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# **Human Health Risk Assessment by Mercury Exposure in SSGM: a Study Case in Brazil**

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# **SUMMARY**

## **•PART I-**

### **•HUMAN HEALTH RISK ASSESSMENT: Conceptual Model**



## **•PART II**

### **•EPIDEMIOLOGICAL STUDY AT SSGM IN BRAZIL**

**(São Chico SSGM at Tapajós SSGM  
Reservoir, Para State, Brazil)**



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# HUMAN HEALTH RISK ASSESSMENT (USEPA, 1989) 4 basic steps

**Source of Pollutant/ Environmental Concern**



**Human Exposure**



**Toxicity values**



**Risk or Hazard Characterization**



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- 1- HOW is SSGM a source of mercury to the environment?**
- 2- Which are the mercury CHEMICAL FORMS involved in distinct steps of SSGM processing?**
- 3- Which are the EXPOSURE kinds involved when it comes SSGM? Occupational vs Environmental exposure or both.**
- 4- What are about cumulative risks considering biological VULNERABILITY (additional health problems) of SSGM communities?**

**SSGM AS A SOURCE OF Hg TO THE ENVIRONMENT:  
37% of the anthropogenic mercury (UNEP)**



**Au:Hg  
1:2.5**





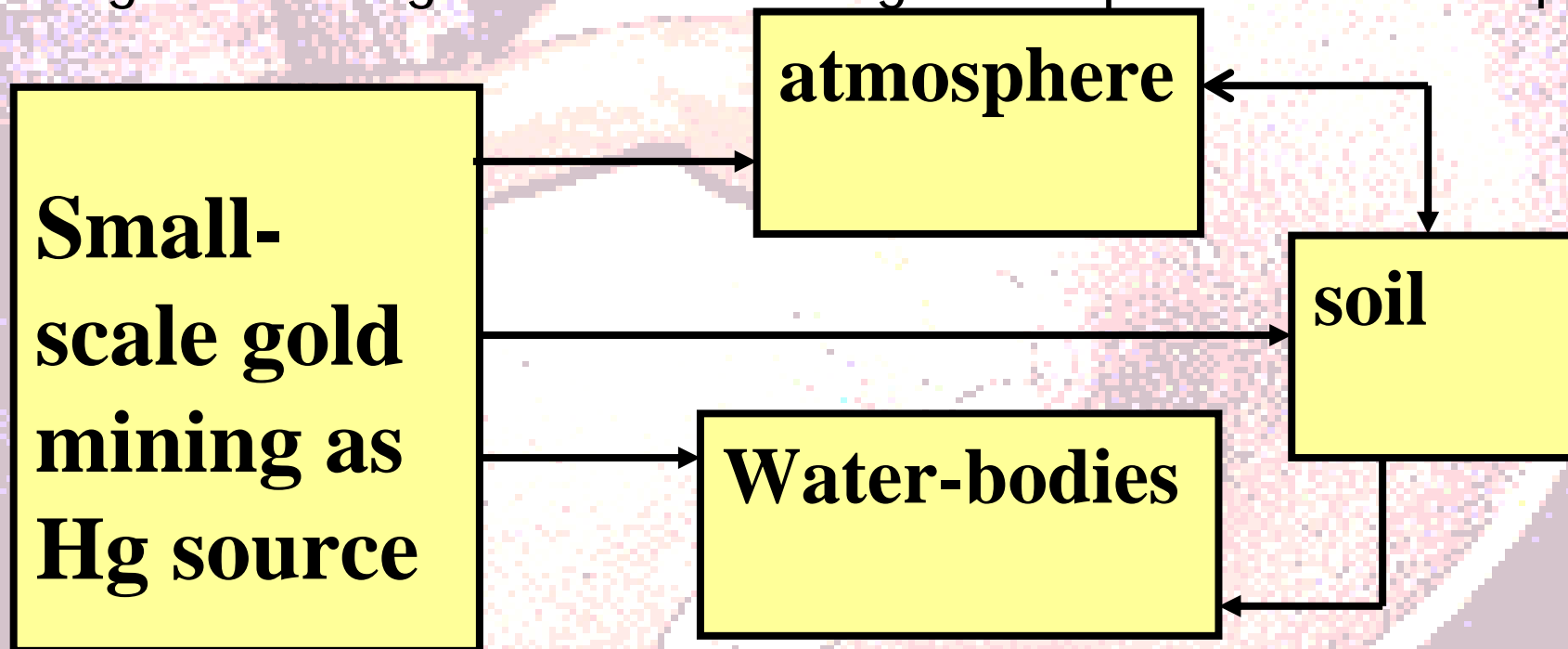
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## SSGM as Hg source to the environment:

waste discharge: tailing ponds or directly in waterbodies

Primary gold ore: Hg associated to Cyanide

Amalgam burning: in the field or gold shops to the atmosphere





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**Hg chemical forms, environmental compartments,  
exposure pathways, tissues absorption and  
adverse effects**

**are interconnected and show RELATIONSHIPS.**



**What does it means?**

**Integration of Hg biogeochemical cycle in the  
environment with toxicokinetics (the biological  
fate) and toxicodynamics (the adverse effects)  
of Hg in the human bodies.**

Hg

Aquatic Ecosystems

MeHg

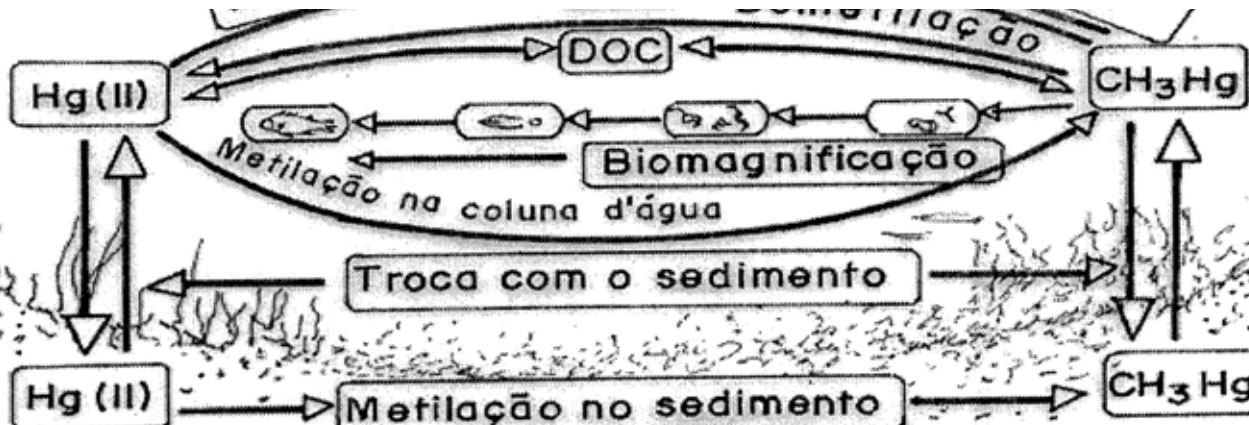
Deposição ( $\text{Hg(II)}$ ,  $\text{CH}_3\text{Hg}$ ),  
Volatilização ( $\text{Hg}^0$ ) e  
Re-emissão ( $\text{Hg}^0$ )

Non piscivorous

piscivorous

Trófica

10 x

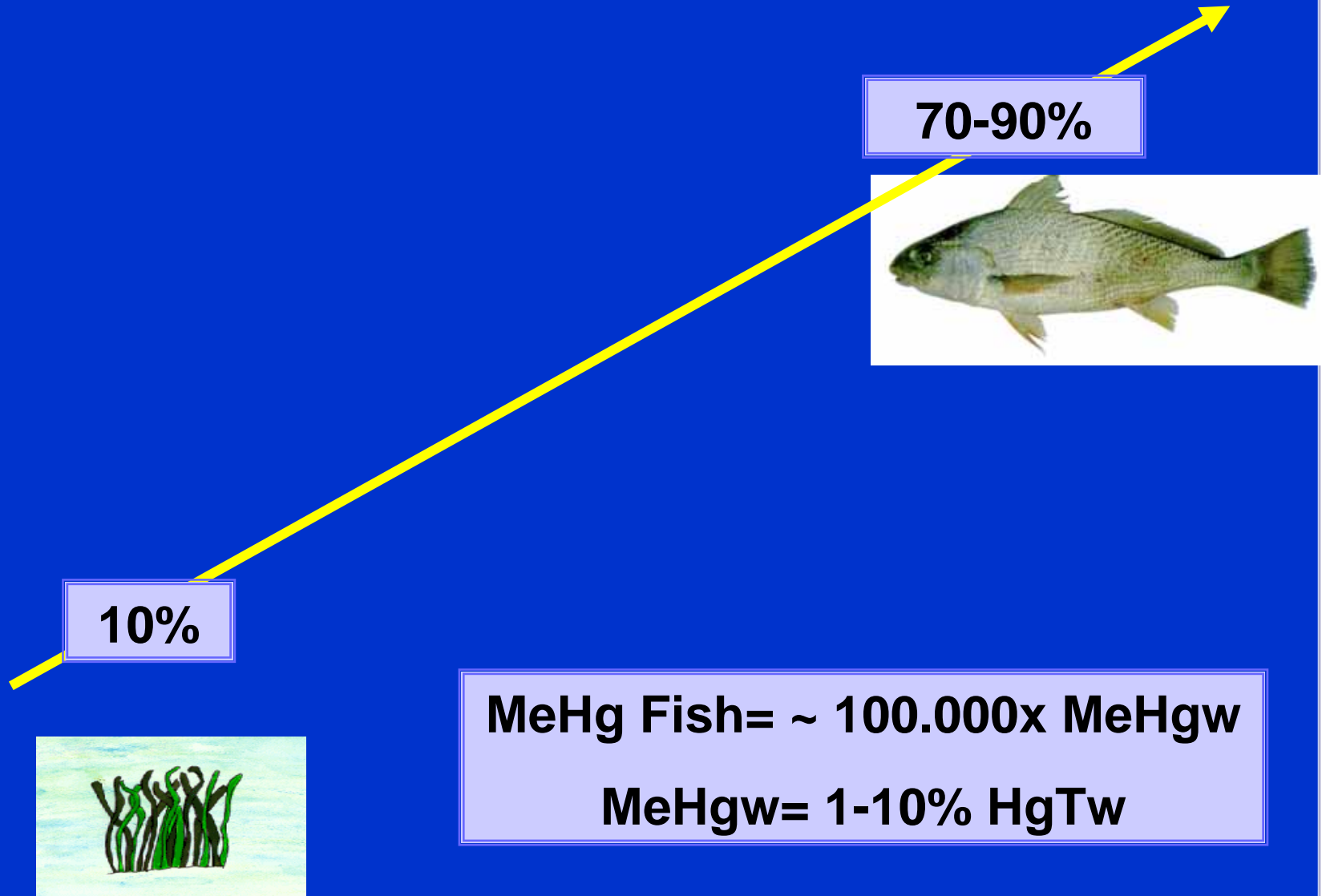






# MeHg BIOMAGNIFICATION in AQUATIC ECOSYSTEMS

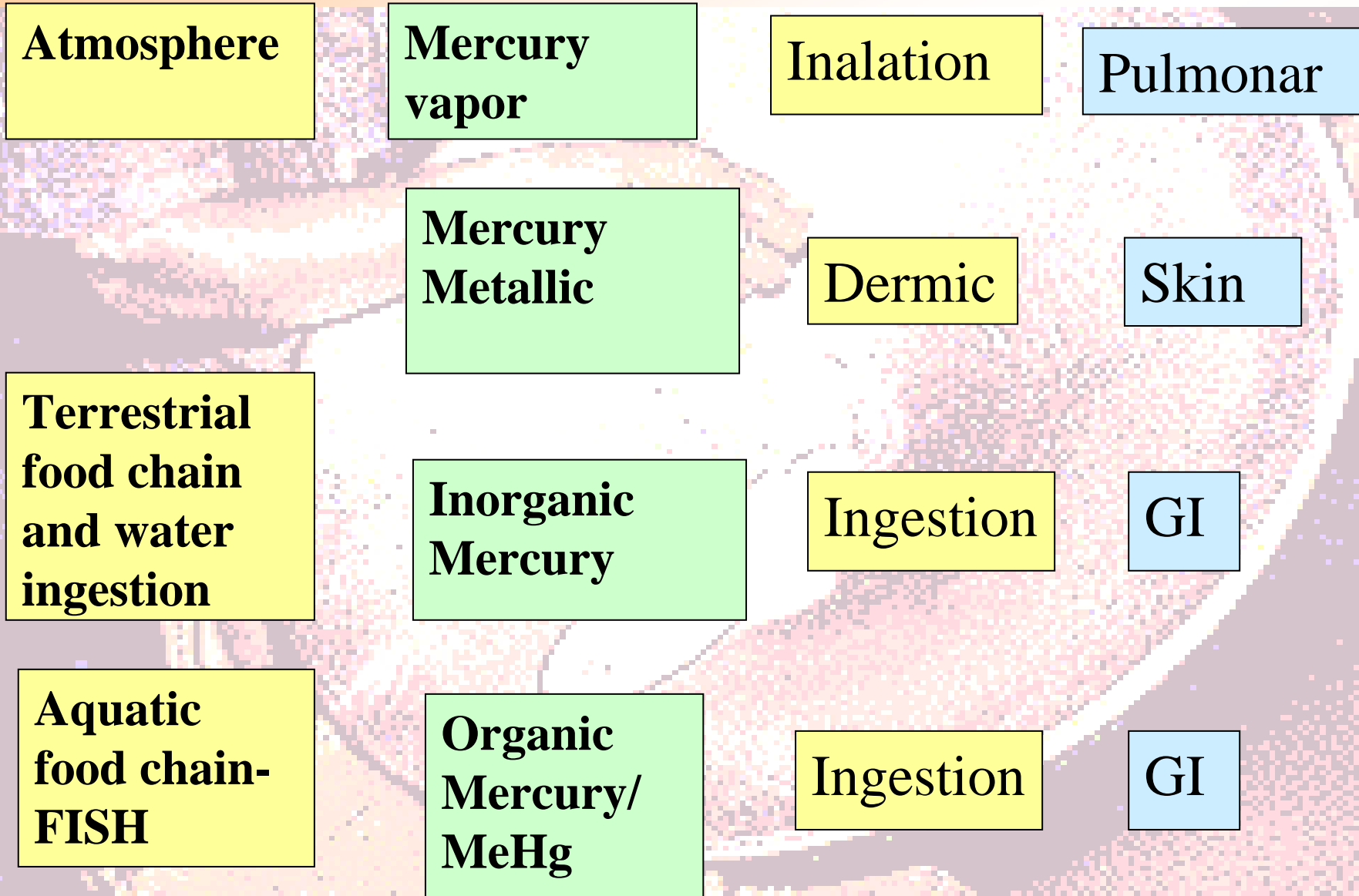
MeHg/ Total Hg Ratio





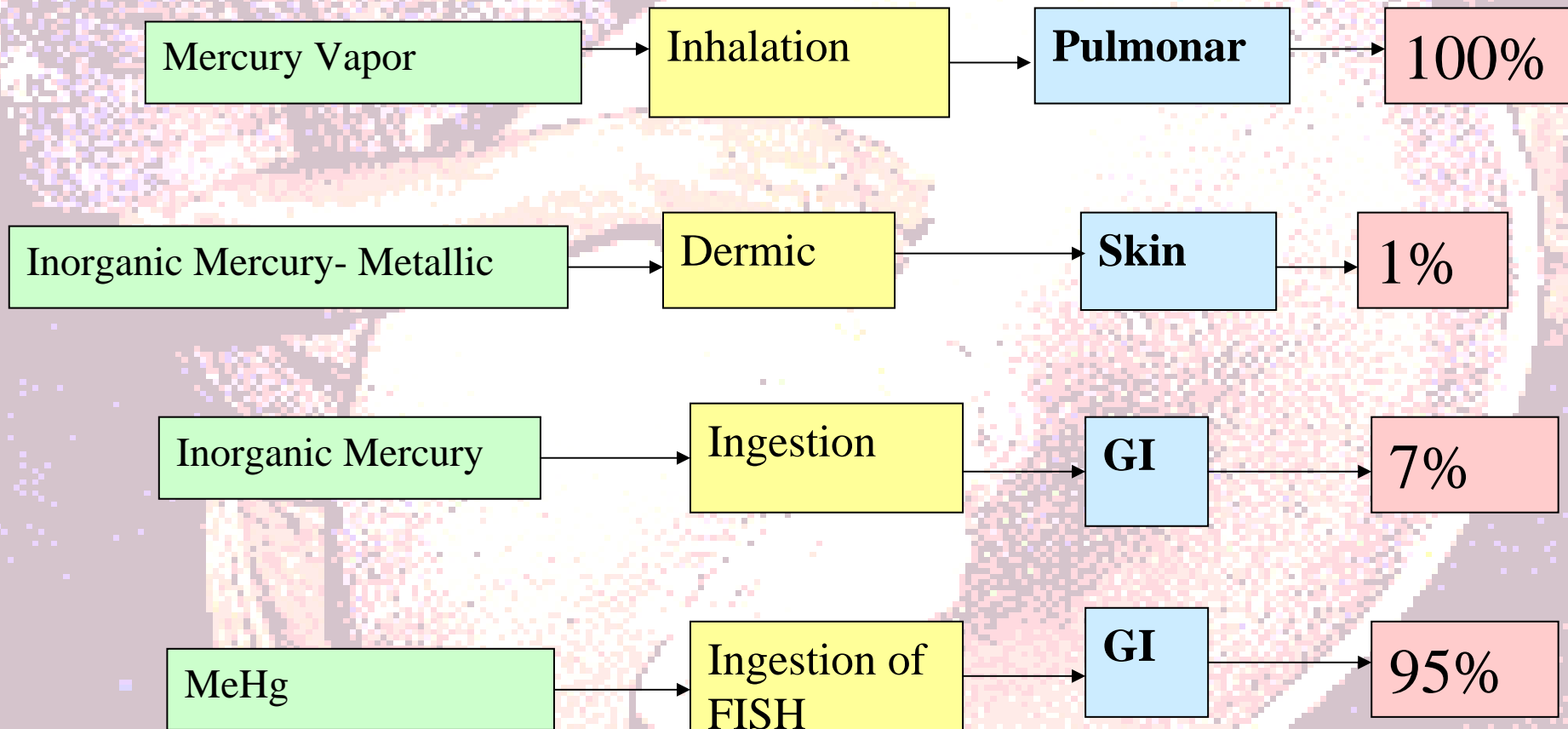
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# Environmental compartments, chemical forms, exposure pathways and tissues absorption





# Human health exposure pathways- ABSORPTION: PERCENTAGE



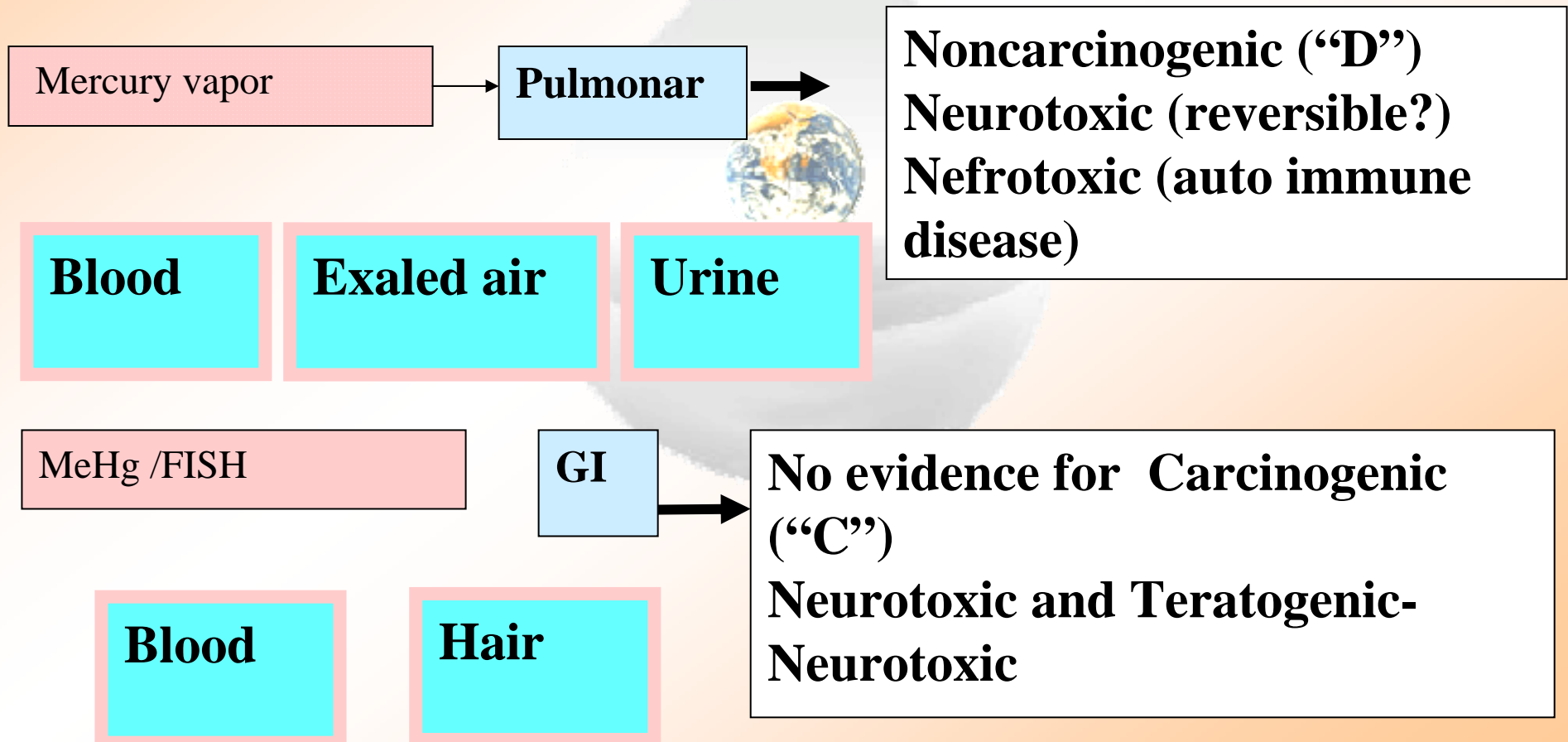
Hg vapor by inhalation and MeHg by fish ingestion are the most important chemical forms and pathways in SSGM



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Hg toxicokinetic determines the monitoring of exposure: by excretion route

Hg toxicodynamic determines the adverse effects





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# Human health adverse effects

Mercury vapor

Pulmonar

Noncarcinogenic (“D”)  
Neurotoxic (**reversible?**)  
Nefrotoxic

**Classical inorganic mercury vapor poisoning:**

**Weakness, fatigue, loss of weight, g.i disturbances**

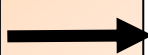
- tremor : hands, lips, tongue
- memory disturbances
- metallic taste
- irritability, excitability, insomnia
- gengivitis and salivation
- auto immune of kidney disease



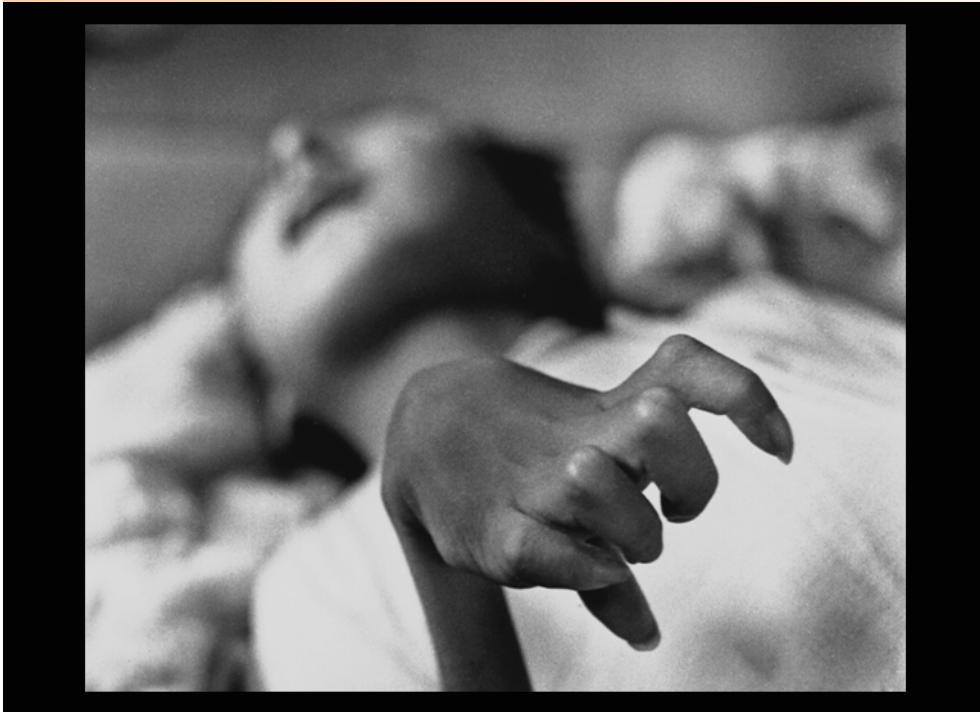


MeHg /FISH

GI



No evidence for Carcinogenic (“C”);  
Neurotoxic and Teratogenic-Neurotox



## Minamata victims

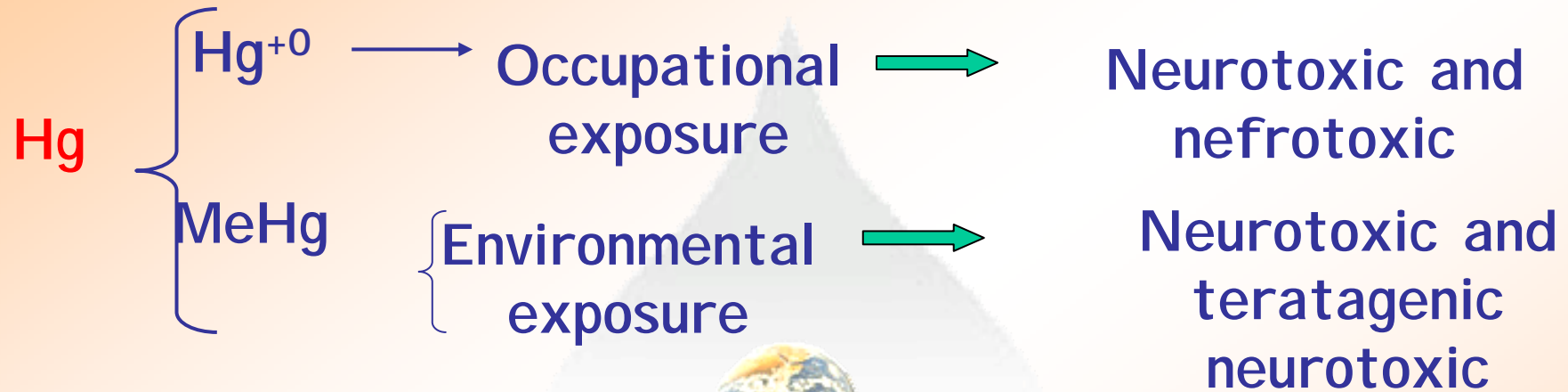


**Teratogenic neurotoxic: IRREVERSIBLE brain damage due to MeHg intra utero exposure even if mothers do not show symptoms**



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# Hg Chemical forms, exposure and effects



SSGM: Occupational + Environmental exposure



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## Part II

# São Chico SSGM

(06° 25' 31" S and 56° 02' 99" W)

Amazon Region, Pará State, Brazil

Part of Global Mercury Project

UNIDO





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# Partners

- **CATEM- Centre for Mineral Technology/MCTI**
- **IEC- Evandro Chagas Institute/Ministry of Health**
- **NAEA/UFPA- Federal University of Pará State**
- **AMOT (SSGM association )**
- **SECTAM- Secretary of Environment of Para State**
- **Itaituba Municipality**
- **Itaituba Secretary of Health; Itaituba Secretary of Mining and Environment**



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# Field work

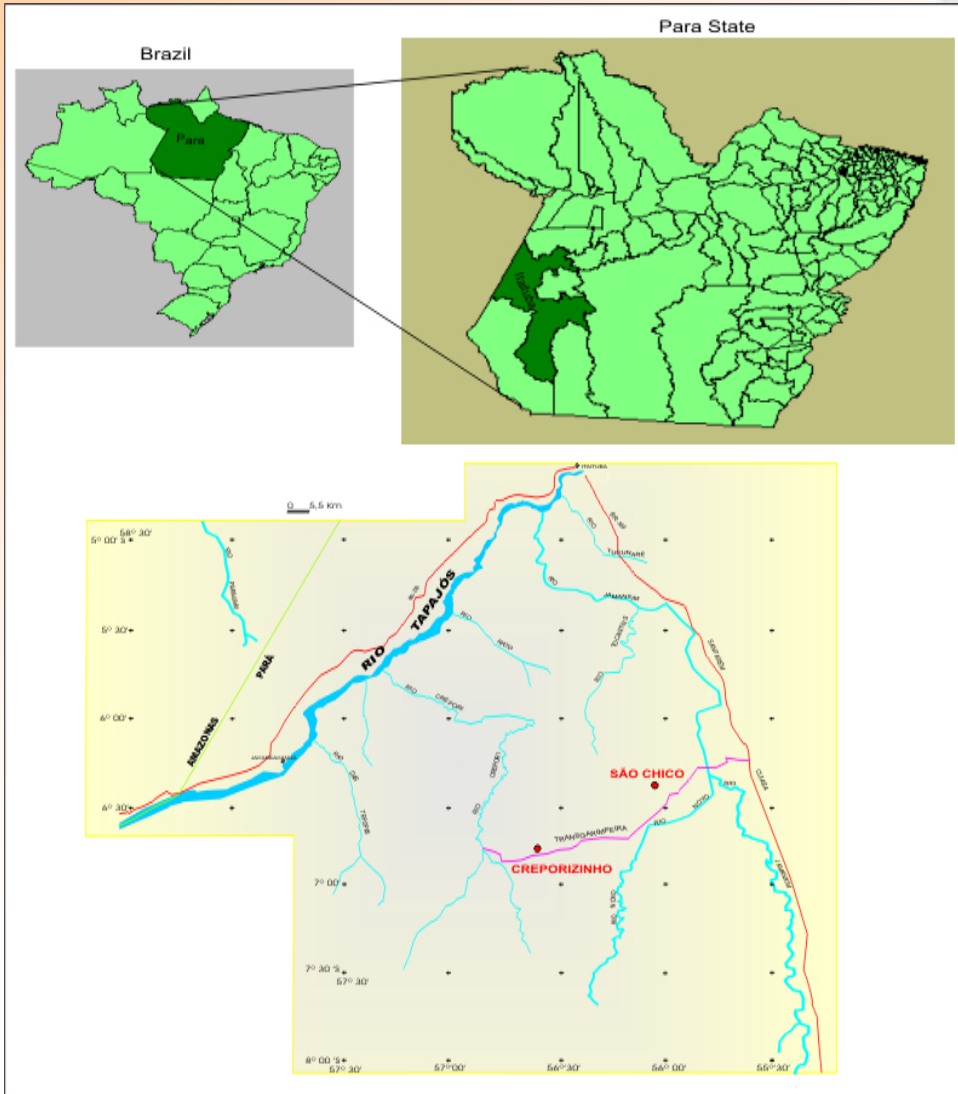
- Researchers: 23 persons
- Period of time: 20 days
- biota, sediments, soils and dusts
- Human blood, urine and hair samples
- Medical clinical evaluation



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# São Chico SSMG SITE

Tapajós Gold-Mining Reservoir 28,745km<sup>2</sup>



[www.embrapa.gov.br](http://www.embrapa.gov.br)



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## São Chico Village and Mining Site

SSGM since 60's





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## São Chico Village



- no water treatment; no waste collection; no domestic sewage treatment
- Rainforest dangers: snakes, scorpions, spider, etc.
- Isolation, mainly during raining season;
- No agricultural/food production
- Food, drink, transportation and medical assistance are very, very expensive (by plane)
- Primary Health Care Place (once a month it is visit by health agent)

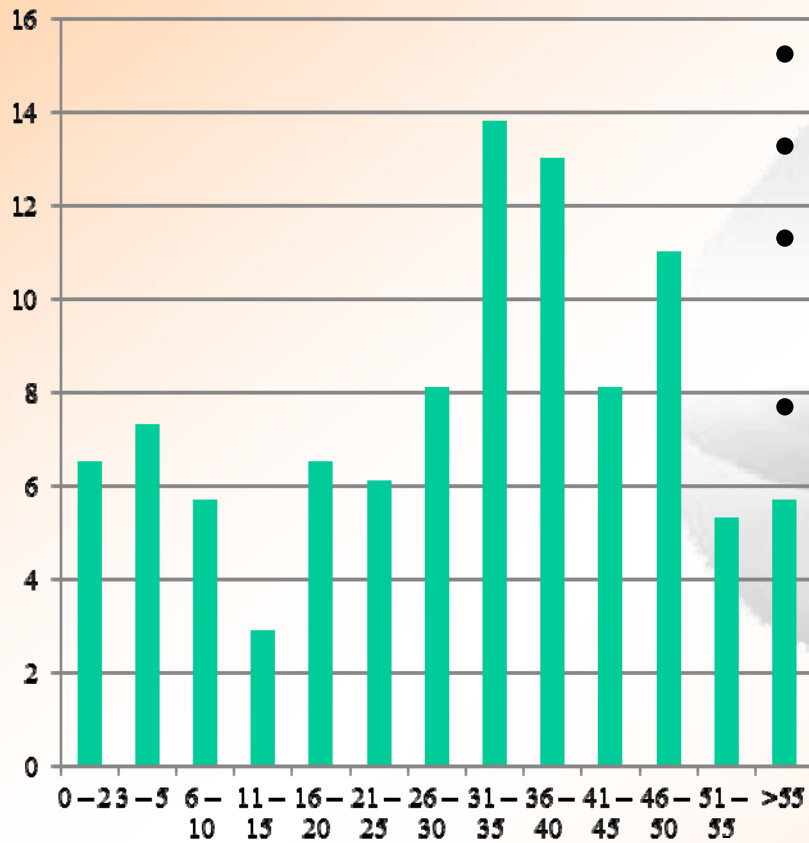
Photos by A.Mathis



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# Population Profile

**Age distribution**



- Men (31-50 years old) are predominant, BUT

- More than 20% are children, BUT

- There is no school

- Low study grade: 2 years in the school

- ~50% of hab. are miners; for more than 10 years

- ~50% are immigrants from Maranhao State;

Alcohol abuse, drugs abuse, smoking and violence is spread in SSGM

High frequency of sexual diseases, including AIDS



# Mineral processing and (bad) work conditions





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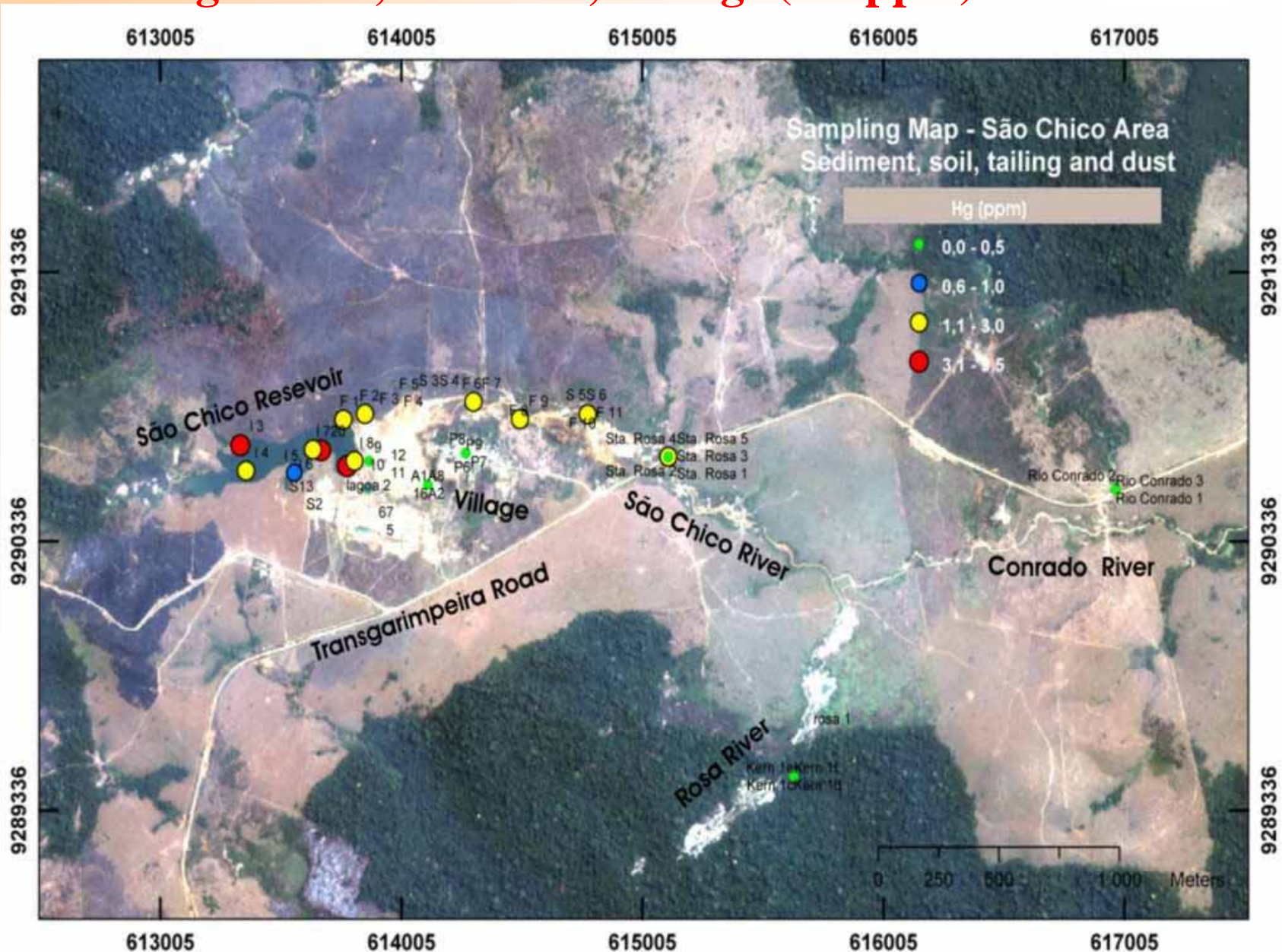
## Abandoned cyanidation unit, close to São Chico Dam







## Hg in soils, sediments, tailings (300ppm) and dusts





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**Hg in Dust and  
Spider Web  
~1.300  $\mu\text{g/g}$   
(inside the house)**



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- **It is difficult perform fish sampling close to SSGM due to the high turbidity in rivers**





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# HgT Analysis at CETEM/LEMA

**Quality control: CRM chart daily results; Accuracy: 98% and Precision: 90% and IAEA International Intercalibration Exercise (annually, since 2000)**



**MeHg**

**GC-ED Akagi's Methodology,  
since 2000**

**HgT by using AAS LUMEX (RA – 915+),  
since 2004**

**For this Project: Abiotic  
samples and fish were  
analyzed by CETEM and  
humans samples were  
analyzed by IEC/MS**

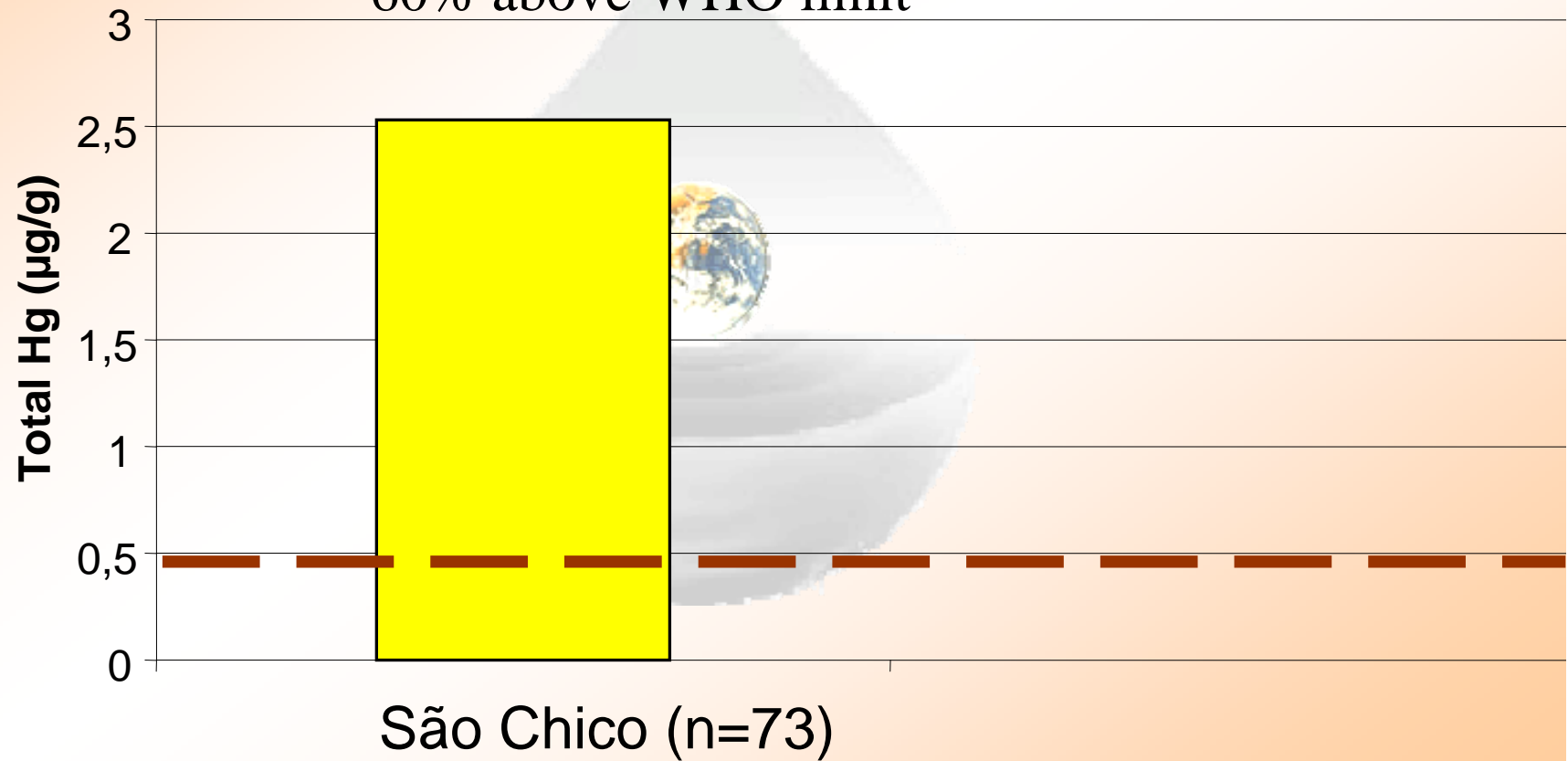


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# Total Mercury in Fish: 13 species



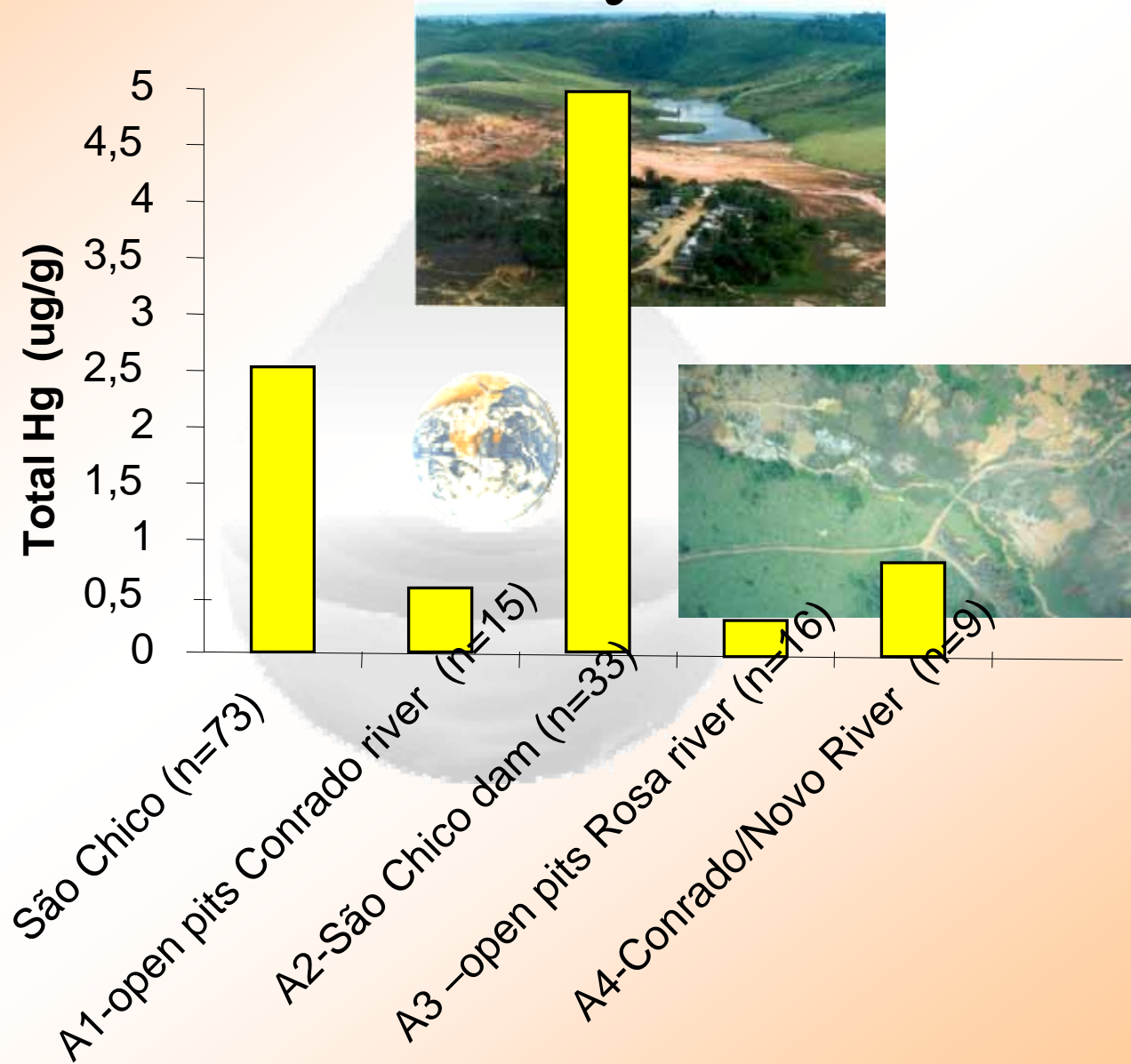
60% above WHO limit





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# Total Mercury in Fish: Sites





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Hazard quotient (HQ) for MeHg intake by fish consumption  
at screening level:

HQ < or = 1: no hazard; HQ > 1: human health hazard

$$\text{HQ} = \text{Dose Intake} / \text{RfD}$$

$$\text{DOSE INTAKE} = C * \text{IR} / \text{Wt}; \text{ where;}$$

C = Hg levels in fish; IR = fish ingestion rate  
(Sociological report: 1 or 2 times weekly; IR ~ 0.02 Kg/day)

Wt = body weight

RfD = Reference Dose (mg/kg/day)

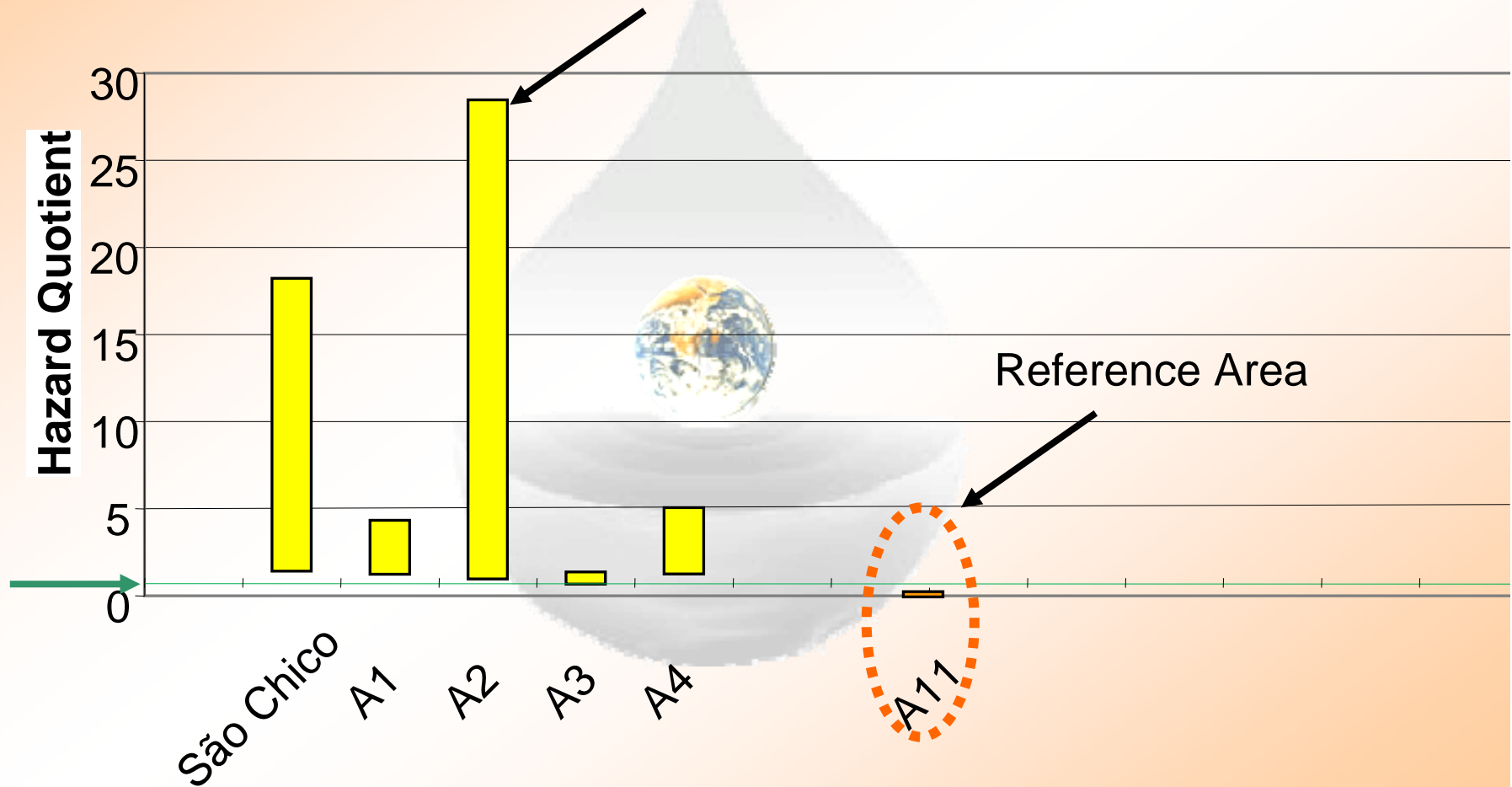
[www.iris.org/](http://www.iris.org/) RfD MeHg = 0.0001 mg/kg/day

(a conservative approach)



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## Human Health Risk by Hg Exposure Due to Fish Consumption (US EPA, 1989)

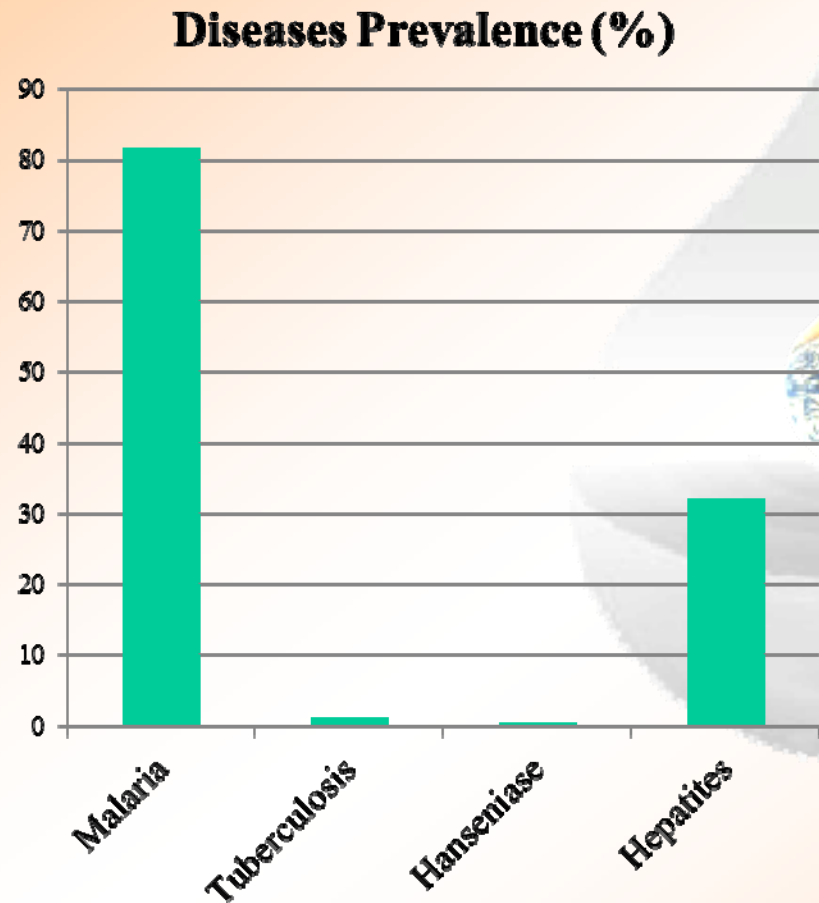






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# Epidemiological Study

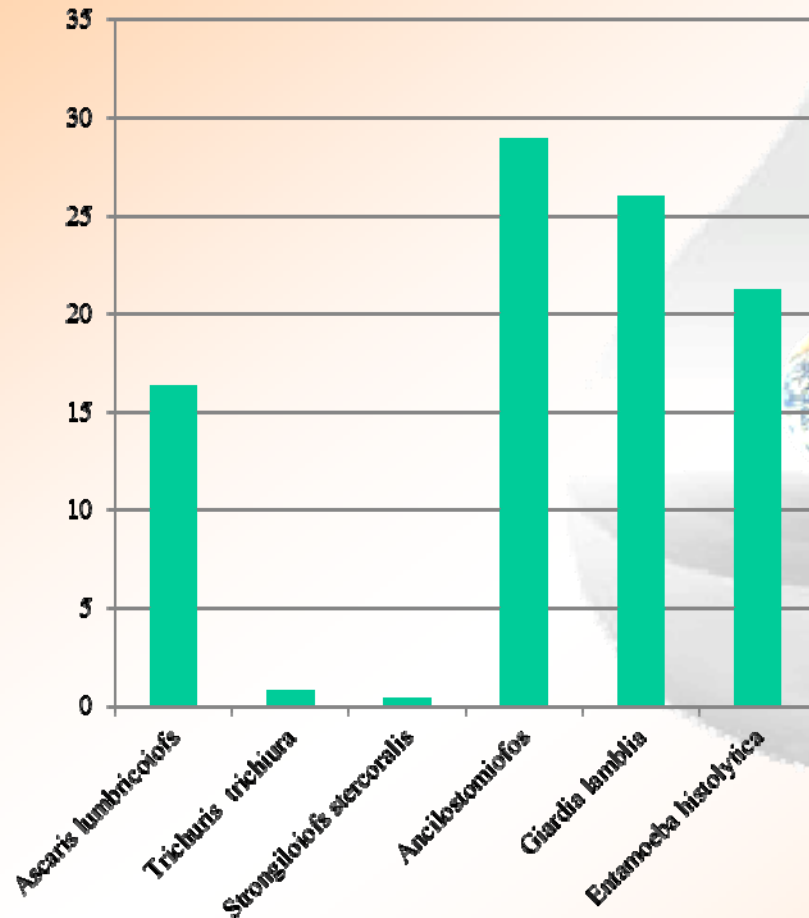


- Brazilian Ethical Comitee approval
- Epidemiologic questionnaire applied
- Malaria: endemic (more than 80% of habitants have or have had malaria more than once) and potential confounder for Hg vapor effects;
- Hepatites: adverse effects on the liver



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# Intestinal Parasites

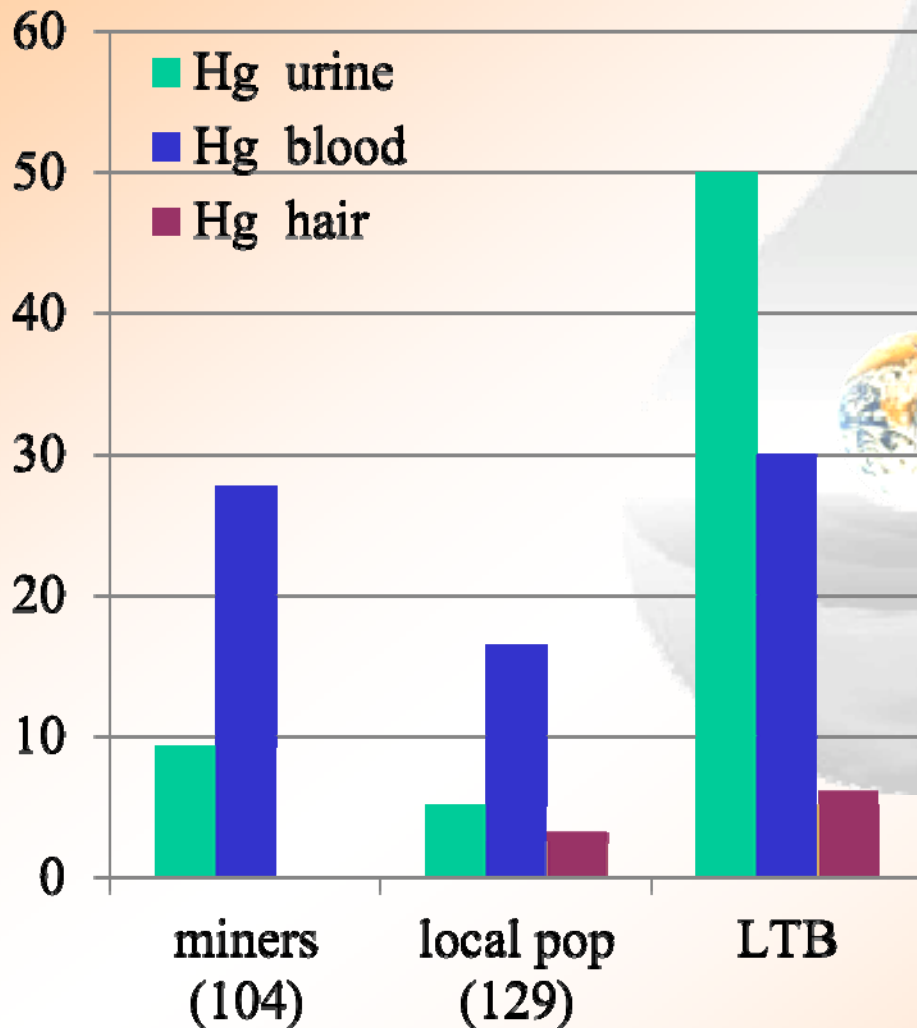


- High incidence of intestinal parasites, which worsen nutrition quality as they decrease the absorption of food's nutrients and cause diarrhea, gi disturbances, **anemia** (other confounder), etc.
- **Health vulnerability**



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# Hg levels in biomarkers: mean value

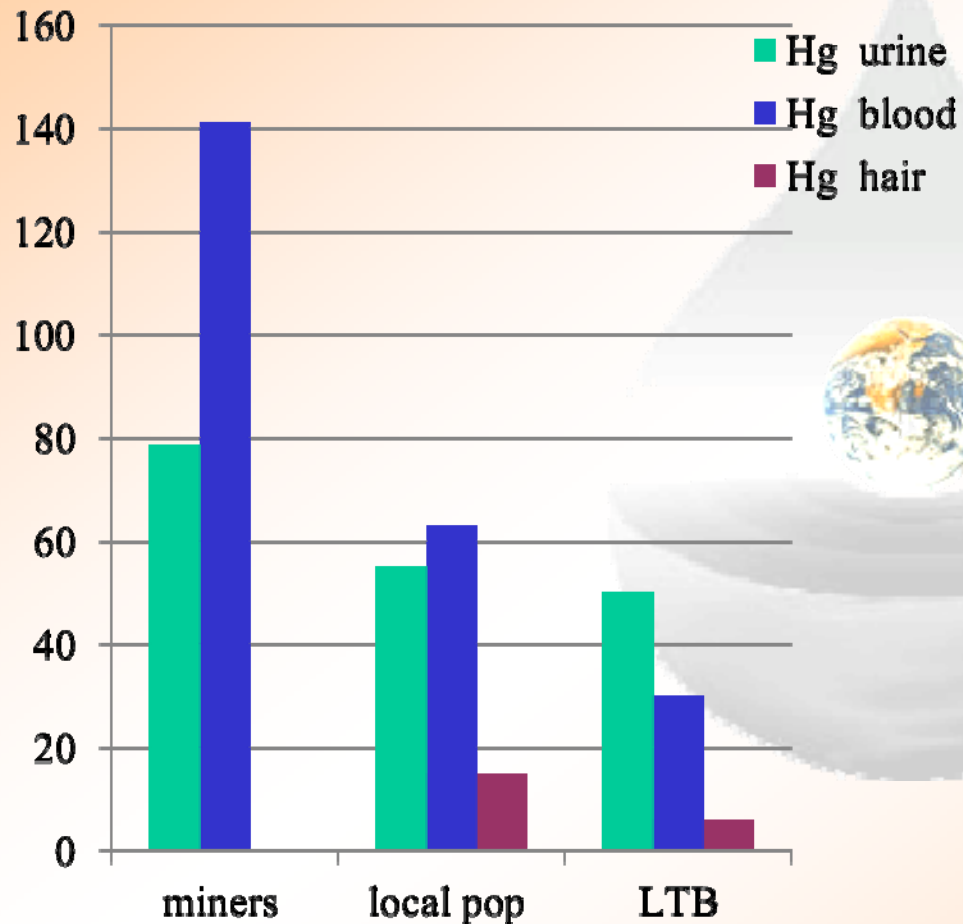


- Hg Chronic Exposure (>10 years);
- Hg levels in miners > non miners
- **Hg in urine:** >80% showed levels between 10-50ug/g (occupational limit)
- **Hg in blood:** > 80% showed levels below 30ug/g (occupational limit)
- **Hg in hair:** >80% showed levels below 4ug/g (WHO limit= 6ug/g)
- **HOWEVER, THERE ARE CRITICAL GROUPS**



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# Critical groups



- Hg levels in miners > non miners
- **Hg in urine:** 3% showed levels above occupational limit
- *Hg in blood:* there are cases higher than 100ug/l
- **Hg in hair:** some individuals showed levels close to 15 ug/g



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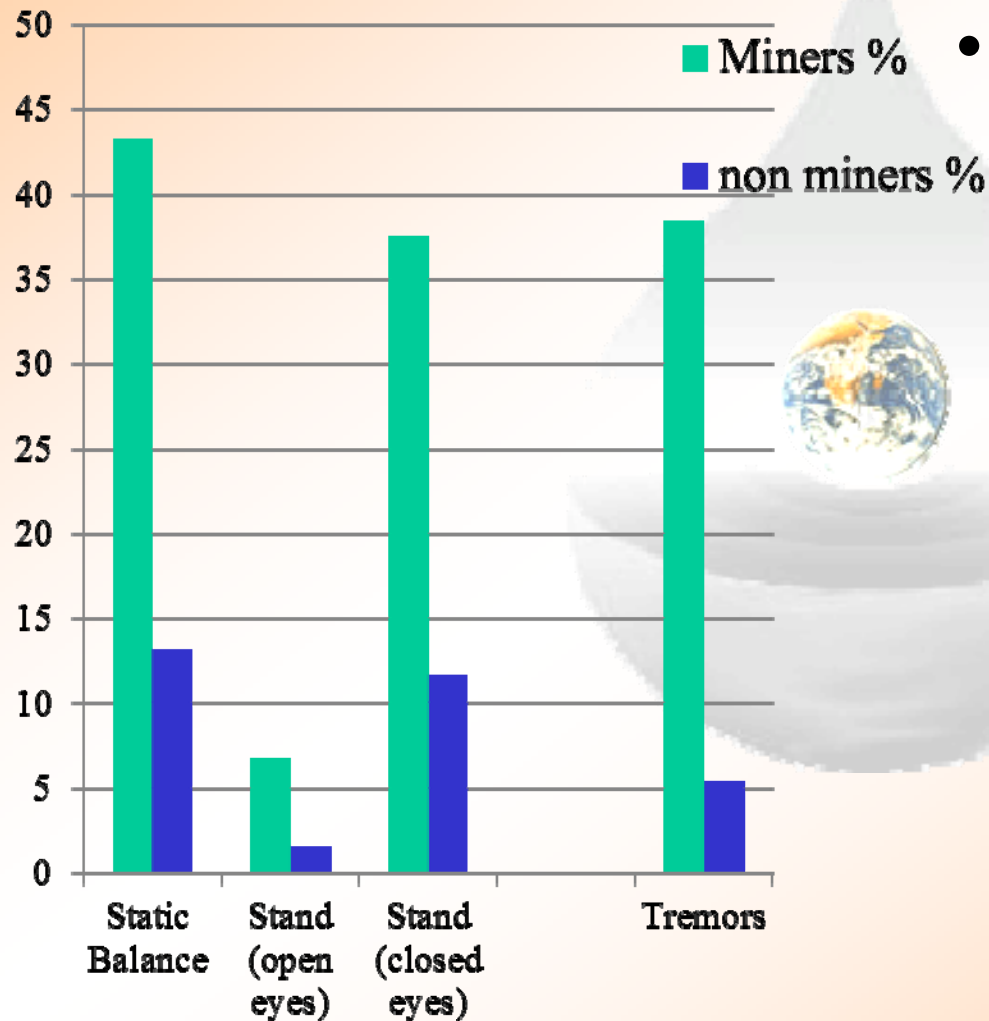
# Medical Evaluation (UNIDO's Protocol)

- Skin, digestive, respiratory, cardiovascular and osteomuscular systems were evaluated
- Self perception of health
- Muscular strength and reflex
- Static and dynamic balance
- The frequency of **hepatomegalia** and **splenomegalia** were **5 and 4 times higher in miners than in non-miners** (potential damage on liver and spleen).
- Liver normal detoxification function may be impaired





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- Miners showed higher frequency of **tremors** and **stand problems**, **mainly with closed eyes**. They are neurologic problems, which may be caused by chronic Hg vapor exposure



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# Conclusions





SSGM are places with low quality of life and high health vulnerability

One should consider this vulnerability to understand that Hg exposure may be worst in these communities;

The outliers (higher Hg levels in blood, urine and hair) should be considered as critical groups;





At SSGM, occupational and environmental exposure are not separate as the workplace is close to the houses or even inside the house; one should integrate these exposure profiles/reference numbers

Hg levels in urine of non miners support this idea

Higher frequency of tremors and static balance impairment associated to high Hg levels in urine and blood indicate neurotoxicity by Hg vapor exposure in miners



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Human health risk assessment estimated high hazard by MeHg exposure by fish ingestion. However, no signs of MeHg toxicity was detected.

The SSGM communities profile is changing, from single men group to family standard communities. This reality needs attention, mainly because MeHg intrautero potential exposure in SSGM



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# To think about

80's

2000's

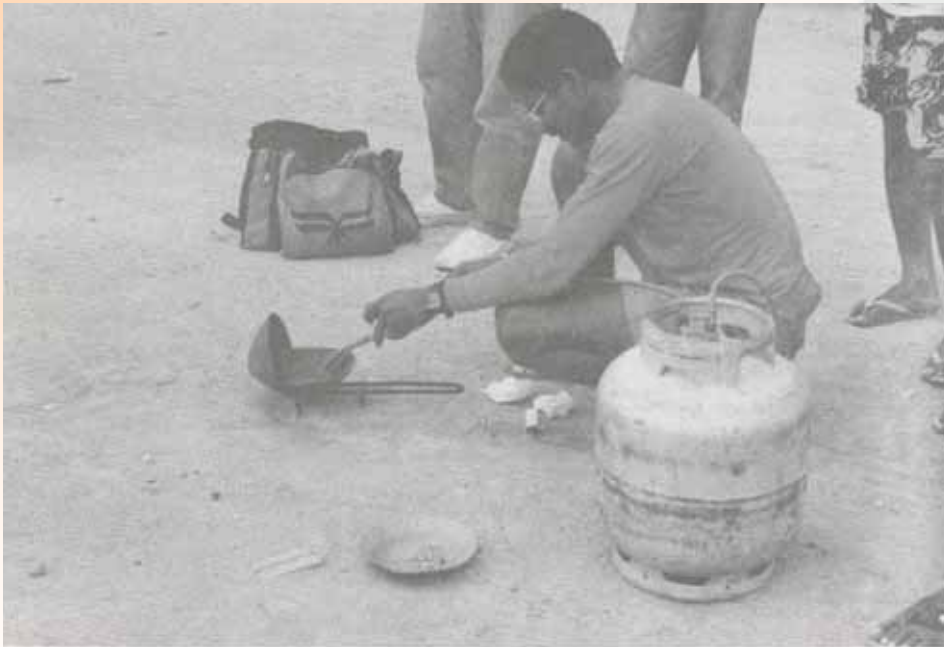


Foto nº 11 - Queima do concentrado amalgamado no garimpo





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**I'd like to thank São Chico  
population and you, for you  
attention.**

**FOR THOSE INTERESTED IN  
FURTHER INFORMATION, PLEASE,  
CONTACT ME AT:**

**[zcastilhos@cetem.gov.br](mailto:zcastilhos@cetem.gov.br)**