Lecture 1
Introduction to ASGM
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ASGM
Overview

• What is ASGM?
• Geology and Gold
• Mineral Extraction
• Mineral Processing
• Mercury Use in ASGM
• Gold Supply Chains
• Formality and Governance
• Spatial Distribution & Seasonality
• Health and Environment
ASGM (Artisanal and Small Scale Gold Mining): Gold mining done by individual miners, communities, or small enterprises with limited capital investment and production. ASGM uses largely manual and semi-mechanised techniques.
Where does gold come from?
Where does gold come from?

- **gold vein**
- **disseminated gold**
- **gold in surface sediments**

Rock containing gold that is targeted by miners = **gold ore**.
To produce gold, the ore must be processed to remove the other minerals.
Ore Grade

The amount of gold in the ore (expressed in g/T)

- Range from <1 to >100 g/T
- Can vary significantly between sites, and even within deposits
• The “gold” recovered from ore is typically a mix of metals
• **Purity is the proportion of this mix that is gold**
  • Expressed in % purity (0 to 100%) or in karats (0 to 24K)
  • Can vary significantly between sites and less so within a site
Correcting from impure to pure (24K) gold:

Weight of gold \times \left( \frac{\text{purity of gold}}{24K} \right)

e.g., You have 100 g of 18K gold. How many g of pure gold?

\[ 100 \text{ g} \times \frac{18\text{K}}{24\text{K}} = 75 \text{ g} \]

100 g of 18K gold is 75 g of 24K gold
Mineral Deposits

Hard Rock Deposits
(Primary Deposits)

Soft Rock Deposits
(Alluvial Deposits)
Extraction – Hard Rock

Open Pit

Mine Shaft
Extraction – Hard Rock
Extraction – Soft Rock
Extraction – Soft Rock
Processing

Crush → Mill → Concentrate

Amalgamate with Mercury → Burn Amalgam → Smelt/Refine
Crushing reduces size of ore rocks

Manual Hammering  Jaw Crusher  Hammer Crusher
Milling

Reduces grain size further. Liberates gold from other minerals in the ore.

Good Liberation: grain size of the ore is fine enough to separate gold particles from other minerals.

* Proper grain size varies with ore.
Grain size Control

Improves recovery by ensuring the proper grain size for the best liberation of gold has been achieved.
Gravimetric Concentration

Removes non-gold minerals from the milled material, reducing the total volume of the milled ore and concentrating the gold particles within it.

Pan

Sluice

Shaking Table
Smelting and Refining

Melts concentrated ore or gold into a solid gold piece. The gold can be further refined (usually by a gold shop or refinery) to pure 24K gold.
Where is mercury used in ASGM?

- Mercury is added to ore to extract gold
- Mercury binds easily with gold, making a heavy mercury-gold amalgam that is easier to separate from the rest of the ore

“AMALGAMATION”
Mercury is added to ore to extract gold
Mercury Amalgamation

1. Mix mercury with ore
2. Recover amalgam (squeeze)
3. Vaporize mercury
4. Sponge gold
Whole Ore Amalgamation
Concentrate Amalgamation
“Mercury use” in ASGM in a Minamata context means:

The net loss of mercury during ore processing

or in other words, the amount of mercury that is lost to the environment during ore processing operations.

Where is mercury lost to the environment?
Mercury Use (loss to environment)

1. Mix Mercury With ore
2. Recover Amalgam
3. Vaporize Mercury
4. Sponge Gold

Images showing the process of mercury use and its environmental impact.
Mercury Use (loss to environment)

1. Crush
2. Mill
3. Concentrate
   - Whole Ore Amalgamation
   - Concentrate amalgamation
   OR
4. Burn Amalgam
5. Smelt/Refine

Mercury Use (loss to environment)
Mercury Use (loss to environment)

Crush → Mill → Concentrate

Whole Ore Amalgamation OR Concentrate amalgamation → Burn Amalgam → Smelt/Refine
Mercury Use (loss to environment)

Crush → Mill → Concentrate → Burn Amalgam → Smelt/Refine

Whole Ore Amalgamation → OR → Concentrate amalgamation

Atmosphere

Tailings

Rivers, lakes, ground water
If waste rock contains enough gold, it is sometimes reprocessed by leaching with cyanide. (worst practice banned by Minamata)
A typical workflow
A typical workflow
A typical workflow
A typical workflow
A typical workflow
A typical workflow
A typical workflow
A typical workflow
A typical workflow
A typical workflow

1. **Mine**
2. **Crush**
3. **Mill**
4. **Concentrate**
5. **Amalgamate**
6. **Amalgamate with Hg**
7. **Sponge Au**
8. **24K Au**
9. **Vaporize Hg**
10. **Smelt & Refine**

**Rivers, lakes, ground water**

**Tailings piles**
Organization of ASGM

Organization of miners

Individuals  Small Businesses  Cooperatives
Workforce

Primary ASGM workforce - number of workers directly employed in the gold production system (receive direct payment from the gold proceeds).

- miners (extraction workers, processing workers, mining/processing foremen), business owners, mining coordinators, cooperative leaders

Secondary ASGM workforce - number of people indirectly financially dependent on the ASGM sector (provide goods and services to the sector).

- agricultural producers, merchants, traders, service providers
Organization of ASGM

Distribution of Revenue

- **Local Authority** (25% of gold produced)
  - **Small Business** (75% of gold produced)
    - Owner (25% Au)
    - Pit Boss (10% Au)
    - Processors (2) (20% Au, even share)
    - Miners (5) (20% Au, even share)
  - **Individual Miners** (Even share of 100% of gold produced)
  - **Cooperative** (75% of gold produced)
    - President (10% Au)
    - Cooperative Members: Miners, Processors, Transporters (65% Au, even share)
Formality / Governance

- Few ASGM operations adhere to national legal frameworks
- Often local governance (Community, Municipality, Local police)
- Understanding the governance structure can provide useful information for inventory work:
  - Understand key stakeholders
  - Determine who to interview
  - Provide insight into local operations
Gold Supply Chain

Domestic ASM

On Site Buyer

Region Buyer

Exporter

International

Intern. Trader

Refiner

70%

80%

90%

95%

98%

99%

International

LBMA

Domestic LSM

Mine

Smelter

Refiner

10g

100g

10kg

50kg

100kg

1000kg

10 Miners

30 Miners

5 Miners

100 Miners
Spatial Distribution
ASGM activity can vary greatly throughout the year, especially in regions with a heavy rainy season and seasonal flooding. During these times of the year, productivity and workforce, and thus mercury use in processing may be drastically reduced.

**Relevance:** Annual mercury use and gold production are often calculated by interviewing about daily productivity. It is important for a researcher to ask clear questions about the seasonality of ASGM in the region so that productivity is not over or underestimated. For example, on Site A, a baseline team finds that 1 kg of Hg is used per day on the site. Miner interviews indicate they work 5 days per week and have 10 holidays per year (250 days of work per year). This would lead the officer to believe: \( 1 \text{ kg Hg/d} \times 250 \text{ d/y} = 250 \text{ kg Hg/y}. \)

However, further questioning reveals that all extraction work stops for three months (~60 working days) of the year due to flooding. There are 190 active mining days and the annual mercury use estimate for the site is \( 1 \text{ kg Hg/d} \times 190 \text{ d/y} = 190 \text{ kg Hg/y}. \)
Environmental Impact

Tailings (waste) release

To water:
- increased turbidity
- increased erosion
- circulation changes
- coastline alteration
- loss of habitat

To land:
- Loss of habitat
- Loss of mining opportunity
Health Impact

Mercury is a **neurotoxin**—detrimental effects on the nervous system

- Skin contact / absorption
- Inhalation
Health

– ingestion
Summary

• 3 key components of ASGM – each offering important information that can be used for ASGM inventory
  • Extraction
  • Processing
  • Markets

• Must understand each facet of ASGM - each is a source of valuable information

• Significant variation in practices between sites, regions and countries -- approaches will be different in every country and will be tailored to each region within.

• To understand ASGM must embrace its variability
Thank you very much!

Questions?