	2015
88,721 **7,097	7,299	15,570	2,321,435 **12,420	13,062	17,239

*** Calculated from the indicated value in USD and using the USD/tonnes in 2014.*

8.3 Informal information on mercury use and trade flows

Trade of mercury

With the exception of South Africa, all of the export countries for which imports into Zimbabwe have been recorded are non-African, the major exporters being the United Kingdom and the United Arab Emirates. However, formal import of mercury ceased in 2013.

The smuggling of mercury into the country's ASGM sector has prevailed following the imposition of mercury trade restrictions upon the majority of pre-existing mercury importers. While mercury import was previously conducted by a number of formal companies dealing with import of mining equipment and chemicals (cyanide, carbon, acids etc.), such as Curechem, Chemplex and Mining Axis House, some years back this was restricted by Environmental Management Agency (EMA), which has cancelled the licenses of these companies and presently licenses only one company based in Bulawayo, namely K. B. Davies. As a regulatory requirement, this formal supplier is obligated to submit quarterly reports on imported quantities and record which buyers it sells to. The company has been visited by the local expert and the reports on imported quantities have been requested from the authorities, but no actual data on quantities imported and sold and information on customers have been obtained.

Trade routes

A study was conducted in Zimbabwe, with the aim of elucidating the origin and routes of informal mercury trade in the country. This study was based on semi-structured interviews with stakeholders and on participatory investigations in active ASGM sites within the goldfields of Shurugwi, Gweru and Kwekwe in Midlands Province in central Zimbabwe.

Several officers from the Zimbabwe Miners Federation asserted that South Africa is the main trader of mercury in Southern Africa, adding that mercury is smuggled as a result of the restrictions and lengthy import process imposed by the EMA. When enquired about the modality of informal inflows, they revealed that dealers smuggle mercury in 34.5 kg flasks (in haulage trucks) and repackage it into 1 kg syrup bottles that are sold off locally, with the resource ultimately distributed in teaspoon portions. It is believed that Zimbabwean and South African traders participate in the trade. One officer of Gold Miners Association, following corroboration from an insider in South Africa, was able to confirm that mercury originates from South Africa in large canisters (flasks). He elaborated "In South Africa, these packages are imported from Russia, sold to traders at a price of ZAR 2,500 (USD 183) and transported across the border via small hired vans locally known as Malaisha Cars". Further, he disclosed that an associate involved in this trade purchases two to three of the canisters and repackages them into 1 kg bottles for sale.

According to a one-time manager of a custom milling center, who formerly sold mercury to small-scale miners, the resource is smuggled from South Africa in canisters, wherefrom it is repackaged into 30 g, 50 g, 0.5 kg and 1 kg parcels. He identified two of the South African importers as Merlin Chemicals [note: not among the South African supplier identified in this study] and a lesser known Indian company, remarking that the smuggling is facilitated by corruption amongst custom officials at border checkpoints. The now freelance metallurgist also pointed out that Indian mercury is of higher quality than Chinese mercury, which is comparatively impure and costs USD 10 – 20 less per kg. "Indian suppliers have the capacity to furnish up to 150 kg per week, and once offered me a stock at a price of USD 140 per kilo," he narrated. From his account, gold buyers play a notable role in the distribution of mercury to ASG miners as part of their credit arrangements with them, and similar involvement is demonstrated by gold custom milling centers. One jewelry owner who deals in the legal purchase of gold from small-scale miners divulged to have

sold small packages of mercury to ASG operators in the past, maintaining that this business line has been terminated given that the local market was challenging. By the account of the ASM Project Leader of PACT, workers employed in a number of large mercury-reliant mines allegedly steal the resource for clandestine sale, thereby feeding into the black market. "I know of dealers who import mercury in 34.5 kg flasks across the border using public buses," he added. Furthermore, he stated that mercury reaching Zimbabwe originates from the USA, wherefrom it transits through Switzerland before entering South Africa.

A number of informants from the Institute of Mining Research (University of Zimbabwe) noted that, locally, mercury is distributed further downstream by millers and pharmacies situated in ASGM areas. A South African based supplier of small-scale mining equipment was approached for further information on the trading channels in South Africa. It was informed that Protea Chemicals, amongst other suppliers, is known to sell mercury in South Africa. He affirmed that Zimbabwean gold buyers fetch mercury from South Africa and that smuggling out of the country is rampant in the border town of Beitbridge. The smuggled mercury is contained in canisters and is portioned into 1 kilo (or less) packaging, most often into medicine bottles for subsequent distribution further down the supply chain. An employee of a local mining supplies provider that was formerly licensed to import mercury for local distribution revealed that the company sold off an average of 15 flasks (equivalent to 510 kg) per month during its peak period, stating that they were not dealing in mercury any longer.

According to a mine owner, an average of 300 grams of mercury is purchased every month for production at the site. He shared that mercury used at the mine is bought mainly from Chinese suppliers, and from numerous mining chemical stores located in the towns of Kwekwe, Kadoma, or Chegutu. “Aside from mercury, the Chinese sell other chemicals, as well as mining equipment, and have dominated the local supply chain as they are currently the cheapest,” he mentioned. On average, mercury is priced at around USD 100 per kilo (September, 2016), although regular customers can purchase it for as low as USD 75 per kg. Smaller portions sell for between USD 8 and USD 10 for 30-50 g. Generally, the larger the quantity purchased, the lower the price. Mercury supplied by the Chinese is sealed in plastic bottles weighing a kilo, while that from other suppliers is sold out in smaller quantities (e.g. full teaspoons sold in small plastic bags). It is alleged that most mercury suppliers smuggle the resource through Baitbridge, paying off drivers of inter-state buses to ensure their parcels are smoothly transported across the border, in which case the drivers either conceal the stocks or bribe custom officials.

The Mine Manager of a custom mill quoted the price of mercury as USD 150 per kilo and USD 10 per teaspoon measure (approximately 30 grams). Informants at the custom mill stressed that they have no stake in the supply chain given that mercury is provided entirely by the customers, and claimed to have no further knowledge of it.

In one visited mine, "mercury is used in the stamp mill and is ordered through the mine’s Bulawayo office,” explained the Mine Supervisor. A bottle with an official KB Davies label was produced as evidence of legitimate mercury procurement. As stated by the supervisor, a 30 g teaspoon of mercury costs US$10. He pointed out that the sale of mercury at the site is closely monitored by the mine owners and that around 2 kilos of mercury are consumed each month.

Six respondents from an informal Makorokoza site on Wandara Mine acknowledged that mercury is used heavily at the site and that it is purchased in small unlabeled bottles in Gweru at a price of USD 85 – 90 per kilo. It was established that 30 g teaspoon volumes are priced at USD 10, and these can extract up to 30 g of gold. Although the monthly consumption of mercury at the site could not be determined, its usage was depicted as significant.

Figure 8.2 The various types of mercury packaging for distribution in ASGM; clockwise from the left: a 34.5 kg canister (flask), bottle, vial, seal bag and knotted plastic packet

According to a mine owner in Gweru, mercury distributed in the area originates mainly from China and enters Zimbabwe via South Africa, where it courses through transit points in Durban and Johannesburg. “An increased demand for mercury has paralleled the growth of ASGM in the country, and this has been largely met by informal supply streams,” he narrated. The informant recounted his previous involvement in the local mercury supply chain, affirming that he no longer deals in furnishing the resource. Mercury is believed to be smuggled in private cars, trucks and buses through the Beitbridge border post, where parcels are concealed or custom officials bribed for cooperation. The resource is normally smuggled into Zimbabwe in canisters, though certain streams come in smaller parcels (1 kilo bottles), having been repackaged in South Africa. The main importers are Zimbabwean traders, as well as a few Chinese suppliers. The current price of a kilogram of mercury ranges between USD 90 and USD 110, yet the Chinese have recently priced the chemical for as low as USD 70 in some parts of the country. Prices have dropped during the past six months, from USD 120-140 to the aforementioned figures. Below bulk supply levels, mercury is commonly sold in smaller portions totaling 30 to 50 g. The amount differs in that some people use the common teaspoon, which measures about 30 g of mercury, whereas others may use a coca cola cap measurement, which amount to 50 g. The price is often equivalent, varying between USD 6 and USD 15, depending on locations and networks, amongst other factors. In South Africa, a kilo may cost as little as USD 45, owing to unrestricted mercury trade and distribution. During the period of 2010-2011, a kilo would cost as much as USD 300-350. Some locals have specialized in this trade, with supply areas extending as far as Tanzania. Tanzanian nationals also visit the country to fetch mercury stocks to Tanzania. This trans-boundary trade is likely to have grown following the establishment of cyanide plants by Zimbabwean operators in Tanzania.

As with value chains of gold, the supply chain of mercury should be envisaged as a triangle, with several major sellers on top, and a large network of increasingly small suppliers comprising the lower ranks. In a final remark, the informant noted that, in Zimbabwe, the supply chain is not dominated by gold-buyers. While some gold buyers do sell mercury, it appears that the majority of mercury suppliers are sellers of mining chemicals and equipment and other retailers.

Actors in the mercury value chain

In light of the information provided by the interviewees, the actors comprising the country's mercury supply chains can be categorized as follows:

- K. B. Davies, the country's only formal mercury importer and retail shop located in Bulawayo.
- Small-scale business people, who purchase a few kilos in South Africa or Zimbabwe and sell it on, often in smaller quantities, with a profit.
- Gold buyers, who sell their gold in South Africa and bring back mercury, which they sell to miners, often on credit subject to the miners selling their gold to them at a price where the mercury cost is deducted.
- Large-scale sellers, who import several hundred kilos a month and have their own distribution networks.
- Sellers of mining chemicals and equipment, who are considered to dominate the supply chain; of these, Chinese traders are the most favorable as they provide the cheapest supplies.

Mercury is readily available throughout the country, especially in towns and settlements close to the mining activities. It is sold in shops selling mining equipment, pharmacies, and by gold buyers and custom millers.

It is alleged that mercury is sold in certain pharmacies situated within ASGM areas, particularly in the town of Kadoma.

Quantities and prices

In the first round of consultations (March 2016), the price of mercury was quoted as ranging from USD 120/kg to USD 160/kg, with smaller portions (30-50g) selling for roughly USD 10. In the course of subsequent field visits, however, a kilo was reported to cost between USD 70 and USD 110, and 30-50 g portions priced as low as USD 6-15. Mercury from China, claimed by some to be of comparatively low quality, was previously reported to cost between USD 120 and 130/kg, and more recently, USD 70/kg in some areas. Prices higher that USD 300/kg have been noted for the period 2010 to 2011.

Sources of liquid mercury other than import

No sources of liquid mercury other than import have been identified.

8.4 Results of ASGM sample sites investigations and initial national baseline estimates

Site investigations took place on 6-9 September 2016 with the participation of one international expert, one local expert and three trainees. The following sites were investigated:

Site	location	Coordinates	Key characteristics
Big Valley Masters/Toss Up Mine (BVM)	Shurugwi Town, Midlands Province	UTM 7856935.9 35K 770581.2	A formal custom milling site with small-scale hard rock based mining operation, having 4 stamp mills and up to 20 underground gold reef-mining shafts. Only mercury is used to extract gold using concentrate amalgamation. It also operates dump processing plant. Retorts are not used. The mine employs about 150 miners
Castle 4 Mine	Felixburg, Gutu District, Masvingo Province	UTM 7850375 36K 275000	A small formal custom milling site with 1 stamp mill and up to 10 underground gold reef-mining shafts. Stamp mills used with concentrate on slides followed by washing pans with mercury. Amalgam is burned in the open. The mine employs about 120 miners. It also has dump treatment plant

Site	location	Coordinates	Key characteristics
Chimona Mining Company (Mirage 4 Milling Centre)	Plot 13, Cycle V, Shurugwi	UTM 7855786.8 35K 770983.5	A small formal hard rock based operations custom milling site with 3 stamp mills. The site operates an underground mine shaft in the vicinity with 1underground gold reef shaft. Mercury mostly added to concentrates in washing pans, through stamp milling, with amalgam burned in the open. It has a dump treatment plant. The site employs 30 miners
Pistol 10 Mine	Kwekwe City	UTM 7948553.5 35K 762696.1	A formal small-scale, hard-rock based operation milling site with a hammer mill and dump treatment plant. Mercury added to concentrates in the separator, with amalgam burned in the open
Wizard 17 Gold Mine	Umfuli Banks Farm, Chegutu East District	UTM 7992245 36K 0211265	A formal small-scale mining site with hard rock based operations on 10Ha land. It has 3 active reef-mining shafts and no processing facility on site. Mercury applied to concentrate in washing pans, cyanidation used at custom mills. The site has 25 miners working on site. Retorts not used

Data for each site are provided to the Ministry of Environment in the form of an Excel reporting system with the site data and national summaries and the site investigation forms.

The summary of the results are shown in the table below (none of the investigated sites were alluvial).

Site type		Hard rock
Number of sites with information on population of miners and basic site information		5
Number of sites with detailed site investigation (level 1-3)		5
Number of miners (rounded, distribution mathematics)	Min	174
	Max	216
Number of miners (simple sum)	Min	166
	Max	224
Average number of miners per site		39
Total gold production, kg/year (best estimate from each site)		62
Total mercury-based gold production, kg/year (best estimate from each site)		62
Percentage of gold production based on mercury amalgamation		100%
Total gold production by whole ore amalgamation, kg/year		-
Percentage of gold produced using whole ore amalgamation (of total mercury-based gold production)		0%
Percentage of gold produced using whole ore amalgamation (of total gold production)		0%
Total gold production by amalgamation from concentrate, kg/year		62
Percentage of gold produced from concentrate (of total mercury-based)		100%
Total consumption of mercury (recycled mercury subtracted), kg/year		71
Total consumption for whole ore amalgamation (recycled mercury is not subtracted), kg/year		-
Total consumption for amalgamation from concentrate (recycled mercury is not subtracted), kg/year		71
Total quantity of mercury recovered from amalgams and sponge gold, kg/year		0
Total recycling rate (% of total used for extraction) (excl. recovery from tailings)		0%
Mercury recovered from tailings and other waste, kg/year		0

Site type		Hard rock
Total releases of mercury to air, kg/year		62
Total releases to water and land (incl. tailings), kg/year		9
Compound mercury to gold ratio (average of all processes) (not accounting for recycling)		1.1
Mercury to gold ratio, whole ore amalgamation		
Mercury to gold ratio, amalgamation from concentrate		1.1
Number of sites where mercury is used (fully or partly)		5
Percentage of sites where mercury is used (fully or partly)		100%
Number of sites where whole ore amalgamation is applied (partly or fully)		0
Percentage of sites where whole ore amalgamation is applied (all sites with detailed investigation)		0%
Number of sites where retorts/fume hoods are regularly used for sponge gold production (fully or partly)		0
Number of sites where retorts/fume hoods are regularly used for gold doré production (fully or partly)		0
Percentage of sites with detailed site investigation where retorts/fume hoods are used (fully or party)		0%
Number of sites where mercury is recovered from tailings and other waste		0
Number of sites with extraction based gold estimate		4
Number of sites with income based gold estimate		1
Number of sites with alternative gold estimate		5
Number of sites with information on number of shafts/pit		4
Average number of shafts/pits per site (for sites with shaft data)		4
Average gold production per shaft/pit (for sites with shaft/pit data), kg/year		14.4
Average mercury consumption per shaft/pit (for sites with shaft/pit data), kg/year		7.2
Average gold production per miner, g/year		319
Average mercury-based gold production per miner, g/year		319
Average mercury consumption per miner, g/year (incl. miners not using mercury)		365
Average number of miners per site		39
Average annual income per miner, UGX/year		1,005
Number of sites where income data are available		1
Percentage women among miners (of total number of miners)		0%
Percentage children among miners (of total number of miners)		0%

The ASM population is estimated at 500,000; some estimates are higher than this, and most observers agree that the number is at least 500,000 miners. PACT (2015) uses an estimate of the ASM population of 500,000 for a socioeconomic baseline survey. It is not specifically indicated how many of these are involved in ASGM, but it is assumed to be the majority.

If the average mercury consumption per miner of 319 g/year from the site investigation is used for a first estimate, the total mercury consumption in the country for ASGM would be 180-200 t/year which is highly unlikely. As discussed in the lessons learned section, there is a clear indication that the counting of "min-

ers" by the site investigations is different from the counting in national inventories, an issue to be methodologically solved.

In Zimbabwe another methodological approach where the number of custom mills and the average production and mercury consumption per custom mill would be used may be a better estimation approach for the aspect of production where custom mills are involved.

The Global Mercury Assessment estimated the consumption of mercury for ASGM in 2009 at 12.5 - 37.5 t/year (mean: 25 t/year). In contrast to other countries in the region, it was assumed that 80% of gold was produced by whole ore amalgamation, resulting in significantly higher mercury to gold ratios than amalgamation from concentrate. At all five sites visited during the field training as part of this project, gold was produced by amalgamation from concentrates. This fact way indicate that amalgamation from concentrates is more common in Zimbabwe today, but more site investigations as part of the development of the national action plan are required.

The estimates used in the Global Mercury Assessment originate from the Global Mercury Project (GMP) report for Zimbabwe (GMP, 2007). The report notes that the estimated numbers of people mining in Zimbabwe has varied considerably. In early 2006, estimates suggested there could be as many as 500,000 miners in the whole of the country, while only 100,000 were active in 2007. In a study completed in 2006, the GMP surveyed mercury imports into Zimbabwe and concluded that official imports had totaled between 20 and 25 tonnes per year for the period 2001-2005 (before the current restriction that has resulted in a situation where the majority is imported illegally). The estimates of mercury consumption were based on these data. As most mercury is imported illegally at present, it is not possible to update the estimate on the basis of import data.

In the absence of newer data, the estimate from the Global Mercury Assessment is considered to constitute the best initial baseline estimate.

9 DR Congo

Due to the security situation in DR Congo, field training in ASGM sites have not been undertaken. Aside from an inception mission to Kinshasa in June 2016, information on mercury use and trade has been collected by local consultants working in the South Kivu province. The data on ASGM in the country are still scarce and do not allow for any baseline estimates.

9.1 The ASGM sector in DR Congo

Organization of sector

While there are some large-scale gold mining operations in the Democratic Republic of Congo (DRC), gold is predominantly extracted by the ASGM sector. Gold is extracted from rivers (alluvial mining) and underground deposits. In alluvial mining, panning and sluicing techniques are used. Underground mining is more laborious, employs larger teams of miners and requires more time and investment. Geenen's description of underground shaft mining within ASGM, based on observations in 2008, 2009 and 2011 in Kamituga, a town in South Kivu Province, provides a god example of how the ASGM sector is organised. According to a paper Geenen has co-written with Bryceson, the organization of gold extraction follows a three-tier division of labour with financiers, organizers and labourers. Financiers are usually gold traders who do not hold any title to the land, but use these investments to guarantee a supply of gold. Pit holders organize the work inside the pits. They usually possess many years of experience in mining or related activities (processing, trade), and some have worked for large-scale mining companies before the war in the DRC. Nonetheless, pit holders can, as well, experience a run of poor returns and be relegated to digging. There is fluidity in the work hierarchy arising from performance. Pit holders shoulder the brunt of financial risk for the mining operation. They hire labour, buy the necessary tools and conduct the mining. As such they are responsible for finding gold, and many of the risks and costs related to fruitless periods fall upon them. Generally, pit holders provide some equipment, batteries for torches, food and medicine for the diggers in periods of no mineral output. As these periods may last for several months or even years in some cases, costs can mount to high sums. Diggers can be divided into different categories, depending on the type of work they do. The drillers (foreurs in DRC), who work their way into the rock mainly with hammer and chisel, are typically young men with some experience in mining and aged between 18 and 40, as the work is physically very demanding and potentially dangerous because of collapsing tunnels (cave-ins). The peleteurs (DRC) remove the waste material and gold-bearing rocks in wheelbarrows or jute bags from the pit. They are typically younger and/or less experienced and receive a smaller share in the production. In addition, specific tasks are carried out by specialized workers who are usually paid a certain amount of cash or quantity of rocks (Bryceson and Geenen, 2016).

Until 2011, underground mining in Kamituga was hardly mechanized, except for some water pumps and compressors. However, Stoop et al. (2016) report on the introduction of ball mills by local cooperatives. Part of the grinding work that was formerly done by women (locally called 'mamans twangaises') is now done by ball mills that work faster and at a lower price. However, Banro Corporation, a Canadian large-scale mining company with concessions in the area, has forbidden the use of ball mills and any other technique that may make ASGM more productive, such as dynamite or electric drilling following the launch of its extensive exploration project in Kamituga (Stoop et al., 2016: 19). The company says it agrees to 'tolerate' ASGM within its concession, as long as the techniques stay 'purely artisanal'. Semi-industrial gold mining is therefore not officially allowed (although it does take place). As a result of this policy, crushing mills are currently concentrated in one mining site (Calvaire), which increases transport costs.

Number of mining sites and geographical distribution

Gold is predominantly extracted in the Eastern part of the country in the former provinces of South and North Kivu, Katanga, Orientale, Maniema, and Equateur. However, gold is also found in the far west of the country, in the Province of Bas Congo, close to the border with Angola.

According to the German Federal Institute for Geosciences and Natural Sciences (BGR), there are 2,700 mines (or ASM sites) in the DRC, 814 of which are gold mines/sites. The provincial distribution of the gold mines/sites is shown in Table 9.1.

Table 9.1 The provincial distribution of gold mines in the DRC

Province (of time of the study)	Number of gold mines/mine sites	Today provinces	Comments
Equateur	1	Nord-Ubangi, Mongala, Sud-Ubangi, Équateur, Tshuapa	Real number likely to be higher
Katanga	48	Tanganyika, Haut-Lomami, Lualaba, Haut-Katanga	
Maniema	105	Maniema	
North Kivu	201	North Kivu	
Orientale	252	Ituri ,Haut-Uele,Tshopo, Bas-Uele	
South Kivu	207	South Kivu	

ASM and ASGM population

Beyond its productive capacity and economic value, ASM is counted as one of the most important livelihoods in the DRC. Drawing on available data, the World Bank has estimated the number of people in the country directly or indirectly dependent on ASM to be between 8 and 10 million, or 14 to 16 percent of the total population (World Bank, 2010). Available estimates for the number of artisanal miners in the Kivu province taken from 2007 and 2010 put the figure between 200.000 and 350.000 (D'Souza, 2007; Pact, 2010). Since 2011, following a governmental ban and an international embargo on 'conflict minerals', many miners who were previously employed in 3T (tin, tantalum, tungsten) exploitation shifted to gold mining as it is lucrative and easier to smuggle (Geenen, 2015). This trend has been characteristic of the Congolese ASGM sector. For instance, production of artisanally-mined gold in South Kivu and East Province (former name of the province where the current Ituri and Haut Uele are situated) was estimated to be 12.000 kg in 2008 (World Bank, 2008), with official gold exports from South Kivu recorded as just 65 kg in the same year (Geenen and Radley, 2013).

Applied extraction methods

According to traders and miners, all gold-bearing ore is ultimately processed by mercury, predominantly through concentrate amalgamation. As stated by the Technical Coordinator from the Artisanal and Small-Scale Mining Section of the Ministry of Mines, there is a shift within the ASGM sector towards formalization and the introduction of mercury-free extraction methods including ACQUAREGIA, acid chloride, etc., though these initiatives appear to be mainly ministerial and donor-driven with little traction among the large number of artisanal gold miners. A parallel, and possibly more significant, trend goes towards the introduction of cyanidation, with some plants having been recently constructed by Tanzanian investors in South Kivu.

Figure 9.1 *Concentrates are mixed with water in a ratio of 1:5 using a small basin (1 small basin of sediments, 4 basins of water). This is transferred into a bigger basin to which 3 to 6 pen caps of mercury are added, at which point the contents are mixed for 10 to 15 minutes. This amount of mercury (3 to 6 pen caps) can be reused 4 to 5 times, before replenishment with an additional pen cap becomes required.*

Legislation

The DRC's 2002 Mining Code and 2003 Mining Regulations prohibit the usage of mercury within the country's mining sector. Moreover, the establishment of 'transformation points' in the value chains of artisanally mined products are subject to authorization by the Provincial Divisions of Mines, as per Article 238 of the regulations. Cyanide and mercury, amongst other hazardous chemicals, can only be used in gold-processing workshops approved by the ministry, and it is illegal for ASGM miners to use these directly.

9.2 Trade statistics of mercury, mercury-added products and gold

Comtrade statistics on import/export of mercury

No import of mercury was ever recorded in the Comtrade database. An export from Kenya of 4 tonnes was reported in 2010 while around 100 kg/year was reported by South Africa in 2013. The data indicates that the mercury is mainly imported through informal channels.

Table 9.2 *Export of mercury 2010-2015 in kg to DRC by country (Comtrade database)*

	2010	2011	2012	2013	2014	2015
Kenya	4,093	nd	nd	nd	nd	nd
South Africa	10	41	1	120	11	nd
Total	4,103	41	1	120	11	nd

Statistics on gold production and trade

According to data from USGS Minerals Yearbook from 2013, the total production of gold in the DRC from industrial mines was 17 t/year. The gold was exported as doré.

According to the Coordinator of Justice Pour Tous, artisanal and small-scale miners produced gold in North Kivu and South Kivu provinces. Most gold exports were undeclared with some of the gold exports from Burundi and Uganda allegedly being re-exports from the DRC. Between 5,000 and 7,000 kg/year of gold was produced at 15 large mines and between 70 and 100 smaller mines in North Kivu and South Kivu provinces combined. Furthermore, between 6,000 and 7,000 kg/year was produced at 813 sites in Ituri Interim Administration, which included 343 sites in Mambasa Territory, 230 sites in Djugu Territory, and 209 sites in Irumu Territory (also refered to by USGS, 2013). Armed groups in Eastern DRC, including the Forces Démocratiques de Libération du Rwanda and units of the Congolese armed forces, obtained revenue from the illegal taxation of artisanal and small-scale miners. The number of sites referred to here is not identical to the number indicated in the previous sections, which illustrated that data from this country are still uncertain and incomplete.

Based on the available information, gold production from ASGM in DR Congo was at least 11,000-14,000 tonnes in 2013. All available information indicates that amalgamation from concentrate is used. If a default mercury to gold ratio of 1.3:1 is used, gold production corresponds to 14-18 tonnes mercury. The Global Mercury Assessment 2013 estimates the mercury consumption in 2012 at 3.8-26.3 t/year (mean value 15 t/year) which is in accordance with the reported gold production estimate.

The gold export is not registered in the Comrade Database.

Table 9.3 Production of gold 2010-2013 in the DRC (USGS, 2013)

Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year	Note by USGS
2010	2011	2012	2013			
12,000	12,000	14,000	17,000	no	6,000 at mines at 813 sites in Ituri Interim Administration	"Gold, mine output, Au content"; Estimated; estimated data are rounded to no more than three significant digits; artisanal and small-scale miners and industrial production

Table 9.4 Net export of gold (Commodity code 7108) 2010-2015 from DRC (Comtrade database)

Net export, kg/year					
2010	2011	2012	2013	2014	2015
Nd	Nd	nd	nd	nd	nd

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9.3 Informal information on mercury use and trade flows

Trade of mercury

Informal in-country trade flows are gaining increased attention in view of the downward importation trend indicated by official trade statistics and widespread anecdotes of unofficial trading channels feeding into the country's ASGM sector.

Trade routes

As part of the project, a rapid study was carried out locally with a view to elucidating, as precisely as feasible, the origin and routes of informal mercury trade in the DRC. This course of research was based on semi-structured interviews with stakeholders and on participatory investigations in ASGM sites within the town of Kamituga.

Kamituga town, located about 180 km southwest of the provincial capital Bukavu, originated as a colonial gold mining town in the 1930s and boomed along with artisanal gold mining activities from the 1980s until the early 2000s (Geenen, 2015). With about 190,000 inhabitants (compared to about 56,000 in 1999, 45,000 in 1994 and 33,000 in 1992), the town is now the third largest city of South Kivu, after Bukavu and Uvira (Geenen, 2015; Stoop et al, 2016). An estimated 15,000 miners have been reported to operate in the township. Stoop et al (2016) refer to a census done by miners' cooperatives in 2013, in which 13,600 artisanal miners were enumerated. The authors compiled a list of 15,290 miners in the combined membership lists of the local miners' committees. The most recent count of 16,000 miners was established in a census carried out in 2015. The number has been fluctuating around 15,000, in correlation with security and climate conditions as well as market dynamics and politics (such as the governmental policies and international measures concerning artisanal mining).

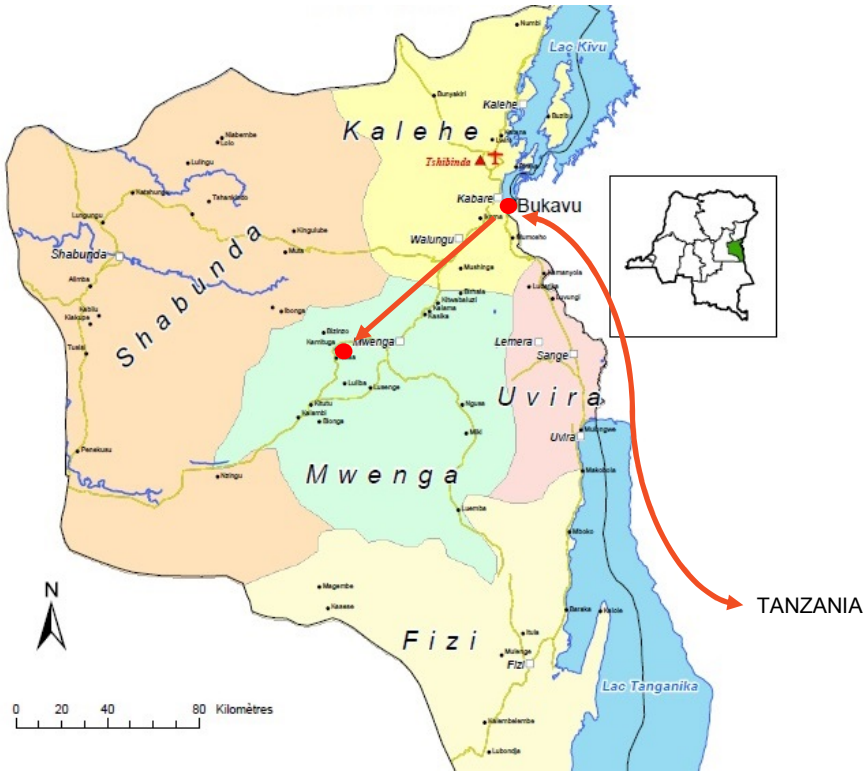

Figure 9.2 Map of South Kivu showing mercury trade routes (orange arrows) and key transit points (red dots)

An initiatory literature review served to provide an overview of DRC's informal mercury trade flows. Previous studies have shown that prior to 2012, mercury was smuggled mostly from Tanzania. The underground market underwent a period of dire shortage following the demise of a key importer, whereafter informal trade flows from Tanzania were re-routed through Uvira, a border city situated along the coast of Lake Tanganyika. Since then, the smuggling courses through this entry point to a transit point in the city of Bukavu, from which it is transported to numerous inland mining areas. There have been reports of recent mercury sales by unknown traders in Kamituga.

In the mining sites, mercury is supplied by gold-brokers who customarily sponsor and resource miners from whom they buy gold. As per the standard arrangement, gold-buyers provide ASG miners with credit, implements, equipment and other consumables on the condition that the miners supply them with the gold produced. Small traders in mining sites are tied to larger traders in the provincial capital through chains of credit and debt relations, as they are to ASG miners.

In an interview, the Mission Director of the Environmental Agency of Congo expressed interest in the study, but was unable to share additional insights into the country's informal mercury trade flows given that the institution has been operational for only four months, with scant findings obtained thus far. He did, however, affirm that mercury is still widely used within the ASGM sector and conveyed the speculation that local gold-buyers play an important role in the domestic distribution of mercury. The Technical Coordinator of the Mine Sector Support Project (Ministry of Mines) stated that the local mercury supply is controlled by clandestine networks, the bulk suppliers of which remain unknown. Further, he alluded to the suspicion that some of the larger laboratories and chemical companies are permitted to illegitimately import and sell mercury due to political favoritism. "There are also anecdotes of mercury being extracted in the provinces of Katanga and Bas Congo," he mentioned.

The Coordinator of Justice Pour Tous, a local environmental NGO centered on the mining industry, provided his view on the informal supply chain of mercury and its end-markets. "The entirety of ASGM in the province of South Kivu is reliant upon mercury, which streams mainly from Burundi and Tanzania," he stated, adding, "In the province, mercury supplies are furnished by middlemen who operate in a highly covert manner given that mercury usage is banned for the mining industry, yet in many areas, the supply chain is dominated by gold brokers". He enumerated Tanzania, Burundi, Uganda and Kenya as the source countries for mercury supplies in the provinces of South Kivu, Maniema and Katanga, and pointed out that Ugandan traders are alleged to supply the resource to the Eastern Province. According to the informant, the foreign traders are predominantly Muslim and are known to trade with their Congolese Muslim counterparts. He specified the local mercury prices as CF 30,000 to 50,000 (USD 30-50) per bottle and CF 10,000 per beer-bottle cap (USD 10), remarking that these offerings are very affordable, considering that miners can opt for the barter arrangement with gold-buyers.

Actors in the mercury value chain

Although little has been established regarding the informal trade flows of mercury in the DRC, findings from the literature review and interviews with credible informants indicate that the local mercury value chain is comprised of the following actors:

- East African traders – who traffic bulk supplies across the border to dealers;
- Middlemen – who specialize in the smaller-scale trade of mercury, supplying smaller packages to downstream markets within mining areas;
- Gold brokers – who sponsor ASG miners (from whom they purchase gold) and sell mercury to them under different arrangements;

› Chemical companies – it is alleged that some chemical distributors and laboratories import mercury and sell it locally.

Quantities and prices[2]

In the DRC, the standard quantities for mercury sale to ASGM operators are the spoon and the pen cap. A spoon can be bought for CF 14,660 – 19,548 (USD 15 – 20), depending on seasonal variations in market accessibility (Kamituga is hard to access during the rainy season), whereas a pen cap is sold for CF 4887 – 5864 (USD 5 – 6). In Bukavu, ASGM users have quoted the price of bulk supplies as CF 293,220 (USD 300) per kilo, though numerous interviewed traders acknowledged recent purchases at prices as low as 127,062 (USD 130) to 195,480 (USD 200) per unit kilo. By other accounts, a measure of mercury equal to the volume of a beer bottle cap costs CF 10,000, while larger, indeterminate quantities are sold in small bottles for between CF 30,000 and CF 50,000 (USD 30 and 50) (photo of bottle provided).

Sources of liquid mercury other than import

According to one informant, there are far-fetched anecdotes of mercury extraction in the provinces of Katanga and Bas Congo.

[2] The exchange rate as at September 28, 2016.

10 Burkina Faso

10.1 The ASGM sector in Burkina Faso

Number of mining sites and ASGM population

The number of ASGM sites in Burkina Faso is estimated at about 600, according to the Ministry of Mines and Energy.

According to information obtained from Ministry of Mines and Energy and Ministry of Environment, 500,000 to 1 million people are involved in ASGM activities in the country. The 500,000 are those who mine directly while the remainder includes people who have related activities on the site, e.g. gold buyers, others trade activities, etc. The miners work for 9 months a year (from October to June). No detailed site inventory exists.

Applied extraction methods

Hard rock mining accounts for 90-95% of the ASGM while the remaining 5-10% is alluvial.

According to the Ministry of Mines and Energy and the Ministry of Environment, all ASGM sites use mercury. Other informants estimated that cyanidation and gold particle collection accounted for 5% of the total.

Some semi-industrial miners use cyanide subsequent to using mercury on the concentrate. One informant indicated that 19% of the sites have been using cyanide for the last three years.

One hundred percent of the mercury is used for amalgamation from concentrate, and no examples of whole ore amalgamation have been identified.

Certification

The Ministry of Mines and Energy issues two licenses:

- AEA exploitation artisanal license. AEA is basic gold washing using mercury in the last stage of gold extraction.

› PESM permit for semi mechanized artisanal groups. These miners have more equipment and do not use mercury, but reportedly use cyanide in the drums during milling.

The table below shows the number of licenses of both types issued over the last 10 years and the estimated gold production.

Table 10.1 Number of licenses

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
AEA	101	154	183	167	171	146	149	188	230
PESM	2	3	4	6	13	18	23	27	32

Table 10.2 Gold production by licensed miners, tonnes

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
AEA	0,2	0,4	0,3	0,5	0,5	0,5	0,9	0,5	
PESM	0	0	0,1	0	0,1	0	0,1	0,01	

Considering the estimated gold production from ASGM mentioned below, it is evident that the licensed mining operations account for a very small part of total ASGM gold production.

UNIDO-USDOS co-funded project in Burkina Faso, Mali and Senegal

In an ongoing study conducted by the Artisanal Gold Council (AGC) in Burkina Faso, as part of a UNIDO-USDOS co-funded project in Burkina Faso, Mali and Senegal, the AGC has been working to improve inventory estimates on the number of ASGM miners, ASGM gold production, and ASGM mercury usage in Burkina Faso (AGC, 2015). The inventory assessments were completed in 2012, at which point there were 243 legal small-scale concessions and hundreds of informal ASGM sites. The study forms the background for the estimates from the Global Mercury Assessment cited below (AGC, 2015)

National mercury inventory

The national mercury inventory from 2007 estimated the total mercury consumption for ASGM in Burkina Faso in 2006 at 0.73 t/y[3] based on a more limited database.

10.2 Trade statistics of mercury, mercury-added products and gold

Data on import to Burkina Faso and export to Burkina Faso as reported by partner countries from the UN Comtrade database is shown below. Until the EU export ban went into force there were some exports from EU countries recorded, but no data are available for the period 2012 to 2014.

The recorded import is well below the consumption of mercury for ASGM of 25-46 t/year estimated in the Global Mercury Assessment.

3 http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/A_Inventories/Burkina%20Faso%20Inventory.pdf

Table 10.3 Import of mercury (28 05 40) 2010-2015 in kg to Burkina Faso by country (Comtrade database)

	2010	2011	2012	2013	2014	2015
France	51	1,048	nd	nd	nd	14
Germany	972	nd	nd	nd	nd	nd
China	nd	1,968	nd	nd	nd	nd
Total	1,023	3,016	nd	nd	nd	14

Table 10.4 Export of mercury (28 05 40) 2010-2015 in kg to Burkina Faso by country (Comtrade database)

	2010	2011	2012	2013	2014	2015
Belgium	862	nd	nd	nd	nd	nd
France	100	nd	nd	nd	nd	nd
Spain	<un	1,932	nd	nd	nd	nd
Togo	nd	6038	nd	nd	nd	nd
China, Hong Kong SAR	nd	nd	2,724	nd	nd	nd
Total	3,860	7,970	2,724	nd	nd	nd

Statistics on gold production and trade

According to the data from USGS Minerals Yearbook from 2013, the total production of gold for industrial mines increased from 23 tonnes in 2010 to 33 tonnes in 2013. This figure does not include ASGM, indicated to fluctuate between 1 and 10 tonnes per year in the Yearbook. The reported export of gold is some 5-10 t/year higher than the reported mine output. In 2015 the majority of the gold was exported to Switzerland (29 t) and India (6 t).

Table 10.5 Production of gold 2010-2013 in Burkina Faso (USGS, 2013)

Production, kg/year *				ASGM included	Estimated ASGM production, kg gold/year	Note by USGS
2010	2011	2012	2013			
22,939	31,774	27,850	32,714	no	no data	"Does not include production from artisanal mining, which was estimated to fluctuate between 1,600 and 5,000 kilograms per year."

Table 10.6 Net export of gold (Commodity code 7108) 2010-2015 from Burkina Faso (Comtrade database)

Net export, kg/year					
2010	2011	2012	2013	2014	2015
27,778	40,772	34,221	36,709	42,232	41,811

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10.3 Informal information on mercury use and trade flows

Trade routes

According to interviews with representatives from the Ministry of Mines and Ministry of Environment, the mercury trade routes are unknown to the administration.

All informants interviewed indicate that mercury is imported from Togo or Ghana. There is no indication that any mercury originates in the North from Mali or Niger.

According to information from the ASM miners' association, mercury flows in Burkina Faso are the result of illegal trafficking organized with some Burkina Faso citizens who emigrated to Ghana many decades ago. These people learned from Ghanaian miners how to process gold. Many years later, they came back and shared their technology with their relatives and friends who also became artisanal miners. In this technology transfer, they introduced mercury into gold mining practices in Burkina Faso. Thus, these migrants in Ghana currently supply mercury to artisanal miners in Burkina Faso, and to many countries in West Africa. At the end of the chain, these same mercury suppliers are the buyers of the large amounts of gold produced by ASGM. The gold bought by these dealers is sold covertly, not under the control of the mining administration.

The major trade routes were confirmed by information provided by another interviewed organization. Mercury used in ASGM in the sites managed by this organization (about 0.5 tonnes) generally comes from Ghana and Togo. It arrived in the ports of Lomé (Togo) or Tema or Takoradi (Ghana). The contact persons in these ports collect the mercury and pack it in different types of containers (5 kg, 25 kg or 50 kg). These mercury containers are transported by truck, pickup truck, private cars or motorbikes. To achieve their destination in Burkina Faso, they used unpaved roads in the bush, or roads where police control is minimal. The transport may take three days to two weeks before arriving in Burkina Faso where the mercury is stored in villages far from main town or cities. When mercury is needed for use in one ASGM site, a container is sent to that site. All of these activities are performed through organized trafficking with several people involved, possibly at high level positions in the administrative and political sphere.

According to information from the customs office in Burkina Faso, customs frequently impounds bottles of mercury being smuggled using buses traveling to Burkina Faso from neighboring countries, mainly Togo. If the smuggler was captured then he would be sent back to Togo with the mercury. If, however, the smuggler escaped, then the captured mercury is sold by auction by the customs office to legal mercury dealers.

Information from several interviewees in Northern Côte d'Ivoire indicated that the main route for mercury entering the Northern mining sites in Côte d'Ivoire is from Ghana via Burkina Faso. In one specific example, the trafficking was organized by the site owners, the gold buyers and their supplier based in Burkina Faso. The suppler in Burkina Faso had its wholesaler in Ghana. The site owner in Côte d'Ivoire could not purchase the mercury directly from the wholesaler in Ghana.

Another site owner in Northern Côte d'Ivoire confirmed that the mercury to extract gold comes from Burkina Faso where it is imported from Ghana. According to the site owner, in Ghana, mercury is removed from ships during their cleaning and packed in bottles or containers of 5 liters. This mercury is mixed with wastes; once wastes are evacuated from the harbor to dumping sites, mercury containers are removed from the wastes and sent to wholesalers. Then the mercury is sent to Burkina Faso using unpaved roads

where there is minimal control by police or customs (information in accordance with the information from the Burkina Faso informants above). If the information is correct, it indicates that the mercury may also be illegally shipped from the exporting country as the mercury is hidden within the ship. Mercury is sold at a price of CFA 40,000 or 50,000 kg (USD 69- 86) by suppliers in Burkina Faso. If artisanal miners and site owners based in Côte d'Ivoire want to buy mercury in Ghana, the price also goes up to around CFA 70,000 and 90,000/kg (USD 120-154/kg). These figures are in accordance with information from other informants, indicating that suppliers from Burkina Faso have the control of mercury trade in this part of West Africa.

Actors in the mercury supply chain

The main suppliers of mercury to the ASGM miners and sites owners are the local gold buyers. The information on trade routes provided above indicates that the gold traders are also involved at higher levels in the supply chain where the gold traders deliver mercury to the local gold buyers. The available information on official importers of mercury in Ghana (see Ghana country report) shows that many different companies are involved in import, but each of the companies has only notified one shipment. This low rate of notification could indicate that the importers are just importing the mercury, but are not otherwise involved in the mercury trade, and that the mercury traders buy empty space in containers on a case-to-case basis.

Quantities and prices

The mercury, once in the country, is sold at a price of 40,000 - 80,000 CFA (approximately USD 69 - 145)/kg. This price varies according to supply and demand and the destination. Thus, in a period where the offer is high, the cost will be low and vice versa. In the case that mercury is sent to another country such us Côte d'Ivoire, the price will increase.

Sources of liquid mercury other than import

No sources of liquid mercury other than import have been identified.

10.4 Results of ASGM sample sites investigations

Due to the rainy season, ASGM sample sites investigations were not undertaken in Burkina Faso. In order to collect field information on mercury trade, an investigation was instead undertaken in cooperation with local experts in Burkina Faso and Côte d'Ivoire. The result of this study is reported in the previous section on trade.

National mercury inventory

The most recent inventory of mercury use in ASGM is based on data collected through a two year period (2011-2012). No detailed data is available for an update of this inventory. The inventory will be updated as part of the development of the National Action Plan within the next two years.

Burkina Faso was used as an example for calculation of the mercury use for ASGM in the Global Mercury Assessment 2013 (UNEP, 2013a); the following is extracted from that assessment.

The Director of the Ministry of Mines, Geology, and Quarries estimates 600,000 adults living on 221 ASGM sites that are registered as ASGM exploitation permits. At least the same number inhabits and operates on unregistered land. The 600,000 is well in accordance with the current estimate of the miner population.

The results used for the estimated were as follows [author's comments in brackets]:

- All ASGM activities use Hg. This began around year 2000. [This seems still to be the situation]
- Whole ore amalgamation is never done. Concentrate amalgamation is done. [This is in accordance with information obtained from the Ministry of Mining]
- Mercury activation is not practiced. Miners do not throw away dirty Hg. Miners never use retorts or recycle Hg in other ways – amalgam is burned using an open flame.
- The amount of Hg used per unit gold produced is on average 1.3 parts mercury to 1 part gold (i.e. a mercury to gold ratio of 1.3:1). This accounts for the Hg that ends up in the amalgam (1 part) and the Hg that is lost during processing to the tailings (0.3 parts).
- 200,000 of the 600,000 official ASGM population (1 in 3) are estimated to be active miners. [Today's estimate is that the number of active miners may be as high as 500,000]
- They produce 20 to 30 tonnes of gold per year (~25 tonnes).

According to the assessment, these estimates are reasonable considering i) the known geology (abundance of gold-bearing formations of sufficient grade throughout the country), ii) the gold production per miner using the observed processing techniques, and iii) through a socio-economic assessment based on the cost of living at ASGM localities. This estimate was discussed with the gold buyers and site owners and the Ministry of Mines and was found to be reasonable by these groups. The amount of Hg used and emitted to the atmosphere is thereby determined as follows: 25 tonnes of gold are produced annually, all of which is amalgamated using 32.5 tonnes of Hg per annum.

In 2013, the registered export of mercury from Burkina Faso exceeded the reported gold production from industrial scale gold mining by approximately 4 tonnes. These 4 tonnes may have been produced by ASGM and officially exported. The remainder of more than 20 tonnes is exported illegally. As indicated for the mercury trade above, the same persons are involved in the illegal mercury and gold trade; the gold is likely illegally exported via Ghana and Togo.

11 Lessons learned

The following section summarize the lessons learned using the methodology described in the practical guideline for ASGM site investigations developed by Artisanal Gold Council (AGC, 2015) and the methodology for national baseline estimates developed as part of this project. Because of the main focus in this project on mercury trade, the training and field investigations focused on those aspects directly used for estimating the gold production and mercury use and releases. Furthermore, a main objective of the field work was collection of information on mercury trade and value chains concurrently with the field training.

The lessons learned may be used for the further application and improvement of the methodologies and tools.

11.1 Field investigations

11.1.1 Definitions used

Definition of "miner"

There is no common understanding as to what workers on a mining site should be included under the term "miner". The term "miner" is used in the guidelines to represent the workers involved in extraction; the guidelines distinguish between "miners", processors and concession holders. The number of miners is estimated by multiplying the number of shafts/pits on the site with the average number of miners per shaft/pit. The number of miners are used in the income-based estimation of gold production where the income of this group of workers, and the share of the total gold production on the site this group receives, are used for the estimation of total gold production. As long as the definition of "miner" is consistent on each site, this method is applicable.

However, the number of miners at the investigated sites is also used for extrapolation, where e.g. the average gold production per miner is multiplied with the estimated number of miners in the country. The total number of miners would typically constitute more workers than those involved in the extraction.

The process can be divided into a number of functions (here exemplified for hard rock mining):

- Extraction of the rock
  - Digger (including drilling and blasting)

  - Haulers (rope pullers)
- Transport for processing
- Processing of the rock
  - Crushing
  - Milling
  - Concentration
  - Amalgamation

Some workers may be involved in more than one of the processes but often the processes are separated between different workers. In Burkina Faso, ASGM miners typically operate in 5–10 person partnerships consisting of representatives of all these functions, whereas in other countries functions are separated and the processing may e.g. take place in other parts of the site than the extraction does, typical of Uganda and Tanzania, or elsewhere at milling sites, as is the case in Zimbabwe.

Besides these functions, we may add persons involved in management or providing various services: security guards, managers, developers, food suppliers, gold buyers, etc.

From workshop discussions with participating counties, a common definition of "miners" as those directly involved in extraction, transport and processing emerged. It is recommended that this definition is used in future inventories.

For a reasonable extrapolation, it is necessary at the national level to clearly define who is included in the number of miners. It is necessary to provide the total number of miners on the sites. In addition, the number of miners involved in the extraction of the ores may be estimated if this number is used for the income based gold production estimate.

With the methodology used for estimating number of miners as well as gold production and mercury use per miner applied in this project (focusing on the workers involved in extraction), there is a tendency to overestimate total gold production and mercury use in the country if the total number of miners in the country using a wider definition (including e.g. extraction, transport and processing) is used for extrapolation.

The results of the site investigations clearly indicate that the gold production and mercury consumption per miner is overestimated using the applied method. Whereas the regression line for the available data on miner population and mercury consumption in Sub-Saharan Africa, shown in the main report, indicates an average of 70 g mercury/miner/year, the national averages of investigated sites in this study range from 94 g mercury/miner/year in Côte d'Ivoire to 319 g mercury/miner/year in Zimbabwe. From one of the most comprehensive studies from the region, Persaud (2015) estimated an average production of 67 g mercury/miner/year in Senegal, close to the average of 70 g mercury/miner/year from the larger data set. The president of the ASM association in Senegal estimated an average of 100 g mercury/miner/year. Some differences between countries may be expected if the data indicates a general trend toward overestimation.

Table 11.1 Average annual gold production per miner by country

	Average gold production per miner, g/year
Senegal	269
Uganda	310
Tanzania	124
Ghana	310
Zimbabwe	319
Cote d'Ivoire	94

A likely reason the for overestimation of the national total is some differences in the numbering of "miners" in the site investigations and the national estimates including:

- The site investigations have focused on the miners involved in the extraction process, whereas the national estimates likely include all persons involved in extraction and processing, and possibly also some of the workers providing other services.
- The site investigations include miners as "full-time" miners, whereas the national inventories include all persons who have been involved in mining activities within the year.

It is crucial for the applicability of the method for national baselines that the definition of a miner is given clarity.

11.1.2 Extraction based gold estimates

The site instigation forms and reporting systems were developed to make the calculations for each site based on one extraction method only. It was expected that it would be most common that one extraction method was predominant at each site and, for simplicity, data was collected and represented for this method with only some minor modifications if other extraction methods were applied as well.

More than one extraction and processing methods

It turned out that it was common to have both hard rock mining and alluvial mining at the same site. In addition, at some sites, different processing methods were used with varying mercury to gold ratios. The method was robust enough to incorporate that both whole ore amalgamation and amalgamation from concentrate were used at a particular site, but could not incorporate more kinds of processes taking place (an issues that was only experienced as a problem at one site). The experience was that it was complicated to make average estimates across different methods and the estimations became less transparent.

Further development of the site investigation forms and reporting system to include separate investigations for the different extraction and processing methods is recommended. In this way, more information has to be collected and processed but the calculation will be more transparent.

Collection data for alluvial sites

The methodology is strongly focused on hard rock mining and omits some details about alluvial mining. Expanding the data collected for alluvial extraction is recommended in order to ease the extraction based gold production estimates for these sites.

No use of mercury

The site investigation forms did not allow for collection of various data on sites where mercury was not used. This has been corrected in the form and data collection system.

More generic methodology for the extraction based gold production

The methodology for extraction based gold production is applicable for hard rock mining sites with relatively well-defined shafts/pits where it is possible to estimate gold production on the basis of the gold in the ore extracted in each of the shafts/pits. Experience, including examples from Nicaragua shown by Artisanal Gold Council at the closing workshop for this project in Entebbe, shows that for some sites the extraction based gold estimate is better obtained on the basis of information from the processing steps. Instead of counting shafts/pits, rather the number of ball mills or custom mills and the average amount of ore processed in these mills may be used for the estimate.

Extending the methodology for extraction based estimates to a more generic methodology is therefore recommended, where the gold production is estimated from:

> gold production = ore units extracted/processed per production unit * number of production units * gold extracted per ore unit

The ore units may be sacks, tonnes or another unit; the production units may be shafts, ball mills, sluices, customs mills, etc. In order to make it straightforward for the site investigators to select a method, it should be considered as to whether the method should still consist of a limited number of pre-defined methods.

11.1.3 Income-based production estimate

The income-based estimation of gold production is challenging and more time is needed at each site if useful income-based data is to be obtained. The method basically estimates gold production using the average income of the miners involved in the extraction, information on how much of the gold these miners receive (in the example in the guidelines, the shaft leader and concession holder take half of the ore) and the number of people within this group of miners. The methodology illustrated in the guidelines is applicable for a situation where the miners also do further processing of the ore. In other set-ups, as the situation was in e.g. Uganda and Zimbabwe, the miners involved in the extraction sell the ore and are not involved in the further processing. In this case, it is necessary to extent the scope of the assessment to include more groups of workers. The site investigation form was not equipped for that situation and the gold production per miner using the income-based estimation method overestimated the actual production.

As for the extraction based method, preparing a more generic method may be considered, where different groups involved in extraction or processing from which the most reliable and consistent information can be obtained, are used as basic units for the estimates. In any case, it would be an advantage to have some more specific guidelines on how to estimate the average income of the group of miners used for the calculation.

According to the guidelines, the gold price should be indicated as a percentage of spot price. However, it should furthermore be possible to indicate the actual price received, as this was the information which in most instances was provided by the miners.

11.1.4 Differences between the two estimation methods

Due to the complexity of the sites and the limited time for site investigation, gold production at the sites could only be estimated with at high uncertainty. The uncertainty is indicated as the difference between the two independent estimates: the income based and extraction based estimates.

The uncertainties regarding the site investigations are indicated by the example with data from Tanzania in the table below. The differences between the two estimates is high for each site, but taking the average of five sites reduces the differences between the estimates. With an inventory of e.g. 40-60 sites, the uncertainty on the average gold production and mercury consumption per miner would be low.

The site investigations were undertaken as part of a training where it was prioritized that the trainees learned about processes and limited time was available for actual data collection. With a trained team and more time per site (for a more thorough investigation, two days per site seems more appropriate), the uncertainty could probably be reduced significantly. What is more important for an accurate estimate of mercury use on the site is the qualitative or semi-quantitative information collected from all sites, used for the monitoring of progress with regard to the requirements of the Minamata Convention (application of whole ore amalgamation, use of retorts, cyanidation of mercury containing tailings, etc.).

For the extrapolation to the national baseline inventory it is, however, of utmost importance that the definition of miners is the same for all investigations (including screening investigations described below) and that the data estimation method is not biased; it should not systematically over or underestimate the actual production and/or consumption.

As mentioned above, the estimation methods could be described more generically and adjusted to the actual situation at the different sites. However, it would also be important to have clear guidelines for the inventory teams to follow, to prevent that new, inadequate methodologies are invented by the team for each site. Even with some training in site investigations, the teams would likely not have the necessary technical training for development of new estimation methods.

Table 11.2 Gold production per miner estimated by the two methods. Five investigated hard rock sites in Tanzania.

	Lwamagasa	Mawemeru	Mgusu	Nyambale Gold Mine	Nyarugusu Village	Average	Standard deviations	Weighted average *
Number of miners **	36-72	400-900	250-750	14-42	300-450			
Gold production per miner, (extraction based) g/year	15	173	71	670	108	207	265	129
Gold production per miner (income based), g/year	167	105	58	103	214	129	61	118
Difference in % of average	168%	49%	20%	147%	66%			9%

* Sites with a large number of miners have higher weight than sites with a small number.

** Includes mainly the miners involved in the extraction.

11.1.5 Subsequent cyanidation

At many sites, the mercury containing concentrate and other tailings are further processed in cyanide plants. The plants are typically located away from the other ore processing operations for safety reasons. The plants do not use mercury but may mobilize the mercury in the tailings. Information on cyanide processing is not included in the guidelines. Extending the site investigation and reporting system with the following information is recommended:

- Percentage of concentrate from the amalgamation step, which is subsequently processed in cyanidation plants
- Percentage of tailing before amalgamation subsequently processed in cyanidation plants
- Estimated gold content in the tailings subsequently processed in cyanidation plants

The cyanidation step may influence the total mercury consumption at a site, and in addition contribute to the production of gold from ASGM in the country. For the extrapolation it is, however, necessary to know how much of the total ASGM gold production is coming from cyanidation plants. Including the cyanidations plants as separate sites in the national inventory with specific calculation methods could be considered. Alternatively, on the basis of experience from a few sample plants, and knowledge of the percentage of concentrate and tailings subsequently processed in cyanidation plants, it may be possible to prepare estimations of the possible gold production by the subsequent cyanidation.

It is assumed that the number and scale of cyanidation plants in ASGM in Sub-Saharan Africa will continue to grow, which understates the importance of including these in the mercury inventory methodology.

11.1.6 Purity

The guidelines mention the purity of the gold (expressed in carats) but do not include the purity in the calculation examples. The purity has not been taken into account; however, in development of the method taking the purity into account in all calculations should be considered.

11.1.7 Detailed interview forms

The site investigation form included information at an aggregate level, where the information typically is obtained by asking questions of different people. The intention is that the site investigator take notes and performs an estimate of the most likely values by combining the different kinds of information obtained. Different information would be available at different sites, and the site investigator would have to critically assess the information obtained - e.g. some informants appear to be well informed and trustworthy, while others are not. The site investigation form had some additional space for personal notes. The experience was that the personal notes taken during the investigations were not useful for others apart from the investigator, and the final estimates consequently were not very transparent.

A decision was made not to prepare interview forms, although for some parts of the investigations it may have been an advantage in order to better document the basic information obtained. The guidelines contain some recommendations regarding which questions should be asked, but not in a systematic manner. We recommend developing some more specific interview guides for different parts of the investigation that the investigators can bring to the field and use when undertaking interviews in order to ensure that the most relevant questions are asked to the right persons. We recommend that the personal notes are stored electronically along with the site investigation forms.

11.1.8 Data quality levels

In order to assess the quality of the different estimates used for triangulation, an indication of data quality levels was introduced. The levels were dependent on the number of actors interviewed and the consistency of the information obtained. The site investigators considered it difficult to use a system combining number of interviewees and consistency. For simplicity, developing a system based only on number of interviewees is proposed.

11.1.9 Data completeness and application of paper forms

The site investigation forms included different options for filling in information and the completed form consequently contained many empty fields. This method increased the risk of missing information because it is difficult for the investigator to check if all necessary information is filled in.

With the suggested revisions of the calculation methods (using more generic methods), and addition of more site information, the paper forms may end up being extensive. Furthermore, electronic forms, where only questions for the selected method appear on the screen, would be an advantage in order to ensure a complete dataset for the methods selected. In addition, electronic forms which can be automatically uploaded by the end of the day into the fields would facilitate easy quality control of the data, while the investigator is still close to the site. We propose developing electronic data collection forms and are aware that such forms are under development by UNITAR.

11.1.10 Time needed for training and site investigations

The training sessions consisted of about 1.5 days' workshop training (in addition to one workshop day concerning mercury trade and country baselines) and 3-4 days' field training. For a deep understanding of the different types of sites and the different ways to organize the work, needed for the development of efficient site-specific data collection strategies, it is proposed that the field training should last for at least one week. Furthermore, it is proposed that training should last for 2 days at each site in order to have time to analyze the collected data and go back into the field and fill in data gaps and fine-tune the estimates.

It should be noted that knowledge about the sector is an asset, but for inventory work, experience in careful data collection and data handling, following a consistent methodology, is equally important. Furthermore, it is recommended that the information collected is regularly checked by an ASGM inventory expert.

11.1.11 Three level approach for site investigations

As discussed below, it is crucial for the national inventory that some information is available for the entire sector. Even if highly detailed information is available for 30% of the sector, national estimates for the entire sector would be highly uncertain if limited data are available for the remaining sites (it would not be known that the investigated sites represented 30% of the sector).

We therefore propose a three-level approach for the investigations:

- Screening level investigations for virtually all sites in the country. As part of the screening, a first estimate of number of miners is made (e.g. from information obtained from local mining offices, claim owners, ASM associations etc.). Furthermore, qualitative, easily observable information is obtained: mining type, use of mercury, use of cyanidation, use of mercury-free methods, application of whole ore amalgamation, etc. The data may be obtained from site visits or from local officials that know the sites,

› Detailed quantitative site investigations of 30-60 representative sites in accordance with the guidelines, not only covering parameters relevant for mercury use and releases but also a number of other relevant parameters

› Targeted investigations e.g. of mercury to gold ratio for main processes and ore types in the country, efficiency of retorts used in the country, more detailed investigations with the aim of better understanding of the sector, etc.

Ideally, the screening level investigations should be undertaken before the detailed quantitative site investigations in order to use these data for the planning of the site investigation program, but it may be more resource-efficient to undertake both types of investigations in parallel to reduce travel time and travel costs.

11.2 Country baselines

The reporting system is efficient in monitoring various parameters such as gender composition, amalgamation method, average gold production and mercury consumption per miner, recycling rates, etc. for investigated sites. Overviews of these data used for planning of further management of mercury use on the sites are provided by the system as illustrated in section 0.

In addition, the summary provides average key figures applied for extrapolation of the country baseline. With a limited number of sample sites, the key figures remain too uncertain for actual extrapolation, but the principles have been illustrated in the reporting system worksheets provided to each of the participating countries for which site investigations have been undertaken.

It was the experience from the training workshops that the principles and methods for extrapolation and development of country baselines were difficult to understand for the trainees within the time allocated for this. Furthermore, the trainees obtained limited experience with the use of the system with the actual data from the site investigations. It was prioritized during the site investigation that the trainees would use as much time as possible in the field to get a better understanding of the field conditions and the methodologies for field investigations.

As the national GEF-financed projects concerning the national action plans for ASGM (NAPs), including the national baseline for mercury use in ASGM, have not started yet, the countries have not had resources for undertaking field investigations beyond those undertaken as part of the field training, and they have not had resources for working with the calculation tool and reporting system.

At the moment, the implementing agencies responsible for implementation of the NAPs are in the process of clarifying which tools and reporting systems should be used for the inventories to be undertaken as part of the implementation of the NAPs. COWI is participating in the discussions on possible tools and reporting systems and has presented the reporting system developed as part of this project to the agencies. Back-to-back to the closing workshop in Entebbe on 15-16 September 2016, a meeting was held to discuss the way forward for the development of these tools. The meeting was attended by representatives from UNEP, UNIDO, UNITAR, COWI, Artisanal Gold Council and a number of NGOs expected to be involved in the development of the NAPs in Sub-Saharan Africa. The discussions currently continue in an informal discussion group consisting of the aforementioned organizations and WHO. It is expected that the implementing agencies will make a final decision regarding the tools and reporting system to be used in the near future.

According to information from Artisanal Gold Council, an update of the guidelines for site investigation is under preparation, and waiting for this update is recommended before any changes to the site investigation forms and reporting system are implemented.

12 Abbreviations and Acronyms

ASGM	Artisanal and small-scale gold mining
CAS	Chemical Abstracts Service
CF	Congolese Franc
CFA	Name of two currencies used in Africa which are guaranteed by the French treasury: West African and Central African CFA
CN	Combined Nomenclature (used in trade statistics)
DRC	Democratic Republic of the Congo
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
GCLA	Chemist Laboratory Agency
GHS	Ghanaian Cedi
NIMH	National Institute for Medical Research
PML	Primary Mining Licenses
TMAA	Tanzania Minerals Audit Agency
TZS	Tanzanian Shilling
UGS	Uganda Shilling
UN	United Nations
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USD	United States of America dollars
USGS	United States Geological Survey
t	Tonnes = 1000 kg
WB	World Bank
WHO	World Health Organization

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Appendix 1 Reporting system documentation