

Developing Baseline Estimates of Mercury Use in Artisanal and Small-Scale Gold Mining Communities:

A Practical Guide

Version 1.0



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GOLD COUNCIL**



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Foreword



This guide is an educational and training document that can be used as a practical introduction to conducting baseline estimates of mercury use in artisanal and small-scale gold mining (ASGM) communities. The guide has been designed to assist governments, civil-society organizations and the private sector in carrying out mercury inventories in ASGM communities, with the primary purpose of providing the baseline needed to measure progress in transitioning away from mercury use. This guide is designed to supplement already existing documents by showing practical field methods that can easily be implemented by a wide variety of stakeholders.



Developing Baseline Estimates of Mercury Use in Artisanal and Small-Scale Gold Mining Communities: A practical Guide

One of the purposes of this guide is to help with the implementation of the Minamata Convention obligations, as specified in Article 7 and Annex C. In particular, the guide addresses the following:

Article 7:

Paragraph 3: Each Party shall notify the Secretariat if at any time the Party determines that artisanal and small-scale gold mining and processing in its territory is more than insignificant. If it so determines the Party shall:

Paragraph 3(a) Develop and implement a national action plan in accordance with Annex C

Paragraph 3(c) Thereafter, provide a review every three years of the progress made in meeting its obligations under this Article and include such reviews in its reports submitted pursuant to Article 21.

Annex C, obligations for National Action Plans:

1(a) National objectives and reduction targets;

1(d) Baseline estimates of the quantities of mercury used and the practices employed in artisanal and small-scale gold mining and processing;

1(g) Strategies for involving stakeholders in the implementation and continuing development of the national action plan;

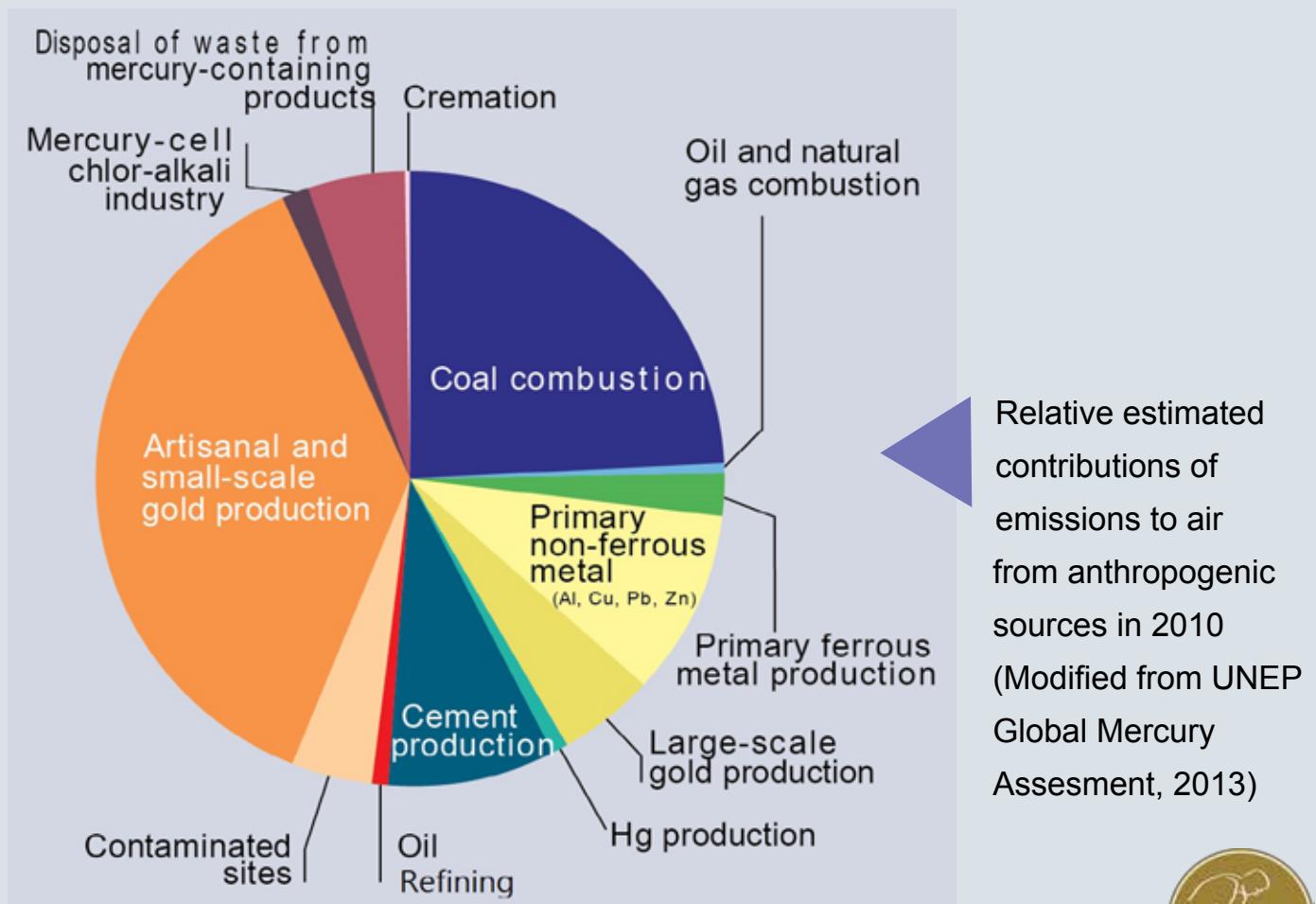
1(j) Strategies for providing information to artisanal and small-scale gold miners and affected communities.

For a thorough discussion on topics covered in this guide, readers may also want to consult UNEP's Toolkit for Identification and Quantification of Mercury Releases; Reference Report and Guideline for Inventory Level 2, version 1.2, 2013, Session 5.2.2 Gold and silver extraction with mercury-amalgamation processes (ASM).



Why Carry Out Baseline Estimates?

Inventories in ASGM provide important baseline information from which governments and other stakeholders can formulate action plans, prioritize and develop intervention strategies and monitor improvements. ASGM has been identified as the world's single largest source of anthropogenic mercury emissions, further highlighting the need for improved mercury inventories in the sector. Improving the ASGM sector and developing sound policies requires a continuous focus and consistent reporting, particularly, in the context of the Minamata Convention, reporting on mercury use.



ASGM Today

- *10-15 million miners in more than 70 countries
- 100 million livelihoods supported by the sector
- Approximately 80% of the sector is informal
- Approximately 15-20% of global gold production (400-500 tonnes/year)
- Direct economy of approximately \$20 billion USD and secondary economy of \$100 billion USD
- Largest source of anthropogenic mercury emissions and releases to the environment (~1600 tonnes/year)

*Estimations for the scale of the ASGM in terms of population and economy, mercury emissions and gold production are based on anecdotally used information and further research is required.



Mercury in ASGM



- ASGM is the largest source of mercury emissions and releases to the environment at ~1600/tonnes per year
- Mercury is a global pollutant that can be transported through the atmosphere and aquatic pathways, contaminating fish worldwide and putting billions of people at risk
- As a powerful neurotoxin, mercury has deleterious effects on humans, plants and other wildlife, and acute effects on people in mining communities where it is used



How is Mercury Used and Lost?



Why is Mercury Used in ASGM?



- It is quick and easy to use
- It is portable and can be used independently and rapidly by miners
- It is relatively effective at capturing gold when there are no other options, but often captures less than 40%
- It is easy to access by miners
- It is relatively inexpensive
- There is a lack of awareness of, and access to, alternatives
- There is a lack of awareness and understanding of the negative health and environmental effects



Key Information Required to Estimate Mercury Use on ASGM Sites

1. Is mercury used?
2. What are the ore treatment/production methods?
3. How much mercury is consumed per unit of gold produced?
4. How much gold is produced?
 - 4.1 - Using the ore extraction based method
 - 4.2 - Using the miner earnings based method



How can this information be collected?

- informal or semi-structured interviews with individuals and groups;
- direct observations;
- counting and physical measurements;
- analysis of official government and trade data;
- structured surveys;
- in some cases, the use of GIS or satellite imagery.

In all cases, adequate sample sizes should be used to improve confidence in the findings (the larger the better).



Key Information Required: Mercury Use

Is mercury used?

On a mine site there are various ways to determine if mercury is being used. Simply asking may not be the best approach; but observation can yield quick answers

What does the gold look like that is being sold on the site?



We refer to this gold as “sponge gold” because of the porous appearance that results from the evaporation of mercury from the amalgam upon heating



Is there equipment that points toward mercury use such as retorts or blow torches?

Gold dust generally has not been produced with mercury



Key Information Required: Ore processing methods

2 What are the ore processing methods?

It is important to understand how mercury is being used. There are two general methods that are helpful to understand in order to make mercury use estimates.

2) Concentrate Amalgamation

Mercury is added to a small portion of the total material processed - a concentrate. Most of the mercury loss occurs to the atmosphere when the amalgam is burnt.

1) Whole Ore Amalgamation

Mercury is added to all or most of the material being processed. Most of the mercury is lost to the tailings (waste) which are typically discharged into water or soil.



Whole ore amalgamation in a 'Rastra'. Mercury is added to all the material that is milled by the turning rocks.



Mixing mercury into a concentrate

See examples in

- UNEP, A practical guide: Reducing mercury use in Artisanal and Small-scale Gold Mining. ISBN 978-92-807-3282-5



Key Information Required: Mercury to Gold Ratio

Measuring Method

The amount of mercury used to produce a given amount of gold is often expressed as a ratio (Hg:Au). If known, this ratio may be used to determine the amount of mercury used on a site/in a country, based on the amount of gold produced. The Hg:Au ratio will differ depending on a variety of factors, and for this reason physical measurements are important.

3 How is the Mercury:Gold Ratio Determined?

This ratio allows mercury use to be determined from gold production estimates.

Whole-ore amalgamation consumes roughly 5 units of mercury per unit of gold (5 Hg: 1 Au); however, this can range from anywhere between 3 and 50 units of mercury per unit of gold.

Concentrate amalgamation consumes roughly 1.3 units of mercury per unit of gold (1.3 Hg: 1 Au); however, this can range from between 1 and 3 units of mercury per unit of gold.

Determining the Hg:Au ratio involves measuring the weight of mercury before amalgamation, the excess amount that doesn't form amalgam, and measuring the weight of sponge gold after it is burned. This determines the amount of mercury lost for the amount of gold produced. A simple formula for calculating this is:

$$\mathbf{Hg\ (total)\ -\ Hg\ (excess)\ \div\ Au\ (sponge)\ =\ Hg:Au}$$

It is also useful to measure the weight of amalgam before burning to determine the amount of mercury versus gold in the amalgam.



Example: measuring the Hg:Au ratio for concentrate amalgam



1. Weigh the total amount of mercury before it is applied to the concentrated ore.



2. Weigh the excess mercury not forming a part of the amalgam.



3. If possible, weigh the amalgam formed after mixing the mercury with the concentrated ore, to better understand the loss of mercury to air versus water/soil.

Example (continued)



4. Weigh the sponge gold remaining after burning.

5. If possible, weigh the gold doré after the sponge gold has been melted in order to understand the % of residual mercury remaining in the sponge (often 5%). This is valuable to know, because sponge gold is often burned in gold shops, located in populated areas.



Key Information Required: Gold Production

4

How much gold is produced?

In order to use the Hg:Au ratio to calculate total mercury use on a particular site, a gold production estimate is required.

Gold production is a sensitive topic, and asking about it directly may not yield results.

Instead, an estimate can be derived indirectly, based on a series of questions and observations. Estimates of gold production typically require knowledge about the number of active miners and the size of the local mining economy. The

methods for determining this information can vary depending on the context and may include:

- Interviews with miners, gold buyers, and other key stakeholders / informants
- Demographic and household surveys
- Counts and observations
- Official reports and trade data



Key Information Required: Gold Production

Two approaches are commonly used to estimate gold production; an **extraction based** estimate and an **earnings based** estimate. The information required to determine gold production using these approaches typically requires understanding total miner population as well as the following specifics:

4.1) Extraction based gold production estimate



- How much ore is extracted from a shaft per day/week?
- How many shafts are on the site?
- How many workers per shaft?
- What is the average ore grade/gold purity?

4.2) Earnings based gold production estimate

- What is the average income of a miner?
- What is the price of gold?
- What is the division of wealth?
- What are the hours/days of work?
- Total miner population



Key Information Required: Gold Production (extraction based estimate)

4.1

How much ore is extracted from the site?

Total gold production can be estimated if the total ore extracted, and average ore grade/karatage are known. This information may be determined through interviews, observations, and physical counts.

To collect the required information the investigator should:

- Conduct miner surveys/interviews asking:
 1. How many workers are there per shaft?
 2. How much ore is extracted per shaft per day?
 3. What is the grade and purity of the gold?
- Conduct a physical count of shafts on site. The investigator should be led around the site by a local authority pointing out all active shafts.

Note: A similar method based on total ore processed may be used. For example, calculating the total number of active mills and their throughput may allow for an extrapolation of gold production if coupled with known ore grade. This may be especially useful in the case of local toll milling operations.



(See Annex 3 for an example mine shaft survey)

Key Information Required: Gold Production (earning based estimate)

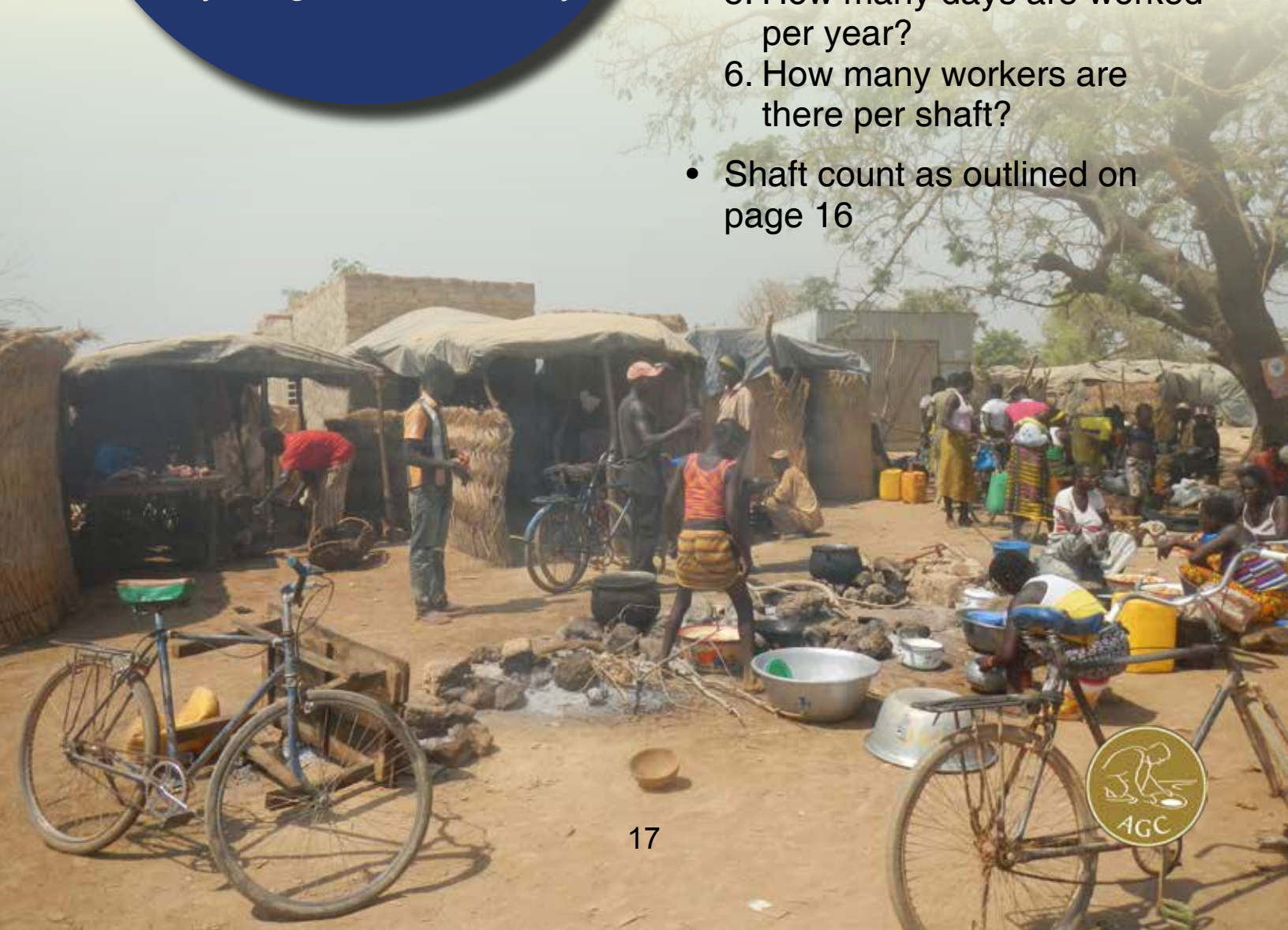
4.2

How much money do the miners earn?

This can be determined through interviews with miners, household surveys, and by gaining an understanding of the cost of daily living in the community.

To collect the required information the investigator should:

- Conduct miner surveys/ interviews asking:
 1. Daily miner income?
 2. On site price of gold?
 3. How are the mining proceeds divided?
 4. How many hours are worked per day?
 5. How many days are worked per year?
 6. How many workers are there per shaft?
- Shaft count as outlined on page 16

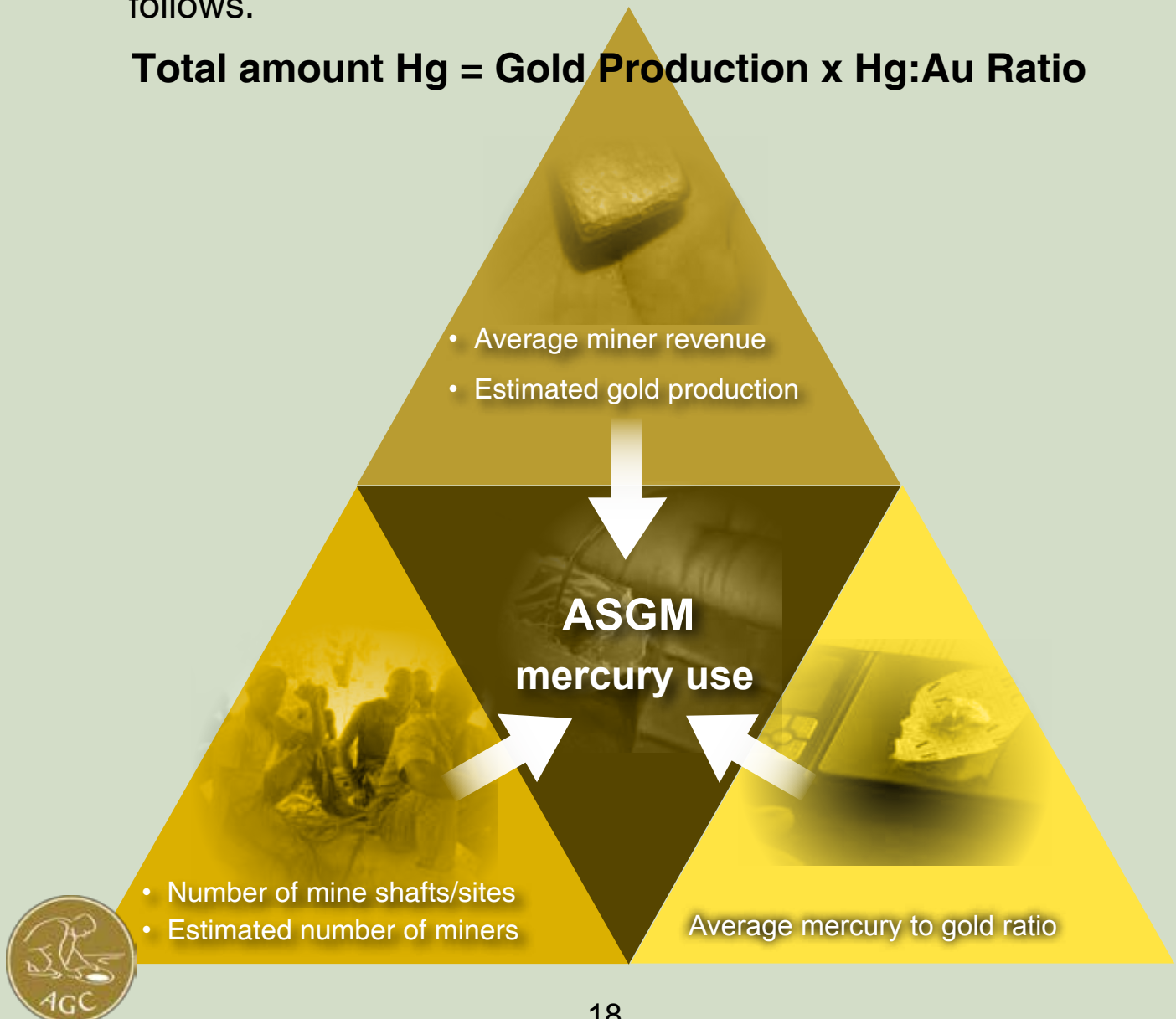


Putting it all Together

Triangulating the Information

Once all of the required information is collected, triangulation may be used to produce site specific and national estimates of mercury use in ASGM. This requires using the various lines of information as discussed previously, from a significant number of mining groups, to formulate an estimate. An example triangulation exercise follows.

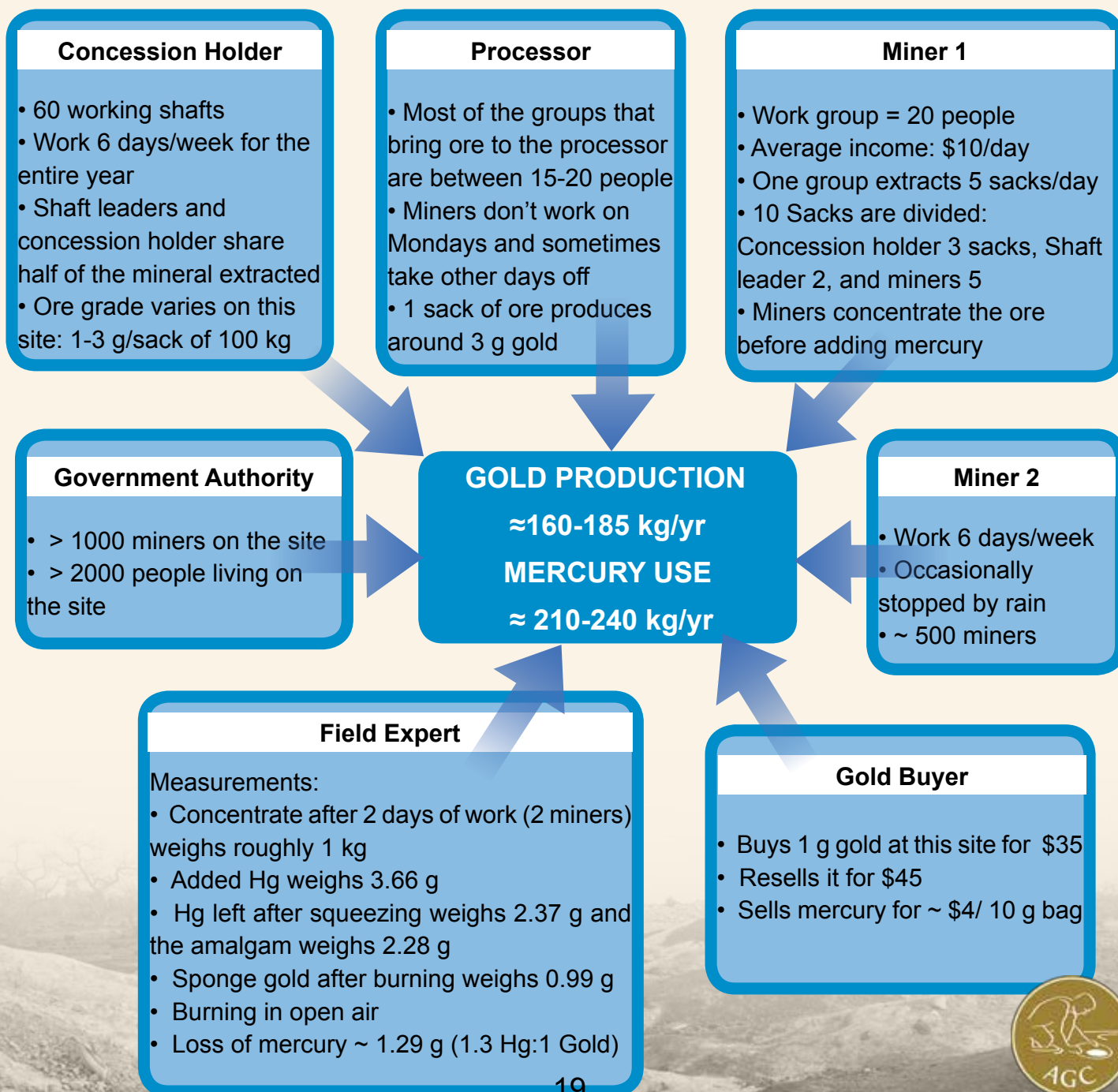
$$\text{Total amount Hg} = \text{Gold Production} \times \text{Hg:Au Ratio}$$



Gold Production Estimate

Rapid Site Estimate Exercise (1/4)

This is a framework for an example exercise, where an estimate is derived through the cross-checking of various data points. To be confident about a site estimate, a significant number of miners/key informants should be interviewed. Information gained from various sources is outlined below:



Gold Production Estimate

Rapid Site Estimate Exercise (2/4)

Gold Production (From Miner Incomes)

Information Required (from page 19):

- Miner income per day = \$10/day
- Working days per year = 270/yr
- Average gold spot price over the year = \$50/g
- Distribution of gold produced = 50% of gold given to miners
- Miners per shaft = 20/shaft
- Total number of shafts = 60
- Percentage of spot received by miners = 70 %

1) Calculate total **number of miners**:

[Number of shafts x Number of miners per shaft = total number of miners]

[60 shafts x 20 miners per shaft = **1,200 miners** (Gov. report >1000)]

2) Calculate total **daily miner income**:

[Total number of miners x daily income per miner = total daily miner income]

[1,200 miners x \$10/miner/day = **\$12,000/day**]

3) Calculate total **annual miner income**:

[Total daily miner income x working days/year = Total yearly miner income]

[\$12,000/day x 270 days/year = \$3.24 million/year]

4) Calculate **annual miner gold production**:

[Total yearly miner income / (Average spot price x percentage of spot received by miners) = Annual miner gold production]

[\$3.24 million/(\$50/g x 70%) = **92.5 kg/year**]

However: this constitutes only half of the production (because the shaft leader and concession holder take half, so the total production would be closer to **184 kg**)



Gold Production Estimate

Rapid Site Estimate Exercise (3/4)

Gold Production (From Ore Extraction)

Information Required (from page 19):

- Number of Shafts = 60
- Daily ore extraction per shaft = 5 sacks/day
- Average ore grade = 2 g/sack
- Working days per year = 270 days/year

1) Calculate total **daily ore extraction**:

[Daily production per shaft x Number of shafts = total daily ore production]

[5 sacks/shaft/day x 60 shafts = **300 sacks/day**]

2) Calculate total **daily gold production**:

[Total daily ore production x ore grade = daily gold production]

[300 sacks/day x 2 g/sack = **600 g/day**]

3) Calculate total **annual gold production**:

[Daily gold production x working days/year = Total yearly gold production]

[600 g/day x 270 days/year = **162 kg/year**]

The estimates of gold production from miner income and gold production from ore extracted may be compared to determine the **difference in gold produced from different estimation methods**:

[Gold production (from miner income) - Gold production (from Ore extraction) = Difference in production from various estimation methods]

[184 kg/yr - 162 kg/yr = **22 kg/yr difference**]

Ideally, if time and data are available, both methods should be employed to reduce uncertainty in estimates. Indeed, this allows for a cross-check of estimate by comparing gold production obtained by each method. Although a difference can be expected, if the numbers vary greatly, we recommend gathering additional information to better constrain results.



Mercury Use Estimate

Rapid Site Estimate Exercise (4/4)

• Determine Hg:Au Ratio

Information Required (from page 19):

- Total Hg added = 3.66 g
- Total Hg remaining = 2.37 g
- Sponge gold produced = 0.99 g

1) Calculate total **Hg loss** during amalgamation:

[Total Hg added - Total Hg remaining = Hg loss]

[3.66 g - 2.37 g = **1.29 g**]

2) Calculate **Hg:Au ratio**:

[Hg loss / Sponge gold produced = Hg:Au ratio]

[1.29 g / 0.99 g = **1.3**]

• Determine Total Mercury Use

The Hg:Au ratio is used in combination with gold production estimates to produce total site mercury use estimates.

Information Required:

- Gold production estimate from either:
 - Ore extraction estimate = 162 kg
 - Miner earnings estimate = 184 kg
- Hg:Au ratio = 1.3

1) **Total extraction based Hg use estimate:**

[Extraction gold production x Hg:Au ratio = Total Hg use]

[162 kg x 1.3 = **210.6 kg Hg**]

2) **Total earnings based Hg use estimate:**

[Miner Earnings gold production x Hg:Au ratio = Total Hg use]

[184 kg x 1.3 = **239.2 kg Hg**]



Secondary Information (1/2)

Secondary information provides supporting evidence to cross-check mercury use estimates and the information on which the estimates are based. While assessing sites for mercury usage, additional information can be collected to gain insight and understanding on artisanal mining communities and the sector as a whole. For example, the cost of daily items such as food or water can give valuable insight into the purchasing power (and plausibility of estimated income) of an ASGM community, compared to a local non-ASGM community.



Production Method

- Type of mineral
- Organization of the site
- Presence of equipment
- Presence of outside groups
 - Tailings management
 - Retort use



Supply Chain

- Gold buyers
- Price of Gold
- Levels of gold buyers
 - Gold refining
 - Mercury supply



Social and Demographics

- Roles of men, women, and children
- Nationalities & interactions and related conflicts
- Distribution of income: family
- Distribution of wealth: community
- Types of work in the community
 - Alternative industries
 - Child Labour
 - Migration patterns



Secondary Information (2/2)



Available Services

- Health Clinics, Schools, and Infrastructure
- Transportation, state of roads
- Government representation
- Access to basic necessities
- Presence of security forces
 - Access to credit

- Presence of latrines
- Workplace security ex. Reinforced shafts, protective equipment and dust reduction,
- Organization of amalgamation areas
 - Fire protection



Hygiene & Safety

- Shaft organization on the site
 - Site hierarchy
- Division of labour and the role of women
 - Effect of the rainy season



Site Governance

Annex 1

National Estimates to Date

An updated database for national ASGM mercury use estimates can be found at www.mercurywatch.org. This database allows users to cross-reference ASGM and demographic data on an interactive map, and also to map their own ASGM projects.

Mercury Hg Watch
Charting the improvement of artisanal small-scale gold mining

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HOME ABOUT SERVICES GALLERY SPONSORS CONTACT DATABASE LOGIN

Map My Projects

Mean ASM Mercury
per
UN data live from UNdata

Mercury Released from ASGM (tonnes/a)

- no estimate made
- 0 to 1
- 1 to 5
- 5 to 10
- 10 to 25
- 25 to 50
- 50 to 500

View

Minimata Convention on Mercury Sep 09, 2014
Open for Signature for 334 days; result 102 countries have signed; 1 has ratified:
<http://www.mercuryconvention.org/Countries/tabid/3428/Default.aspx>

MERCURY (kilo) 75.42 GOLD:MERCURY ratio 0.45 GOLD (ozt) 1169.20 -3.70 SILV



Annex 2

Example Observation Checklist / Count

Name of site: _____

- Number of active shafts?
- Number of miners per shaft?
- Ore extracted per shaft per day?
- Average grade of ore?
- Number of active mills?
- Cost of using the mill per sack?
- Number of sluices?
- Cost of using sluices?
- Number of gold buyers?
- Price of gold being paid?
- Cost of mercury per bag?
- Number of merchants?
- Number of restaurants?
- Cost of a bottle of water?
- Cost of a soda?
- Cost of a beer?
- Cost of a meal in a restaurant?
- Cost of cigarettes?
- Cost of canned food?



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

Notes



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