

A woman wearing a white headwrap and an orange shirt is sitting on the ground, working with a child in a blue shirt. They are processing gold ore in a bowl. The woman is using a wooden tool to crush the ore, and the child is holding a stick. There are several bowls and a large white container nearby. The background is a dirt ground.

Health Issues in Artisanal and Small-Scale Gold Mining

Training for Health Professionals

Version 1.0



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An Artisanal Gold Council (AGC) document, produced in collaboration with the United Nations Industrial Development Organization (UNIDO), the Global Environment Facility (GEF), and other donor agencies as per above. This document draws on some of the concepts in the World Health Organization's (WHO) *Children's Health and the Environment*. www.who.int/ceh

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Available online at: www.artisanalgold.org

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One of the purposes of the manual is to help with implementation of Minamata Convention obligations as specified in Article 7; Annex C. In particular the manual addresses the following three elements from Annex C that must be included in National Action Plans.

(e) Strategies for promoting the reduction of emissions and releases of, and exposure to, mercury in artisanal and small-scale gold mining and processing, including mercury-free methods;

(h) A public health strategy on the exposure of artisanal and small-scale gold miners and their communities to mercury. Such a strategy should include, inter alia, the gathering of health data, training for health-care workers and awareness-raising through health facilities;

(i) Strategies to prevent the exposure of vulnerable populations, particularly children and women of child-bearing age, especially pregnant women, to mercury used in artisanal and small-scale gold mining;



Who is this document for?

This document was created to guide the training of health practitioners on certain health risks that are common in the Artisanal and Small-Scale Gold Mining (ASGM) sector.

While there are many health risks in the ASGM sector, this guide is limited to risks specifically related to ASGM, particularly those that are rarely covered by general university professional trainings .

This guide provides additional information and does not replace an appropriate professional training or a medical instruction manual. The diagnostic tests mentioned in this guide should be undertaken by a qualified person that is already a trained health professional.

What is Artisanal and Small-Scale Gold Mining (ASGM)?

ASGM is an ancient activity that consist in extracting gold from rocks or sediments. This can be done in several ways, depending on the type of ore deposit. In West Africa, ASGM is mainly done in primary rock, which involves the following steps:

1. Extraction



The gold-containing ore is extracted from the soil through digging, often in wells or gallery .

2. Crushing



The ore is then crushed using rudimentary methods, such as a hammer.

3. Milling



Then, it is ground using a mill, in order to obtain a very fine powder.

4. Washing



This is then concentrated and washed with the help of sluices and pans.

5. Panning



6. Amalgamation



To capture the gold, mercury is added which then forms an amalgam (mixture of mercury and gold).

7. Burning of the amalgam and gold recovery



Finally, the gold-mercury amalgam is heated so that mercury evaporates, leaving only a porous “sponge gold” product behind.

Mercury: 3 types



There are 3 types of mercury: elemental mercury, methylmercury and inorganic mercury compounds. In gold mining, elemental mercury is used directly in the ore processing, which often leads to miners being in contact with it. In addition, in certain cases and under certain specific aquatic conditions, elemental mercury can also be transformed into methylmercury.



Elemental Mercury (Hg)

is a heavy silver liquid metal. When heated, it turns into invisible vapors. Even at room temperature, it releases toxic vapors.



Methylmercury (MeHg)

is an organic compound that can accumulate in the food chain, particularly in fish and seafood.



Cinnabar



Salt

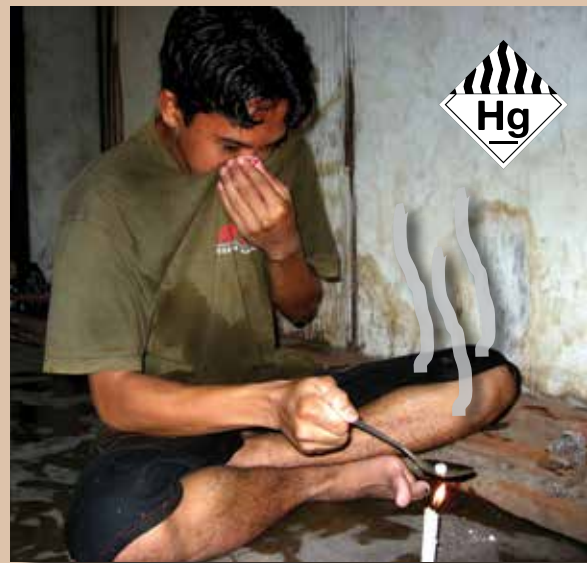
Inorganic mercury

exists in different forms such as salts. They are often found in manufactured products, such as batteries.

An overview of ELEMENTAL Mercury exposure in ASGM communities

Direct Exposure is mainly due to the presence of elemental mercury (Hg) vapors.

- The exposure is often severe and acute. It is a high dosage that can be absorbed up to 80% by the lungs.
- It causes damages mainly to the kidneys and lungs, but also to the nervous system.

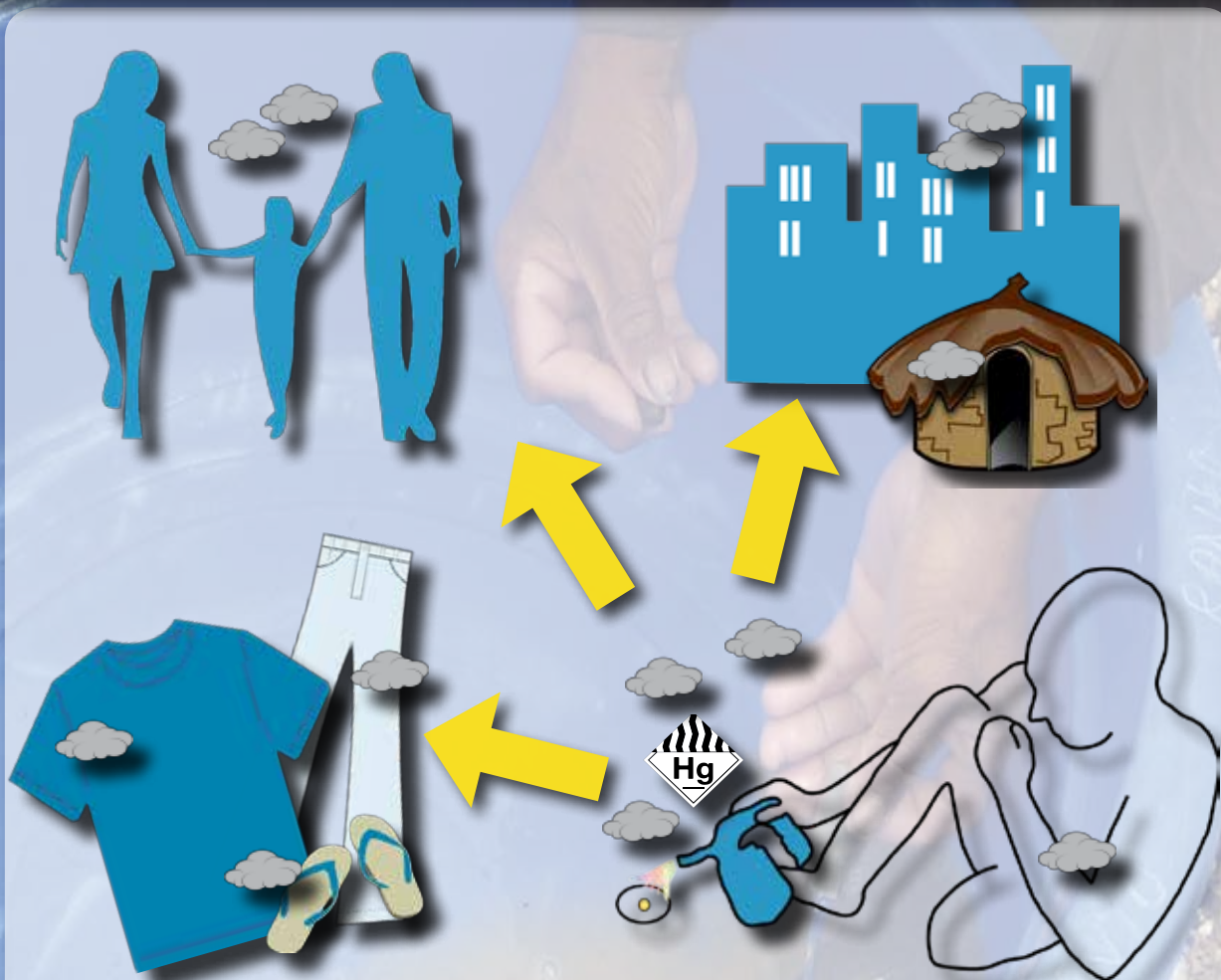


The amalgam is mixed and then heated in open air and releases a lot of noxious vapors. The person who burns the amalgam and those in close proximity will breathe in a large amount of mercury vapors.

Exposure to ELEMENTAL mercury in ASGM communities

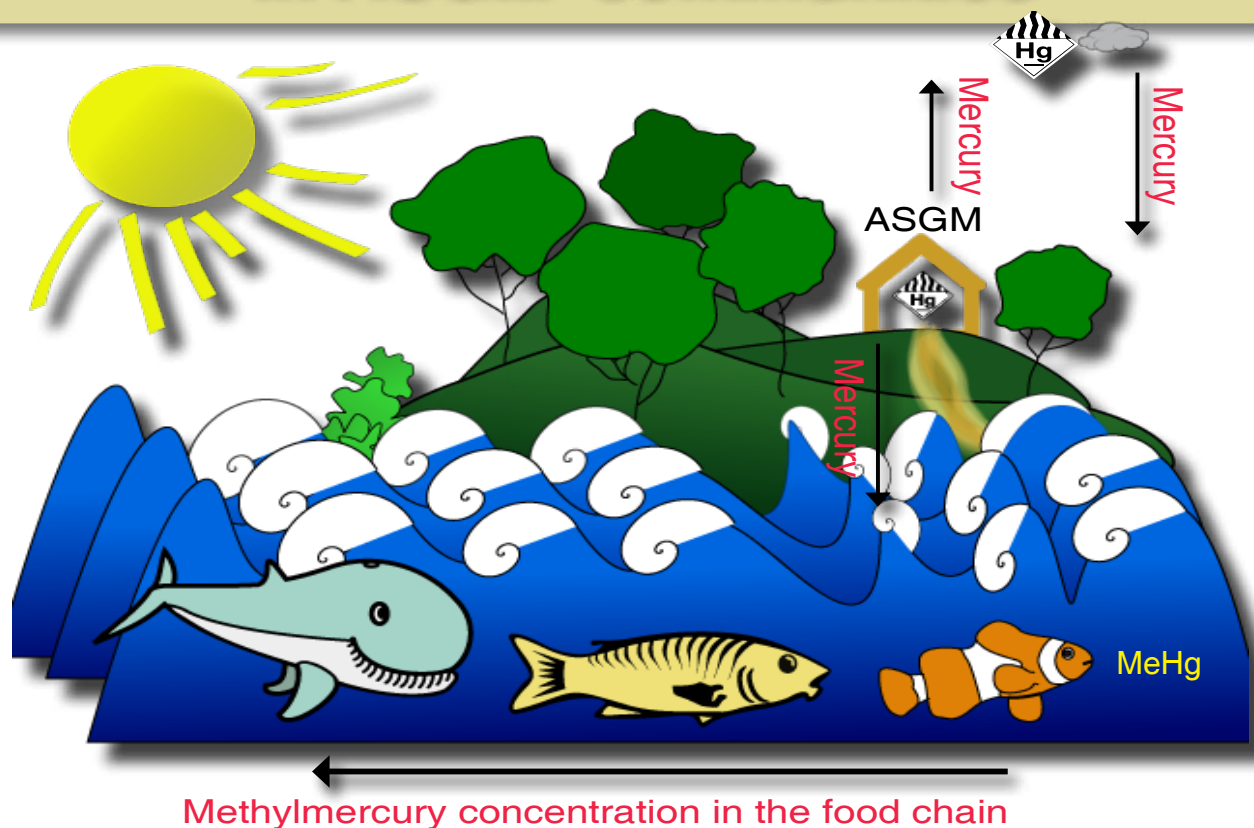
Indirect Exposure is due to the presence of elemental mercury vapor (Hg) contaminating surrounding surfaces.

- This exposure is often chronic and consists of small to medium doses that can be absorbed up to 80% by the lungs.
- It causes significant neurological disorders.



The amalgam is heated and releases mercury vapors. The vapors are then deposited on cloths, walls and surrounding surfaces, contaminating these objects. Anyone in contact with these objects will also inhale noxious fumes, even a long time after the amalgam has been burned. These vapors can also be carried by the wind towards the village and residences and in turn, contaminate these also.

Exposure to METHYLMERCURY in ASGM communities



- Under specific aquatic conditions, elemental mercury released in air, water or soil can potentially be transformed into methylmercury (MeHg). This can occur close to ASGM sites or further away.
- Methylmercury accumulates in the food chain (biomagnification). The large piscivorous fishes contain more MeHg than smaller piscivorous fishes.
- Human exposure is due to the consumption of fish contaminated by MeHg.
- Exposure is often chronic and sometimes severe. It usually consists of small to medium doses that are absorbed almost in totality by the bowels (up to 95%).

In ASGM, the main toxicity risk is due to ELEMENTAL Mercury

Absorption

Mercury enters the body through:

The lungs
(inhalation)
~80-85%
absorbed

The digestive syst.
(ingestion)
Less than 1%
absorbed

The skin
(contact)
Less than 1%
absorbed

Distribution

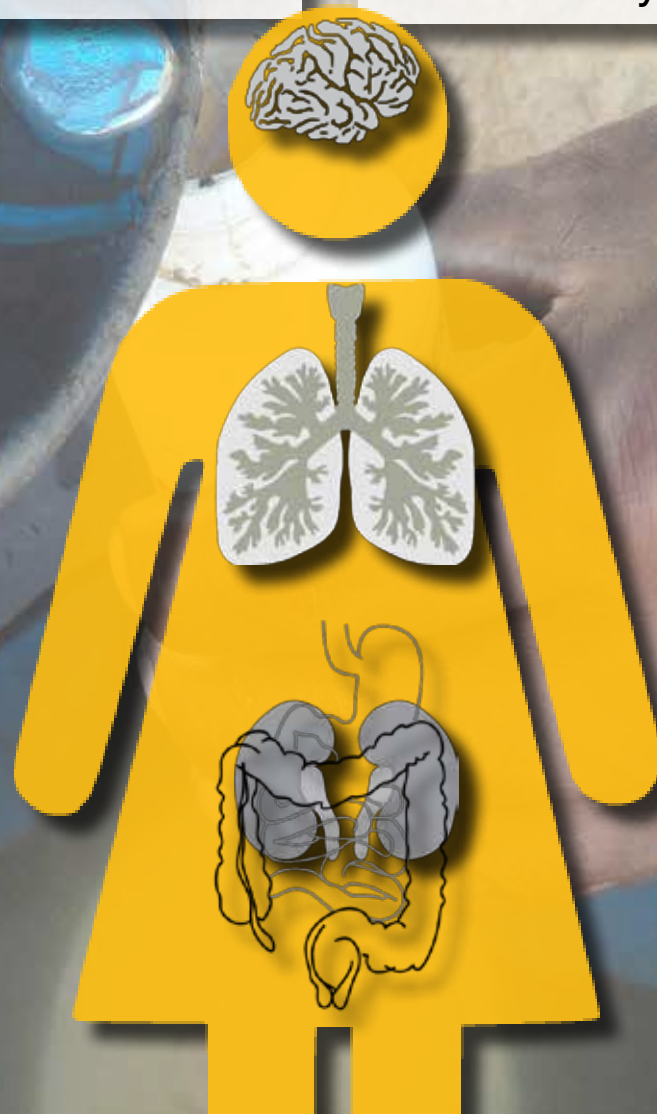
Mercury spreads into the body and reaches the following organs:

Brain
Kidneys
Lungs
Skin
Foetus

Elimination

Mercury leaves the body by:

Urine and
Feces
(Biphasic half-life
of 2-4 days and
15-30 days)



ELEMENTAL Mercury: Effects of chronic exposure in adults

Chronic exposure to mercury is very common in ASGM and can affect the majority of the community.

Target System

Symptoms

Nervous System

- Ataxia (uncoordinated walking)
- Impaired balance and coordination
- Metallic taste
- Excessive Salivation
- Headaches
- Fatigue
- Emotional changes
- Tremors
- Increased deep tendon reflexes
- Acrodynia (children)

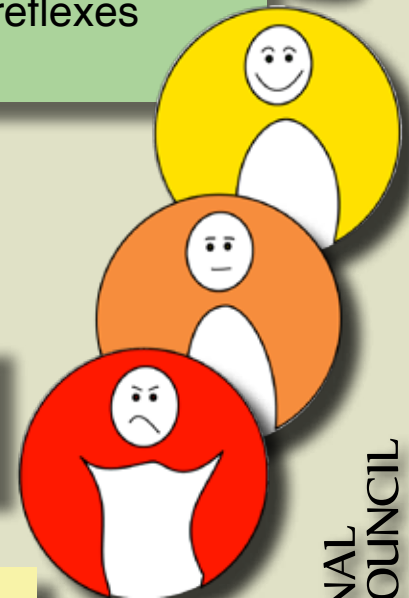


Digestive System

Discoloration of the gums, gingivitis

Immune System

Reduced immunity



The symptoms can take many years to appear. It will depend on the severity of the exposure, the individual and his age. The effects can be irreversible.

ELEMENTAL Mercury: Effect of acute exposure in adults

Acute exposure to elemental mercury occurs commonly only in a minority of miners, especially those who burn amalgams.

Target system

Symptoms

Respiratory system

- Chest pain
- Dyspnea
- Cough, hemoptysis
- Pneumonia
- Massive and rapid pulmonary fibrosis
- Respiratory Failure (rare)

Cardiovascular

Hypertension, Palpitation

Urinary System

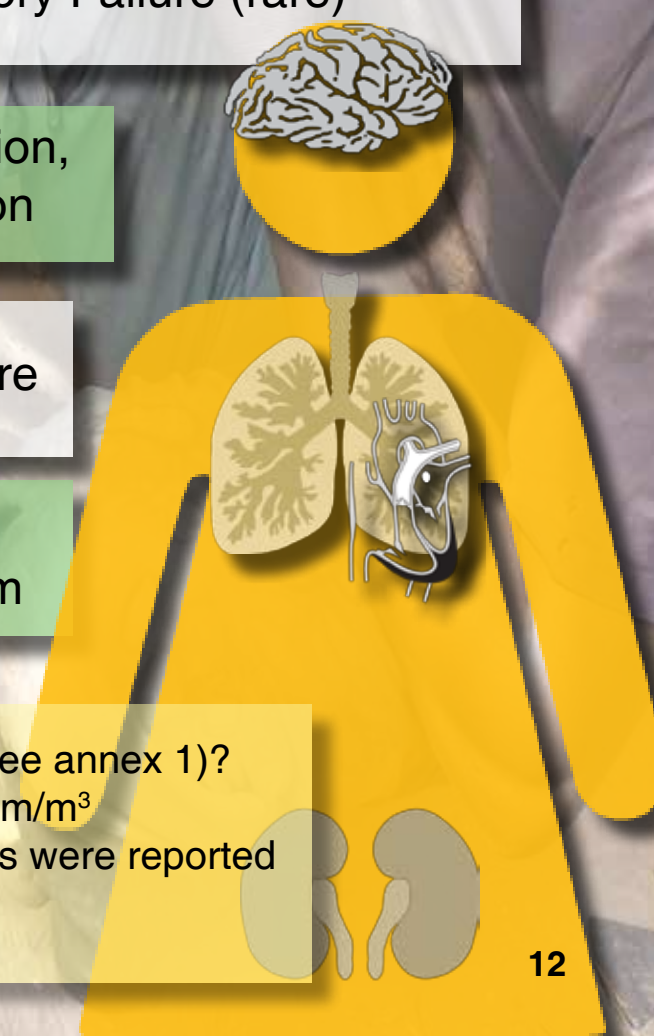
Renal Failure

Nervous System

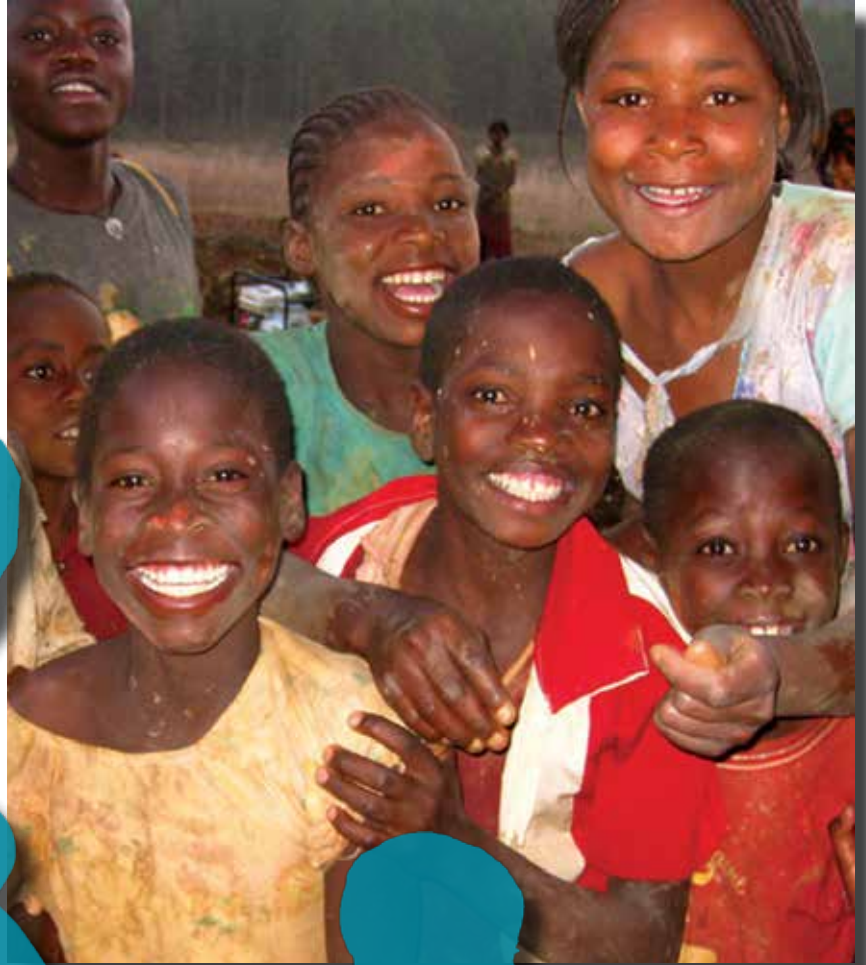
Confusion and delirium

At what dosage should I be concerned (see annex 1)?

- Public chronic limit (WHO)=1 microgram/m³
- Acute limit = Not defined but the effects were reported starting at 1200 micrograms/m³



ELEMENTAL Mercury: Effects in children and pregnant women



The effects are the same as in adults, but are much more severe during brain development, and it starts as soon as conception (hence the danger to pregnant women). The effects also manifest themselves more quickly than in adults and for chronic exposure, may be irreversible.

Toxicodynamics: ELEMENTAL Mercury

Inhalation of
Hg vapor

Rapid diffusion through the
alveolar membranes

Passage into the
blood

Rapid oxidation in red
blood cells or other
organs (Hg^{2+})

Hg^{2+} forms a compound
with other molecules

Lipophilic nature of Hg^{2+} = passive
diffusion through the blood-brain
and placental barriers

Target organs: brain, kidney, liver

Mercury Myth no.1

Is drinking water that is contaminated with elemental mercury a major source of poisoning?

NO. Elemental mercury is not soluble and is poorly absorbed by the digestive system. However it is best not to consume contaminated water whenever possible.

Mercury Myth no.2

Is the miner contaminating himself when he uses his bare hands to mix the mercury with the ore?

Trick question! Yes, but mainly by inhaling the toxic vapors rather than by the skin.

METHYLMERCURY (in ASGM)

Absorption

Digestive System
(ingestion
contaminated fish)
~95% absorbed

Distribution

Brain
Cardiovascular
system

Elimination

Feces and Hair
(half-life of 45-70
days)



METHYLMERCURY: Effects of chronic exposure

Target System	Symptoms
Nervous System (Cerebellum)	<ul style="list-style-type: none">• Ataxia (uncoordinated walking)• Impaired balance and coordination• Metallic taste• Excessive salivation• Headaches• Restricted visual field and decreased hearing
Cardiovascular	<ul style="list-style-type: none">• Hypertension• Heart Attack
Urinary system	Renal failure
Development of the nervous system (children)	<ul style="list-style-type: none">• Mental retardation• Cerebral palsy and malformations• Epilepsy• Loss of vision or hearing• Language disorders• Memory disorders

Depending on the type of exposure, the individual and his age, symptoms may take years to manifest themselves. The effects may be irreversible.

Mercury Myth no.3

Is it more dangerous to consume fish caught near a ASGM community rather than in the ocean, for example?

It Depends:

- Of aquatic conditions
- The type of fish (the size of the fish and if it is piscivorous)
- The amount consumed

In fact, it is possible that the fishes are more contaminated tens of kilometers away from the mining site. But it is impossible to know without doing a study.

Diagnostic - Hg Intoxication

1. *Clinical Observation*

Neurological Assessment including (see Annex 2) :

- Coordination
- Balance
- Fine Motor Skills
- Quality of movements
- Memory



Cardiac and Respiratory Assessment including, among other things, blood pressure and lung and heart auscultation

Vision and Hearing Assessment

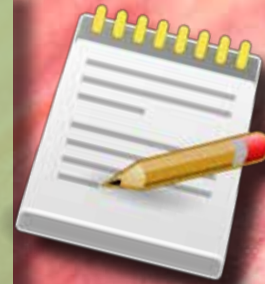


Diagnostic - Hg Intoxication (cont.)

2.

Medical History

- Symptomatology
- History of potential exposure to mercury: the role in the community, the location of the housing in relation to the amalgamation area, etc.



3.

Knowledge of the ASGM sector

- Methods of gold extraction (ore processing) and preventative methods



4.

Biomarkers (laboratory)

- Urine (exposure to elemental mercury)
- Blood (total exposure- methylmercury and elemental Hg)
- Hair (Methylmercury exposure)



Treatment

Reduction or elimination of mercury exposure

Chelating agents may be used with a dosage specific to the agent. However it is not an optimal treatment if the exposure is not reduced or eliminated.



For example, a burning center located far away and downwind from the village can reduce mercury exposure



Reduction or elimination of mercury exposure : simple solutions

1. Women and Children should never be in contact with mercury



2. Mercury should be stored **outside** in a solid bottle with a tight fitting lid. Always keep a layer of water over the mercury to prevent the vapors from escaping.



3. Wear **gloves** if you touch the amalgam, or use a stick.



Reduction or elimination of mercury exposure : simple solutions (cont.)

4.

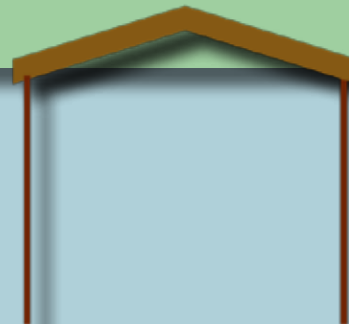
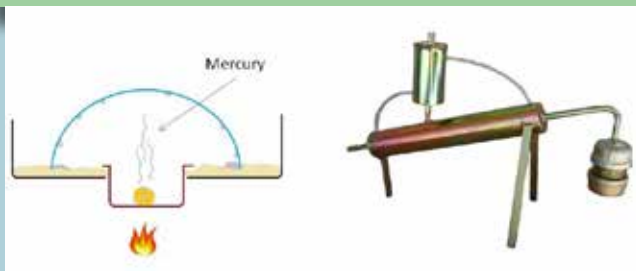
If, possible, use a **respirator with activated charcoal**. This is the only type of respirator that will protect you against mercury vapors. Normal masks or fabric are ineffective.



5.

Create a **designated area** where the amalgam will be burned and the equipment will be left (including work clothes). The area must be well ventilated, far from the village and placed so that the prevailing winds do not bring the vapors towards the residences.

Use **a retort** adequately (see the retort guide) .



Dust

Dust exposure is frequent in ASGM and can affect the majority of the community. The health risks on many elements, such as:

- The soil composition, for example if there are important amounts of silica, lead, etc.
- The size of the dust particles inhaled: the smaller the particles, the deeper they penetrate into the lungs and the greater the damages.

Dust Exposure in ASGM



Direct Exposure: The miners breathe in dust particles during ore milling, which is often done with cereal mills or other inefficient and dry mills

Dust

Dust Exposure in the ASGM communities

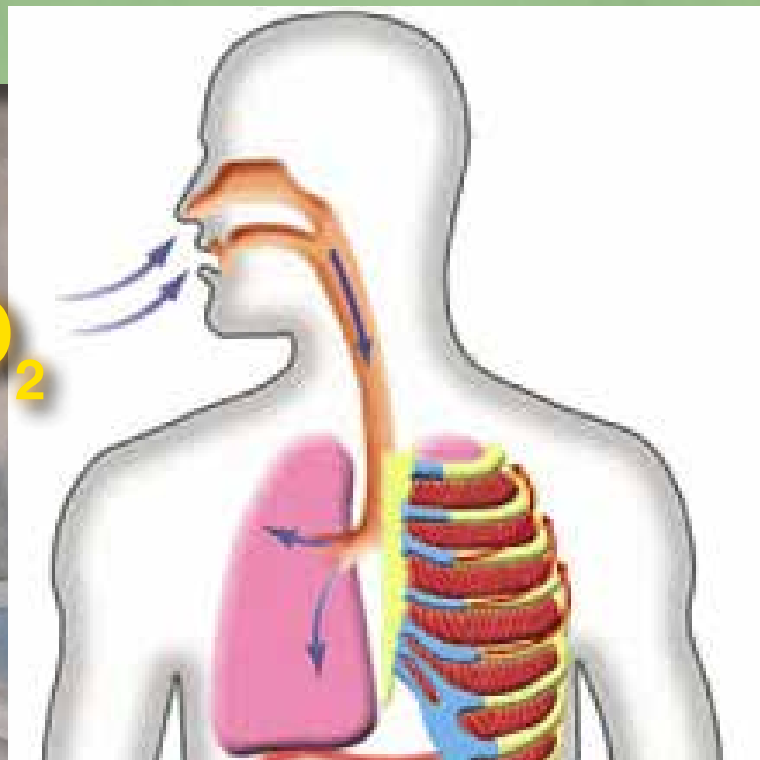


Indirect Exposure : When dust is carried by the winds towards the village, ASGM communities may also breathe it in. Dust can also be deposited on the ground where children may ingest it and the dangerous metals that it contains.

Silica (SiO_2): always present in varying quantities

- When ASGM is performed in primary rocks (or veins), silica is very common. This is due to the fact that gold deposits are often contained within quartz veins.
- The health risk increases when the dust contains pure silica or silica that has recently been fractured (often the case in gold mining) .
- Silica, when inhaled, may cause inflammation, fibrosis and pulmonary silicosis.

SiO_2



Diseases associated with silica

Diseases

Chronic Silicosis:

- Long latency period (+10 years)
- Chronic exposure to low doses

Accelerated Silicosis

- Short latency (< 5 years)
- Chronic exposure to larger doses

*Often Fatal

Symptoms

- Often asymptomatic at the beginning
- Dry cough
- Shortness of breath and difficulty breathing (dyspnea on exertion)
- Pulmonary inflammation
- Pathological sounds with auscultation
- On X-R: presence of nodules in the upper lungs
- Last stage: generalized weakness and weight loss

- Same symptoms as chronic silicosis but faster
- On X-R: Presence of enlarged nodules that are merged into the upper lungs, and pulmonary edema
- Last Stage:
 - Generalized weakness and weight loss
 - Massive Pulmonary Fibrosis

Diseases associated with silica (cont.)

Disease

Acute silicosis (rare)

- Very short latency period (days to months)
- Acute exposure to very large doses

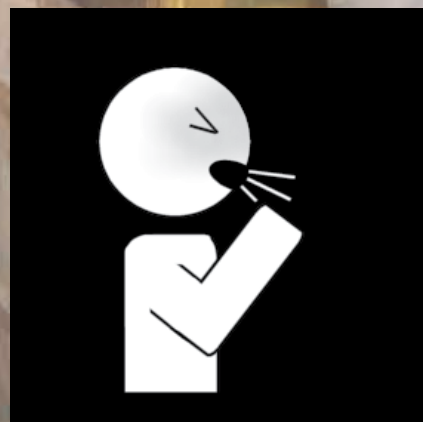
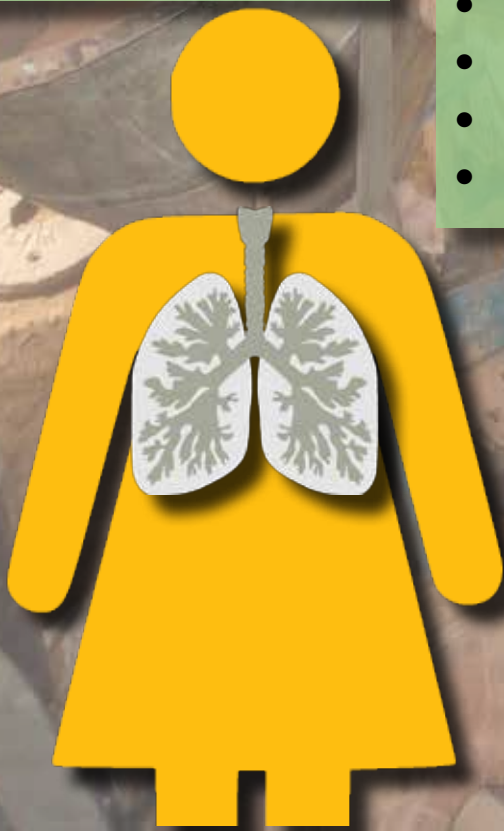
*Fatal

Symptoms

- Lung Inflammation, cough, dyspnea
- On X-R: Presence of basal infiltration.
- Last stage:
 - Generalized weakness and weight loss
 - Massive Pulmonary Fibrosis

Pulmonary Tuberculosis

- Persistent cough and productive hemoptysis
- Constant Fatigue
- Weight Loss
- Loss of appetite
- Fever and chills



Pathophysiology: Silica

SiO_2 particles $< 5 \mu\text{m}$ are deposited in the alveoli

Macrophages carry SiO_2 towards the tissues and lymphatic system

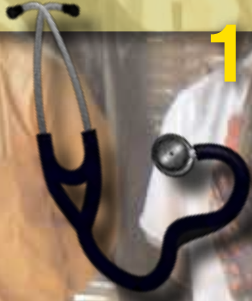
Cytotoxic effects on macrophages

The macrophages release mediators

The mediators damage lung tissue and increase the production of collagen

Development of silicotic nodules

Diagnosis



1.

Clinical Observation

Respiratory evaluation including auscultation of the lungs. In most cases, there is no particular sign.

2.

Medical History

- Symptomatology: cough and shortness of breath
- History of potential exposure to silica



3.

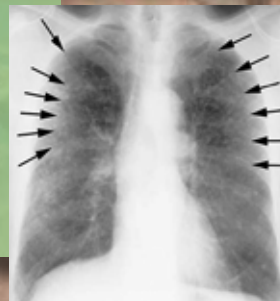
Knowledge of the ASGM sector

- Methods of ore processing
- Protection methods
- Mineralogy of the region

4.

X-Rays

Presence of silicotic nodules, particularly in the upper lobes



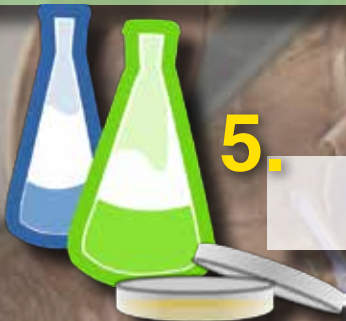
Silicotic nodules

Massive Pulmonary Fibrosis



5.

Standard procedures for detecting TB



Treatment

1. Reduce or eliminate dust exposure.

2. If the dust contains heavy metals such as lead, chelating agents may be employed, with specific dosages corresponding to the agent.

3. There is no treatment for silicosis, whatever the type, except for the treatment of opportunistic infections and symptom relief.

4. Normal TB care.

Reduction and elimination of dust exposure: simple solutions

1. Keep crushing and milling areas away from inhabited areas.

2. Ensure the crushing and milling areas are located downwind so that the dust is not pushed into inhabited areas.



3. After a days work, change your clothes and leave them at work .



Reduction and elimination of dust exposure: simple solutions (cont.)

4. Use wet milling methods (the water can be recycled)..



5. Use protective masks. Only masks specially designed for dust are effective.

6. Increase ventilation in crushing and grinding areas, tunnels, etc .



Role of Health Professionals

Primary Prevention

- Diagnose disorders related to ASGM.
- Educate each patient on how to reduce exposure to mercury and dust.
- Educate ASGM workers on ways to reduce exposure to mercury and dust.
- Put pressure on miners' associations leaders to adopt clean technologies.
- Put pressure on community and miner leaders to organize and create a monetary fund to improve health practices in the community.

Secondary prevention

- Systematically organize and report health data to national authorities. The role of surveillance cannot be underestimated!
- If the rate of mercury contamination of local fish is considered high, educate the population about the proper amount of fish that can be safely consumed.

Medical Care

- Use chelating agents when necessary; use physical rehabilitation in the case of neurological impairments; treat associated infections

Occupational Health and Safety Approach

The *Occupational Health and Safety* approach should be applied in the context of ASGM. Although this approach is beyond the scope of this guide, we present here a non-exhaustive list of risks that may apply to the ASGM sector. There are many textbooks on this subject and we encourage you to consult them for more information.

- 1) Risks associated with technologies other than mercury and dust, such as accidents and injuries, landslides, musculoskeletal disorders, noise, etc.
- 2) Risks associated with the social environment, such as drug or alcohol abuse, risky behaviors, conflicts, exploitation of women and children, etc.
- 3) Risks associated with hygiene and sanitary conditions existing on sites, such as transmissible and infectious diseases.

Annex 1: Clinical Neuropsychological Tests

There are many clinical tests that can assess the various neurological elements discussed earlier. The following tests are selected examples that do not require any specialized equipment .

Coordination

-Ataxic gait

Observe the patient walking. Note a decrease in the base of support, an increase in oscillation, a lack of balance, etc...

-Finger-nose

The patient alternately touches his nose and the finger of the health worker's finger. The health practitioner can move his finger slowly to make the test more difficult.

-Finger Coordination

The patient touches alternately his thumb with each finger of his hand.



Balance

- Double stance balance

The patient stand on his two feet and closes his eyes. Observe if the patient maintains his balance or starts to oscillate strongly.

- Unilateral Balance

The patient stands on one foot, eyes open. Observe if he can maintain his balance for more than 5 seconds.



Annex 2: Basic Toxicology Concepts

Adapted and excerpt from : Lapointe, G., CSST- Notions de Toxicologie (2004), available on the internet for free and in french at: www.reptox.csst.qc.ca

To better understand the effect of toxins on an organism, some basic concepts in toxicology are required. Many books on this subject exists and we invite you consult them for more information and details.

What is toxicology?

Toxicology is the science of poisons. It studies the harmful effects of chemicals on living organisms.

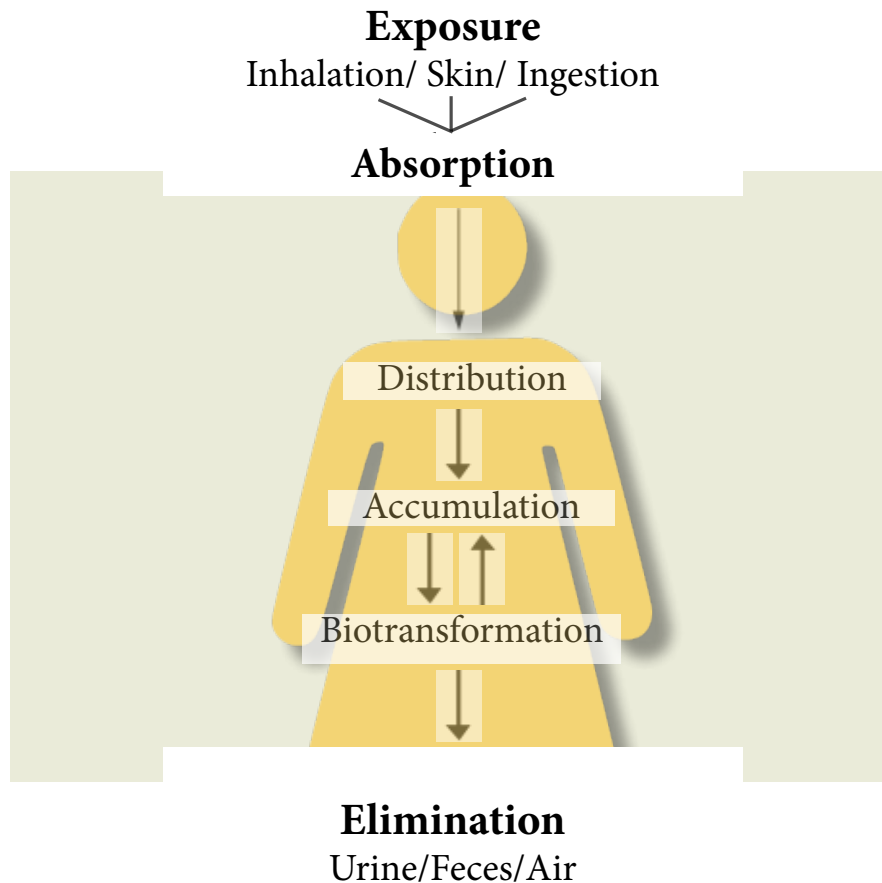
What is the exposure pathway?

The exposure pathway represents the way a toxin enters the organism. When an organism is exposed to a chemical, it can be absorbed in various ways:

1. Respiratory Tract (inhalation): at the level of the respiratory membranes or the pulmonary “tree”, where the majority of gas exchanges between the alveoli and the capillaries occur.
2. Dermal (skin)
3. Digestive Tract (ingestion)

What are the main stages in the progression of a toxin into the organism?

1. Absorption : the penetration of the product into the organism
2. Distribution : when the product reaches the blood system, it can be carried throughout the organism
3. Accumulation : the product can accumulate in the target organs
4. Biotransformation : the organism (often the liver) has the ability to transform the product into another compound, which can make it more or less toxic.
5. Elimination : excretion is often done through urine, feces, sweat or exhaled air.

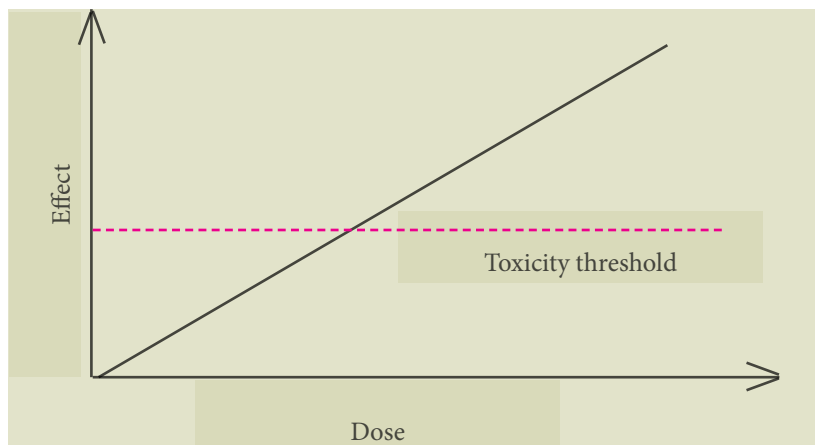


The toxic effect (toxicity) of a product depends on the dose, the route of absorption, the toxicity of the product and the time required for the appearance of lesions .

- An acute effect appear rapidly and can be reversible or irreversible.
- A chronic effect takes a long time to develop but is often permanent.

The dose is the amount of a substance to which the organism is exposed to.

The dose-effect relationship: generally the higher the dose, the greater the effect. There is often a toxicity threshold that corresponds with the appearance of symptoms.





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