Global Mercury Project

Environmental Assessment in two Small Scale Gold Mining Areas in Indonesia Biogeochemical Aspects

Saulo Rodrigues-Filho et al. (2004)

Country Task Force Meeting
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Project Staff

UNIDO – Project Coordination Unit

Christian Beinhoff – Chief Technical Advisor

Pablo Huidobro – Project Manager

Marcello Veiga – Small Scale Mining Expert

CETEM – Centre for Mineral Technology

Saulo Rodrigues Filho – Team Leader

Roberto Villas Bôas

Zuleica C. Castilhos

Ronaldo L. C. dos Santos

Allegra Viviane Yallouz

Bernhard Peregovich

Silvia Egler

Flavia M. F. Nascimento

Luiz Roberto Pedroso

University of Munich

Institute of Forensic Medicine

Stephan Boese O´Reilly

Stefan Maydl

Alexandra Dittmann

Sven Illig

Gustav Drash

UNIDO OFFICE JAKARTA

Mr. Masayoshi Matsushita

Country Focal Point

Mr. Thamrin Sihite

Assistant of Country Focal Point

Ms. Selinawati

OUTLINE

- **Objetives**
- **Materials and Methods**
- **Description of the study areas**
- **Mining and Processing Techniques**
- **Results of the Environmental Assessment**
- **Conclusions and Recommendations**

OBJECTIVES

- Conduct an assessment of the magnitude of mercury contamination in two study areas affected by gold mining areas in Indonesia;

- Provide technical support for intervention measures;

OBJECTIVES (cont.)

- investigation of existing geochemical sources of Hg, also prior to the establishment of a mining activity (background);
- evaluation of Hg bioavailability and mobility through characterization of hydrochemistry, geochemistry, mineralogy and bioindicators.

MATERIALS AND METHODS

- **768 samples** split into **420 biological** indicators as fish, plants and shells, and **348 inorganic** indicators, as sediments, soils and water;
- Total suspended solids (TSS) and water play a pivotal role in assessing mercury mobility and the nature of pollution;
- Mercury transported either in solution or onto suspended particles may settle forming mercury sinks;

MATERIALS AND METHODS

- It was sought the collection of naturally settled TSS samples where favorable hydrodynamic conditions were found;

- Preparation of sediment, soil and tailing samples consisted of wet sieving (< 74 µm) and drying at 40 °C;

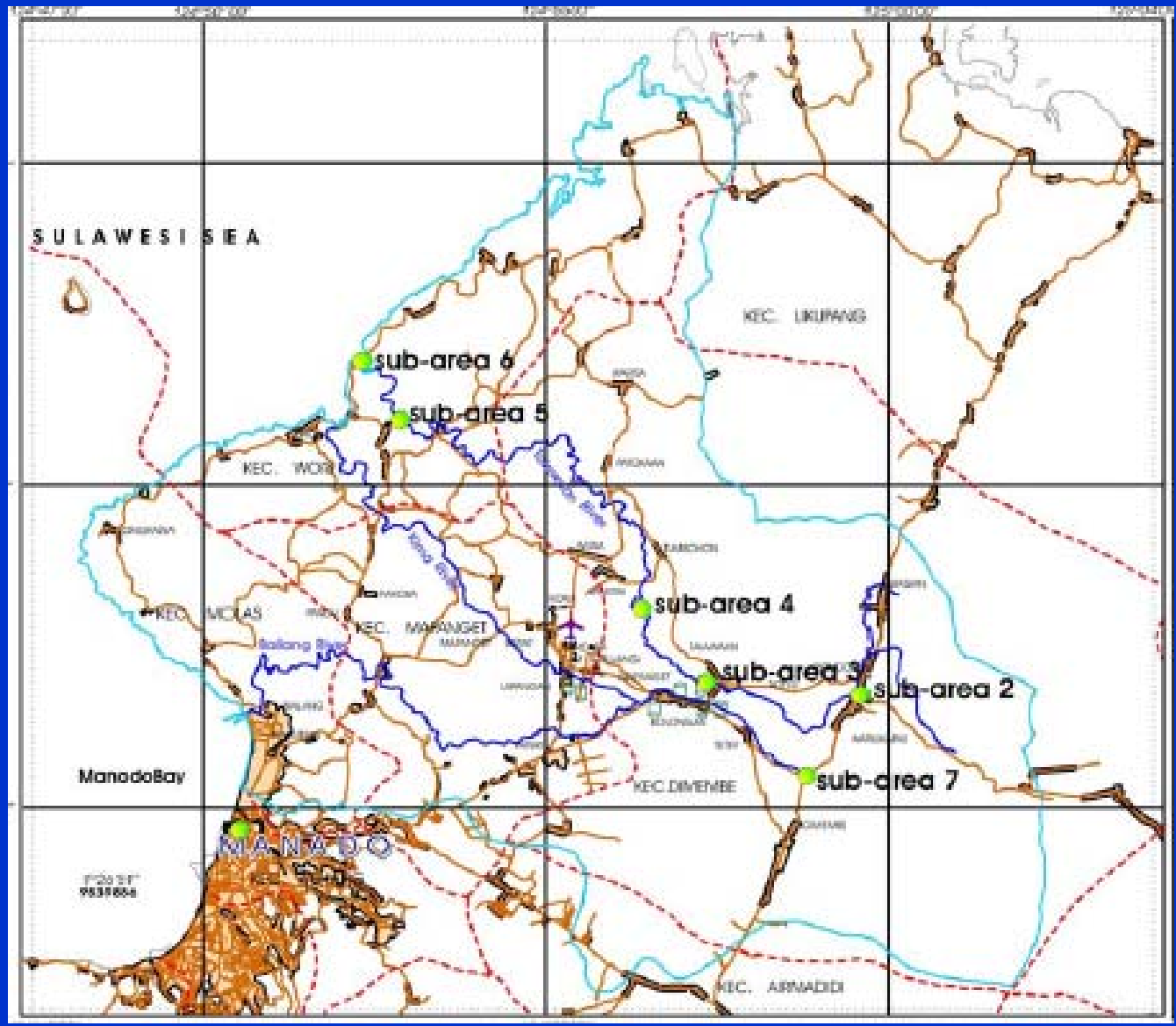
- After removing the individual axial muscle (fillet) of fish, each sample was placed in polyethylene bags and ice boxes, and frozen after reaching hotel facilities.

MATERIALS AND METHODS

- Analytical method for total Hg follows methodology developed by Akagi and Nishimura (1991). acid digestion followed by reduction to elemental mercury, aeration and measurement by cold vapor atomic absorption spectrometry;

- AAS with pyrolisis used in the field (LUMEX)

North Sulawesi - Indonesia



North Sulawesi – Indonesia

Sampling Campaign – September 2003

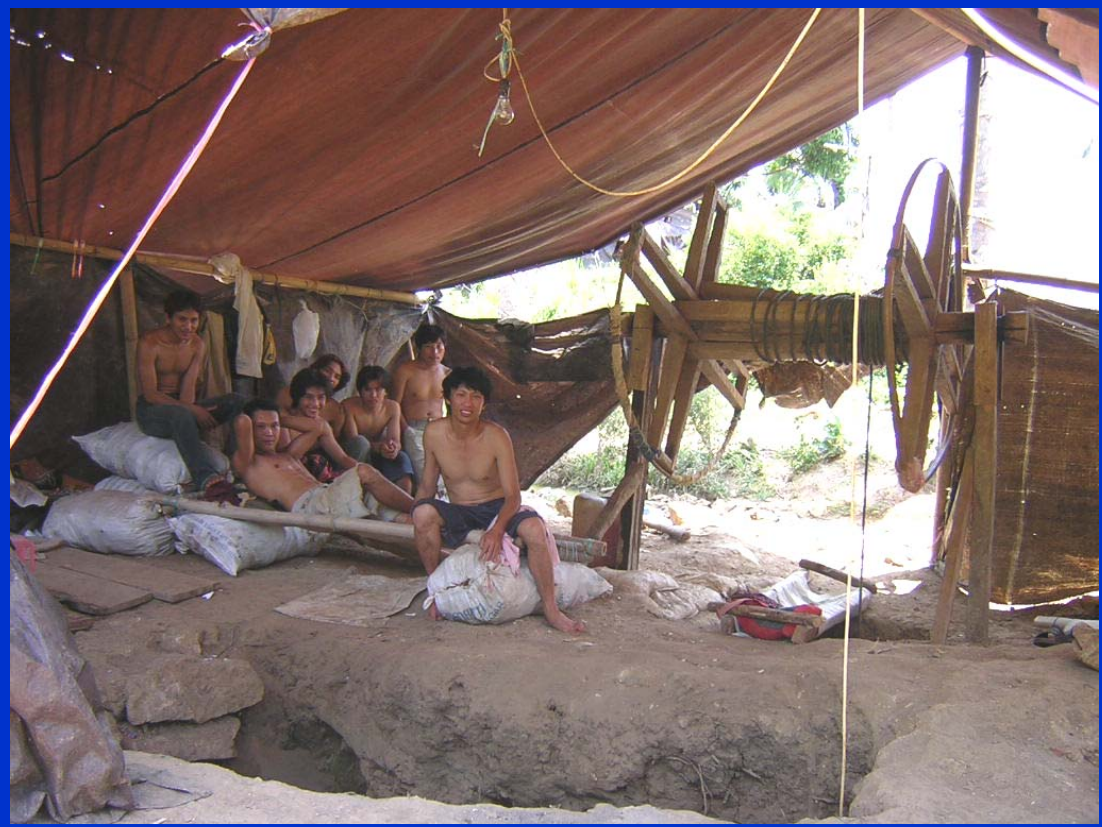
- 157 fish samples
- 149 inorganic samples (soils, sediments and water)
- 57 bioindicators other than fish (plants, roots, mussels and corals)
- 250 human samples (blood, hair and urine)
- Total of 613 samples

Tatelu-Manado-North Sulawesi

Mining area – hills, shafts and coconuts plantation

Tatelu-Manado-North Sulawesi

- Shaft and manual elevator
- Very young miners, estimated 1000 to 1500 ones



Hard Rock Mining

- inside a narrow shaft 50-70 cm wide
- pushing 30 kg ore sacks from 30 m of depth to the surface
- primary gold ore
- quartz veins in volcanic rocks

Mineral Processing

- Further transported to ball mills („trommels“)
- 2 km downhill close to Talawaan Creek

Mineral Processing (cont.)

- Crushing the ore by stomp mills
- High grade ore
- Less material, less physical impact
- Chemical impact ??

Mineral Processing (cont.)

- Filling crushed ore into „trommel“
- Further crushing and direct amalgamation - without gravity concentration

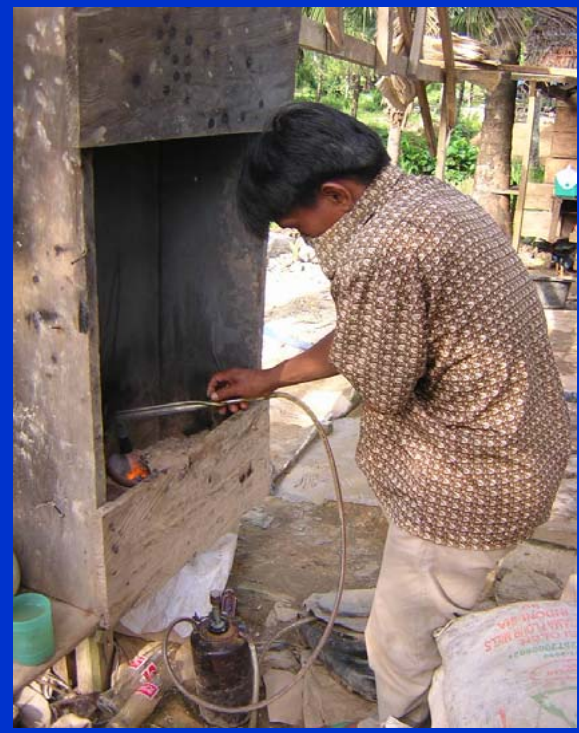
Mercury Loss - Tatelu

- 1 kg Hg per trommel
- 3 cycles/day
- 12 trommels per unit
- 100 units in Tatelu
- ~ 1000 tons/year used! (not lost)
- Hg recycling of 98%

Mercury Loss – Tatelu (cont.)

- Consumption/Loss of 15 kg Hg/month/unit
- Au production of ~300 kg/year in Tatelu
- Estimate of 18 tons/year lost to the environment
- Huge ratio Hg:Au of 60 ! (normal ratios fall in the range of 1 to 2)

Mercury Loss – Tatelu (cont.)



- Roasting of amalgam without retort in any corner
- An occupational health hazard – Hg release to the nose
- Average 10g Au/day for a group of 10 miners

Cyanidation - Tatelu

- Sacking of amalgam wastes for cyanidation
- Cyanidation tanks (20 tons/batch)
- Average Au prod. 400 g/batch
- Average Hg recovery 800 g/batch (only)

Cyanidation – Tatelu (cont.)

- Au-Hg-loaded charcoal burned in open air
- Remaining Hg goes to cyanidation tailings in neutralization ponds
- Unkown effects of cyanide-Hg complexes to both the environment and health

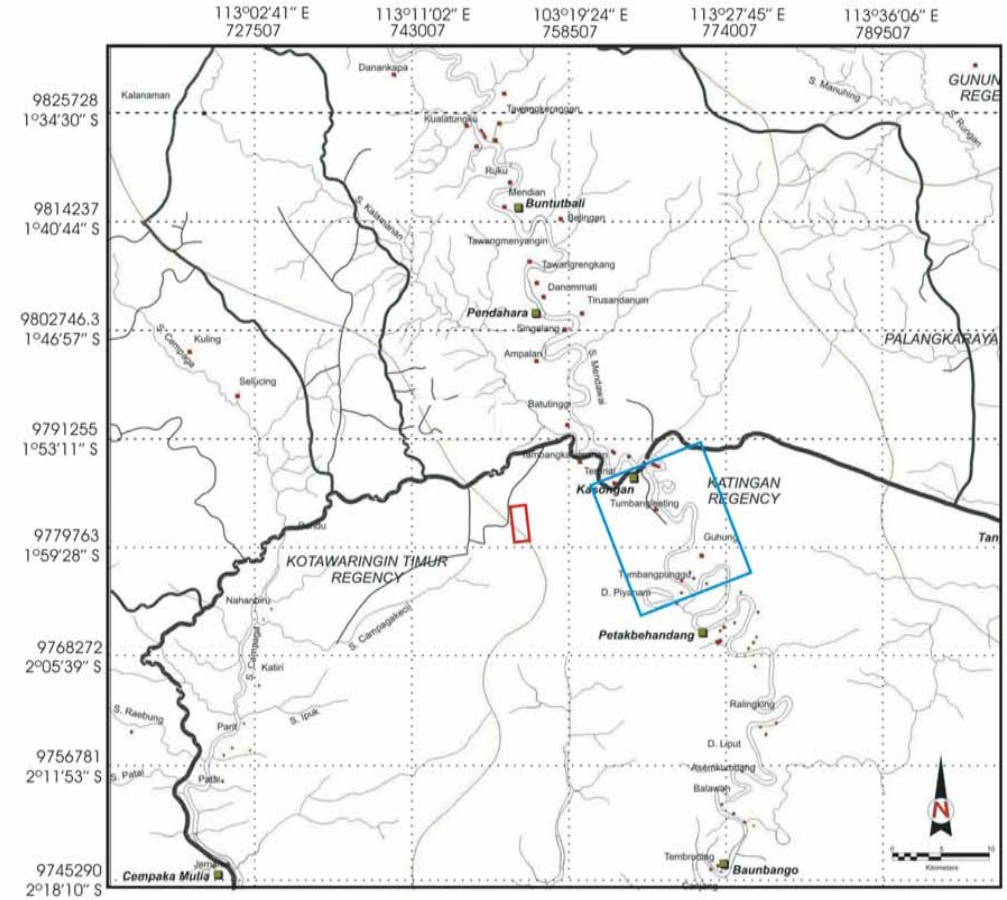
Emission Sources of Hg in North Sulawesi

- Gold fields of primary deposits; direct amalgamation; no gravity concentration (high Hg losses)
- Gold shops and amalgam roasting (Hg to the atmosphere)
- Cyanidation of amalgamation tailings
- Erosion of naturally Hg-enriched soils: through both long-term atmosferic precipitation from diffuse emissions and Hg bearing minerals (volcanoes)

Central Kalimantan - Indonesia

CT BRASIL Ministério da Ciência e Tecnologia | CETEM | CODS - Coordenation of Sustainable Development

SAMPLING MAP OF CENTRAL KALIMANTAN AREA - KATINGAN RIVER - INDONESIA



LEGEND SAMPLING AREAS

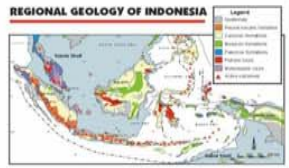
Katingan River

Small Scale Mining

COORDINATES OF SMALL SCALE MINING

754131 E, 9781550 S - 1°58'29" S, 113°17'04" E

PROJECTION SYSTEM/DATUM: WGS 1984/ Zone 49 S



UNDP Project GLO/01/G34 - Removal of Barries to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies

Central Kalimantan – Indonesia Sampling Campaign – September 2003

- 262 fish samples
- 199 inorganic samples (soils, sediments and water)
- 43 bioindicators other than fish (plants, roots, mussels and corals)
- 250 human samples (blood, hair and urine)
- Total of 754 samples

Central Kalimantan - Indonesia

- Galangan Mining site, an alluvial plain
- Former rain forest (intensive logging)

Central Kalimantan Indonesia

- Sand, gravel and peat (dark drainages) not directy affected by volcanic eruption
- Alluvial gold exploration
- Huge physical impact
- Chemical impact ?

Mineral Processing

- Au concentrate, without mercury, recovered from sluice boxes (relatively low Hg losses)
- Amalgamation of Au concentrate in ponds, also used for bath (white mud is caolinite)
- Estimated 2000 miners

Mercury Loss - Galangan

- 1 kg Hg per operation
- 20 kg of concentrate
- 1 cycle/day
- 500 units in Galangan
- Carefull panning
- Hg recycling of 99%

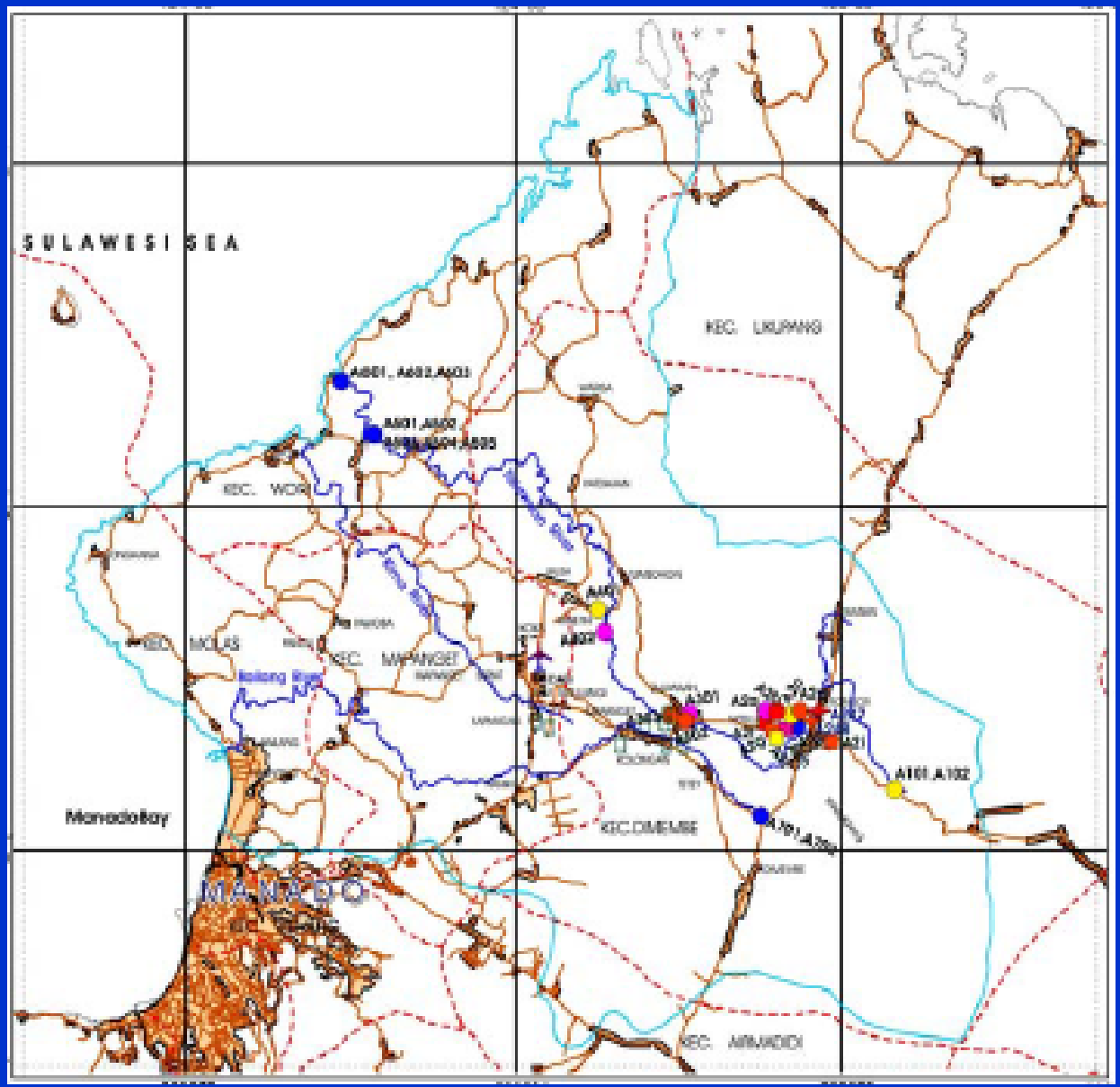
Mercury Loss – Galangan (cont.)

- Amalgam after squeezing ready for roasting in open air
- Gold bying shops in Kereng Pangi, 5 km from Galangan
- Estimate of 2 tons/year of Hg lost
- Ratio Hg:Au of ~ 2.4

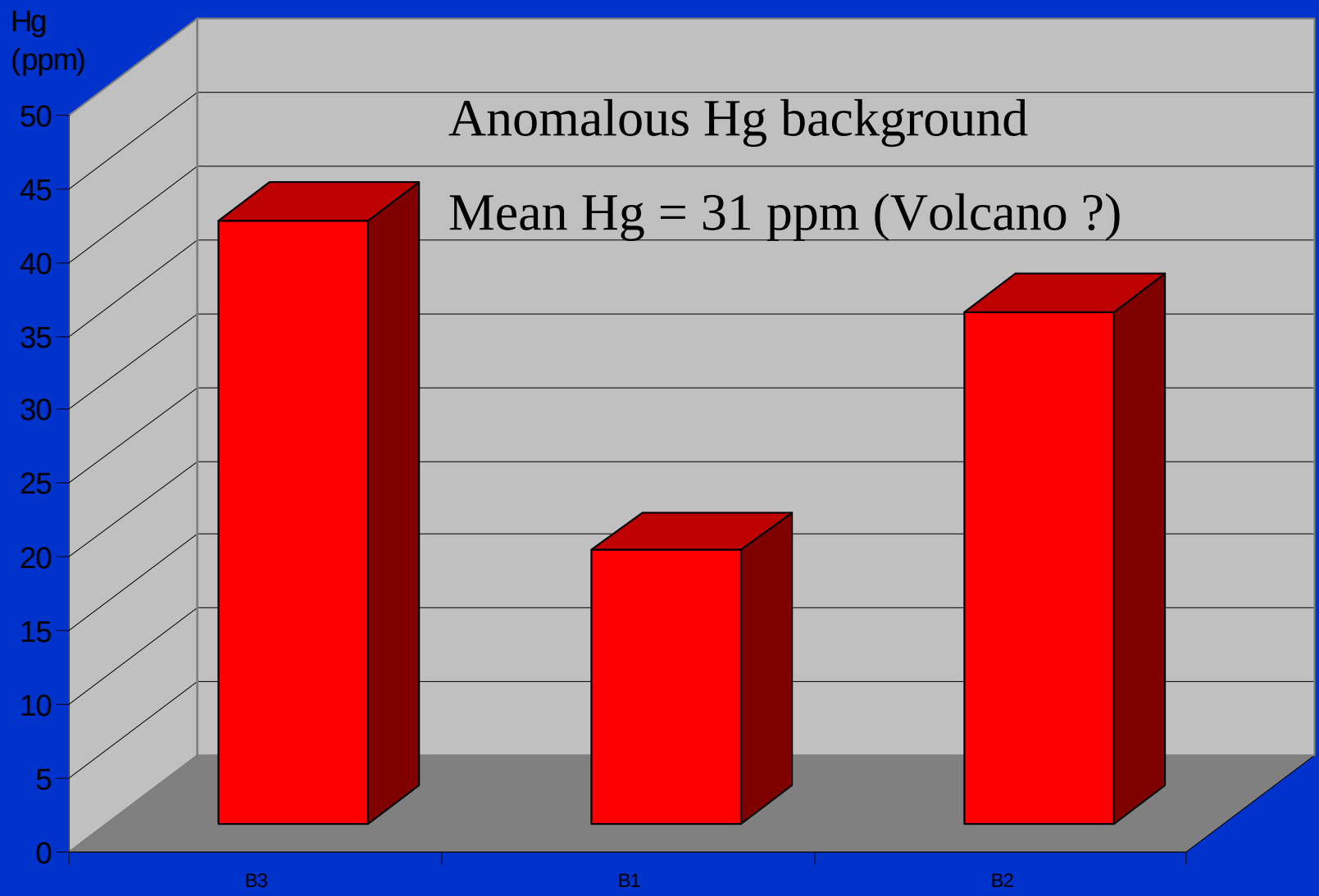
RESULTS – TALAWAAN NORTH SULAWESI

- Hg in sediments, soils, tailings and biota

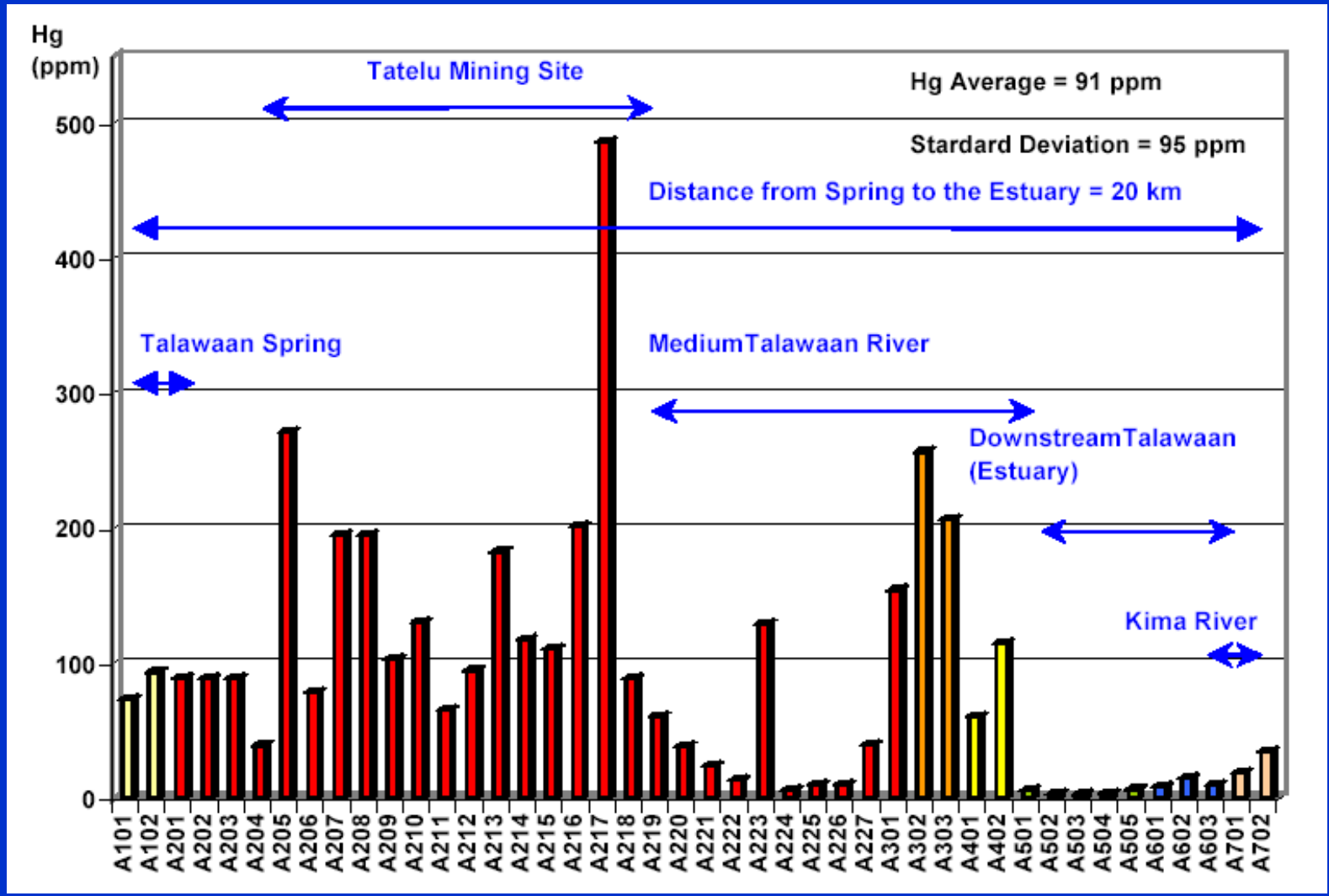
Hg in sediments and tailings



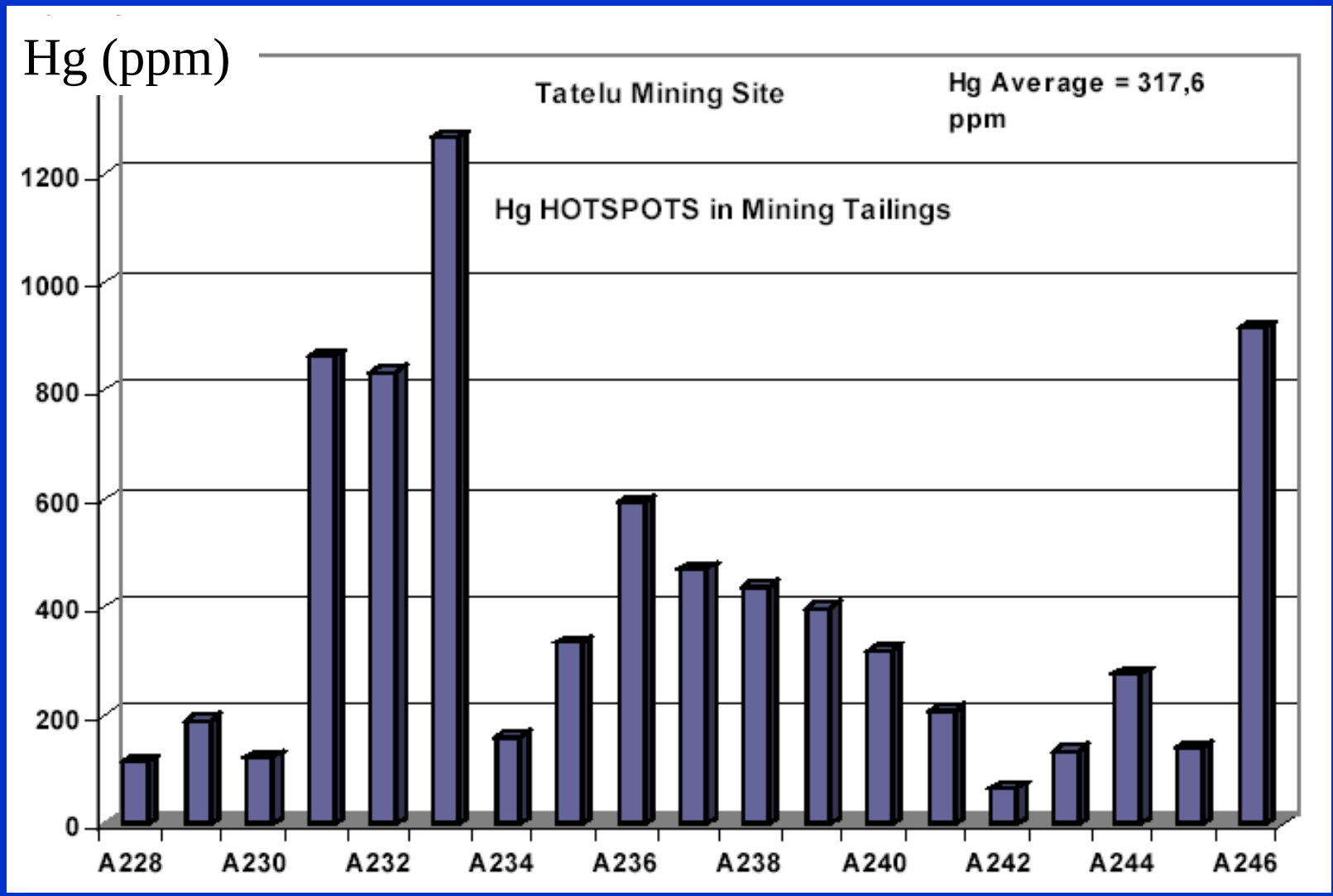
Hg in undisturbed sediments – Talawaan upstream - silt-clay fraction



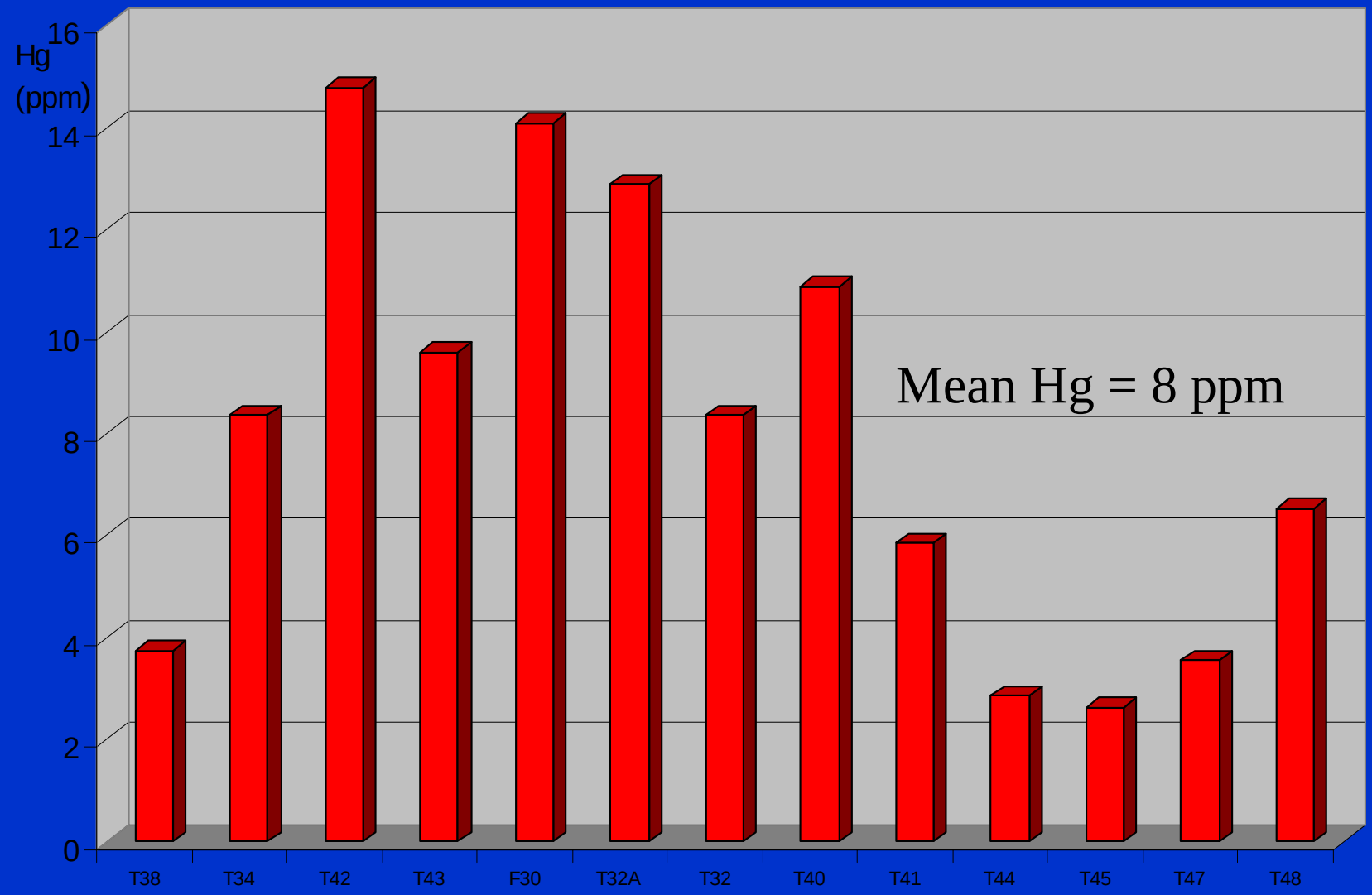
Hg in sediments - Talawaan Watershed
Silt-clay fraction



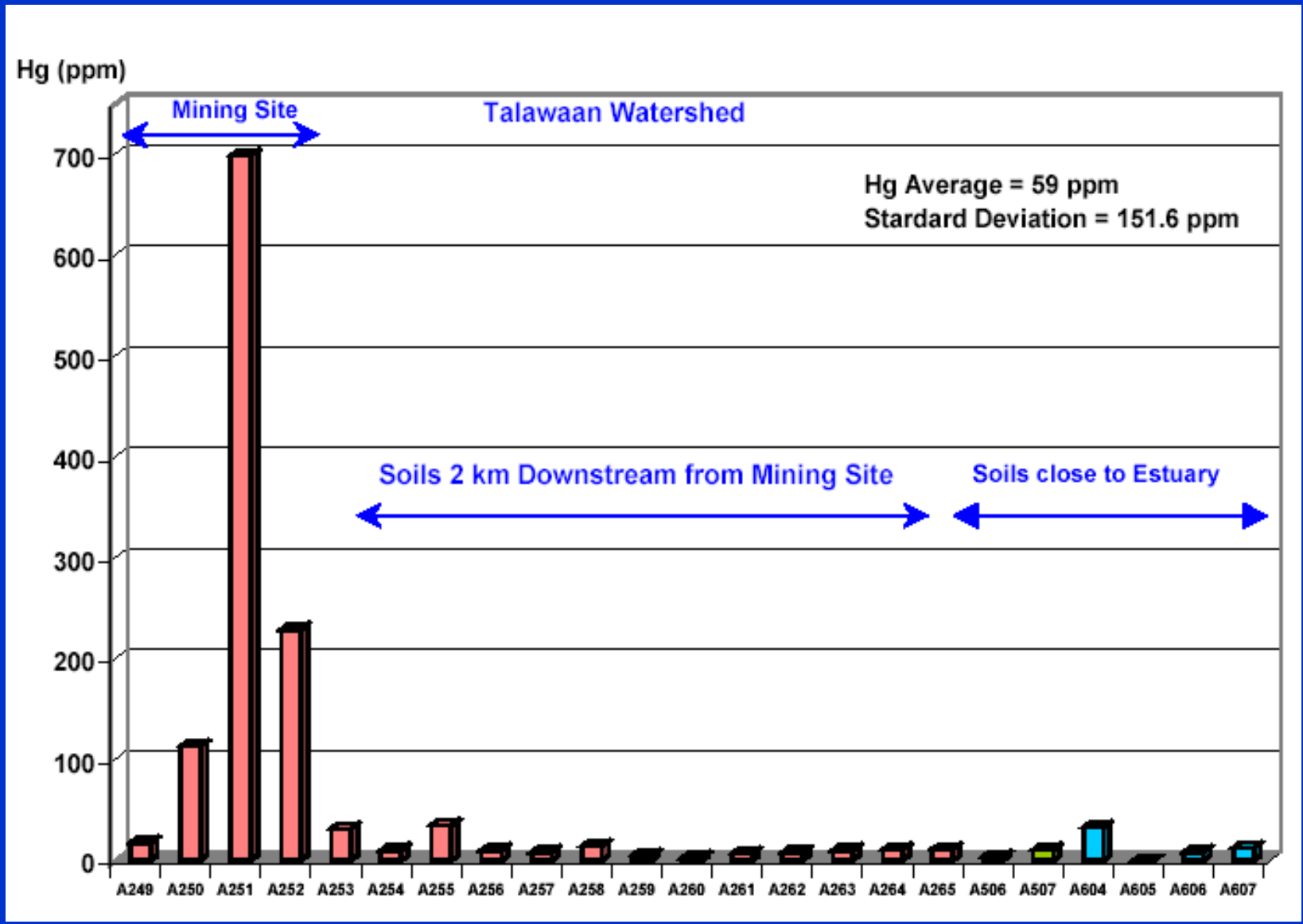
Hg in mining tailings - Talawaan Watershed – Mining sites Hg Hotspots



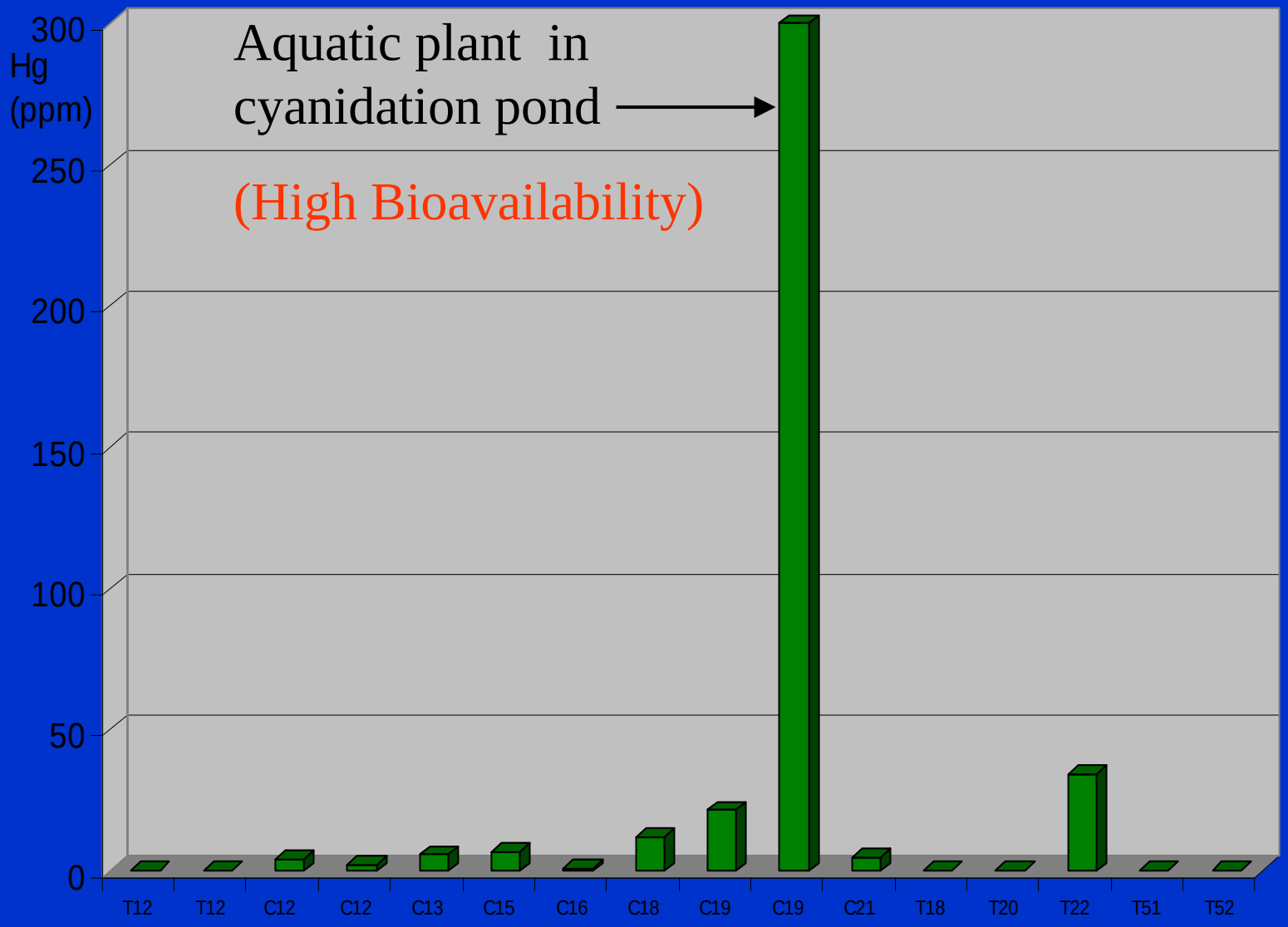
Hg in sediments - Talawaan downstream - 5 to 20 km from mining sites - silt-clay fraction



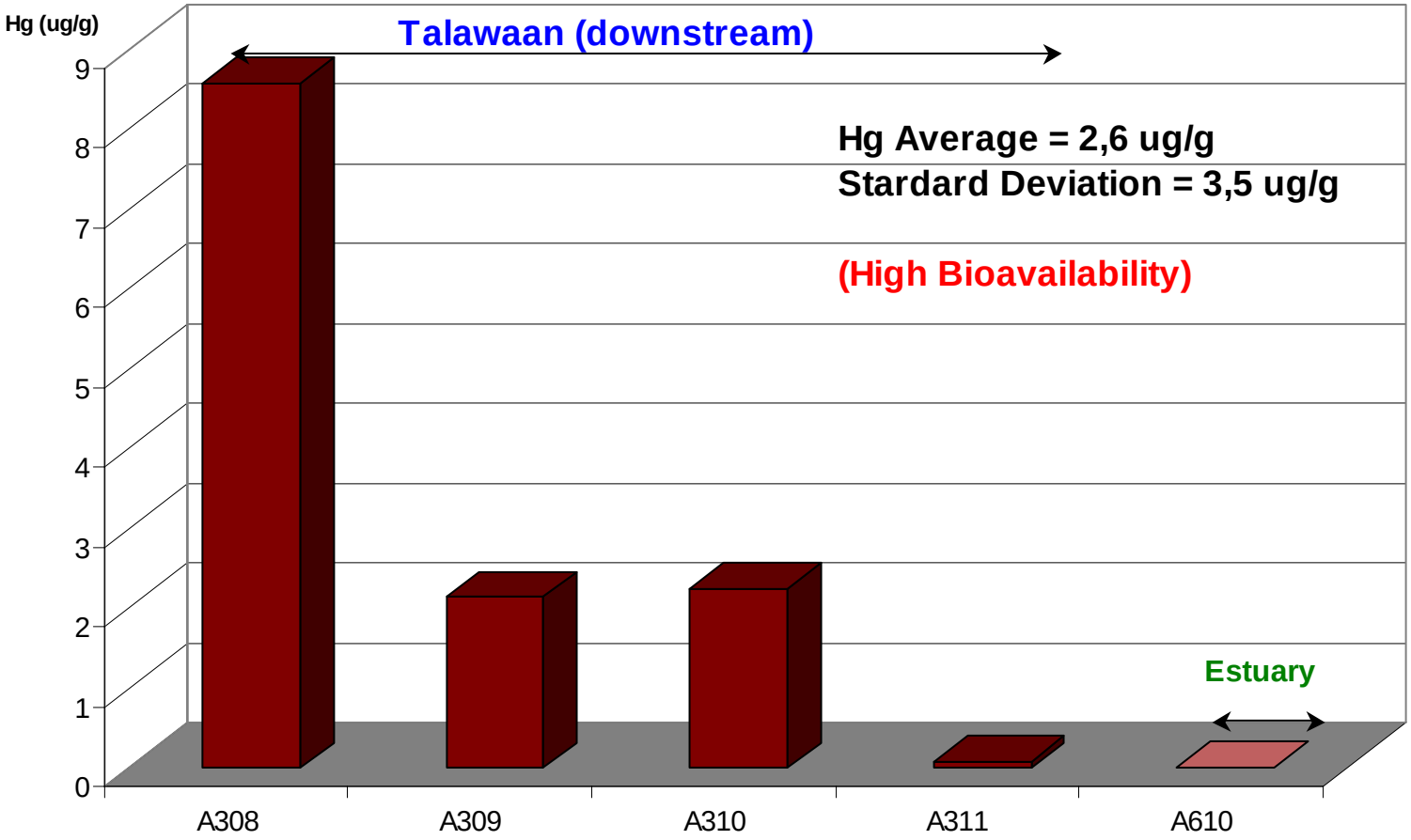
Hg in catchment soils - Talawaan Watershed



Hg in wild plants and vegetables - Talawaan Watershed – Mining sites



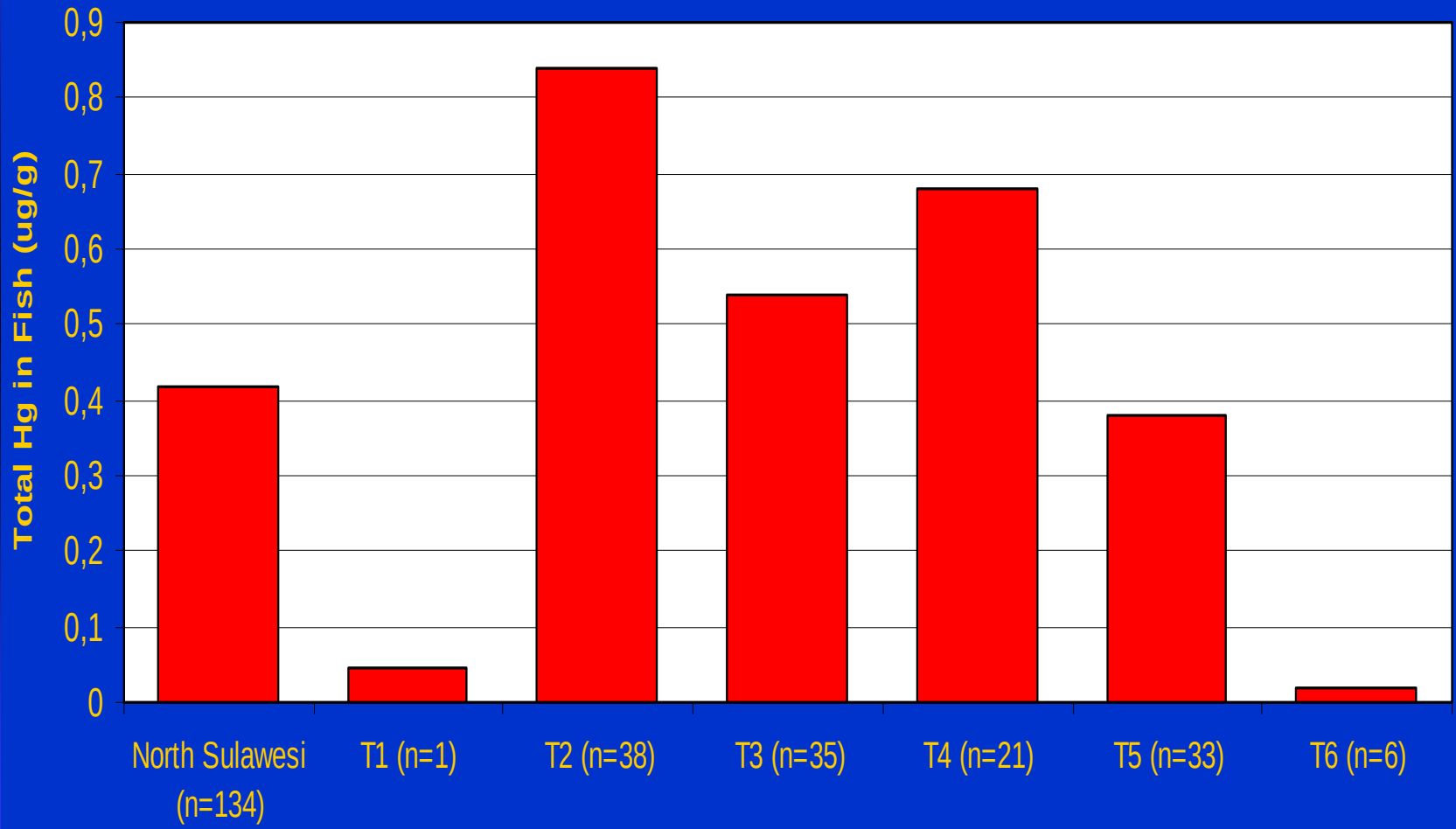
Hg in mollusks– medium course and estuary Talawaan River



Hg in Fish – North Sulawesi

Site	Sampling location	N	Hg-μg/g
T1	Upstream of the gold mining areas; fish farming activities	1	0.044
T2	5 Km downstream of T1; gold mining activities	38	0.84±0.40
T3	Downstream of cyanidation plants	35	0.54±0.40
T4	3 km upstream of estuarine region	21	0.68±0.62
T5	Estuarine region, high fishing activity	33	0.38±0.19
T6	Reference area. Toldano river	6	0.02±0.01

Hg in Fish – North Sulawesi



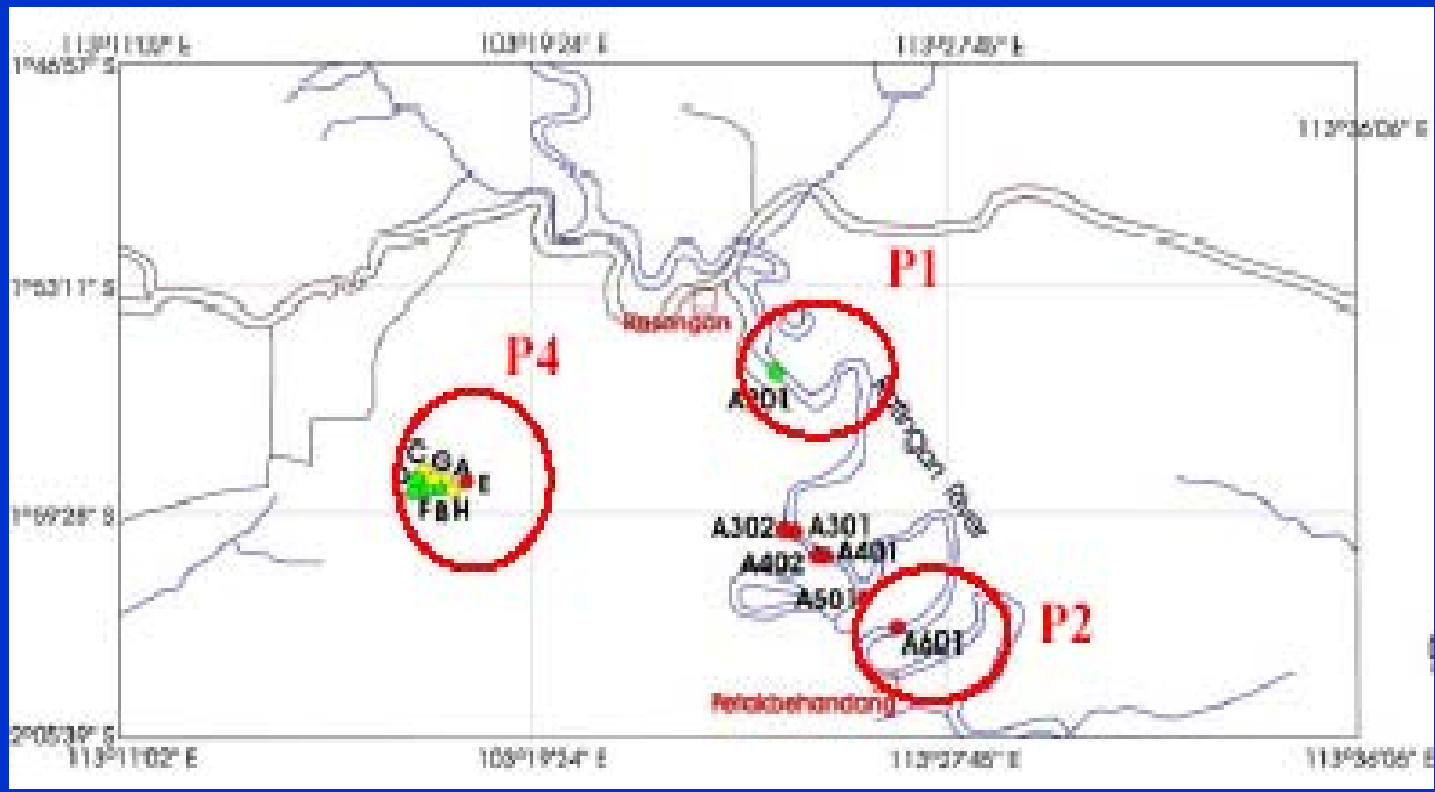
Hg in Water – North Sulawesi

- A reduced number of water samples were checked for assessing their quality in relation to guidelines for drinking water.
- In the main mining sites, mean Hg level in water reachs 1.8 µg/L, while down to the estuarine region Hg levels drop to a mean value of 0.1 µg/L, which falls below the maximum limit of Hg for drinking water established by the World Health Organization (WHO, 1980).

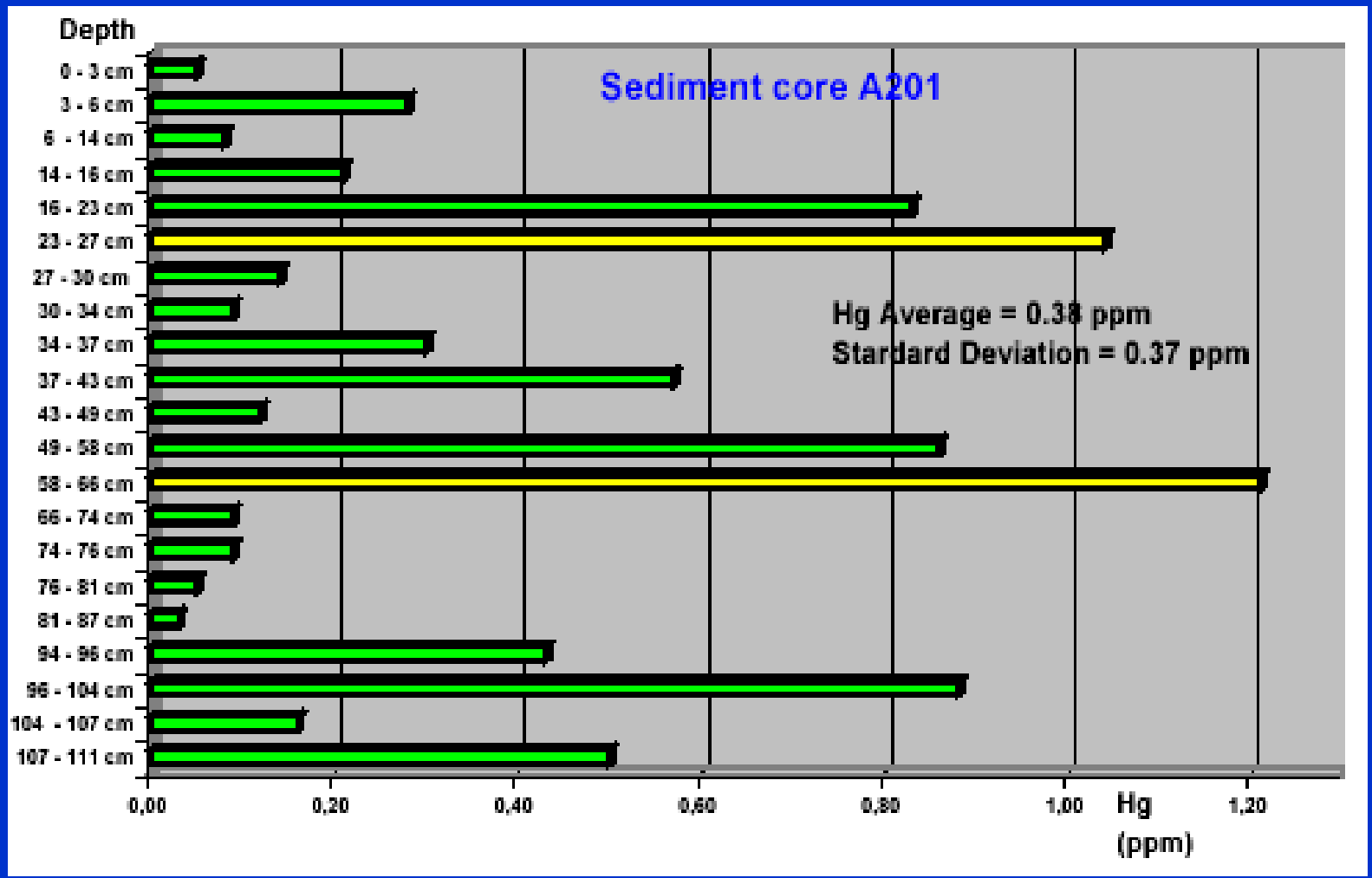
RESULTS – GALANGAN CENTRAL KALIMANTAN

- Hg in sediments, soils, tailings and biota

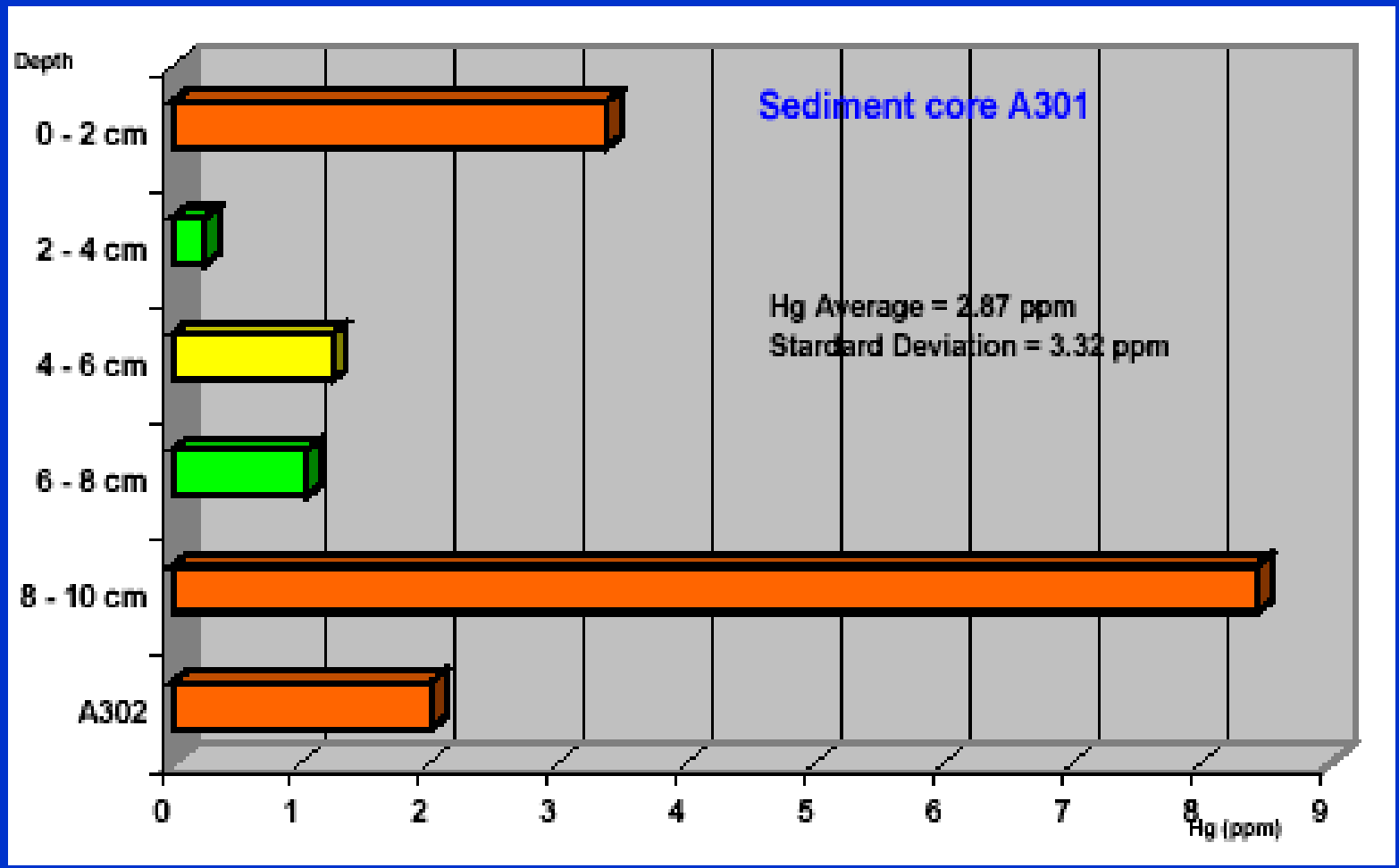
Hg in sediments, soils and tailings



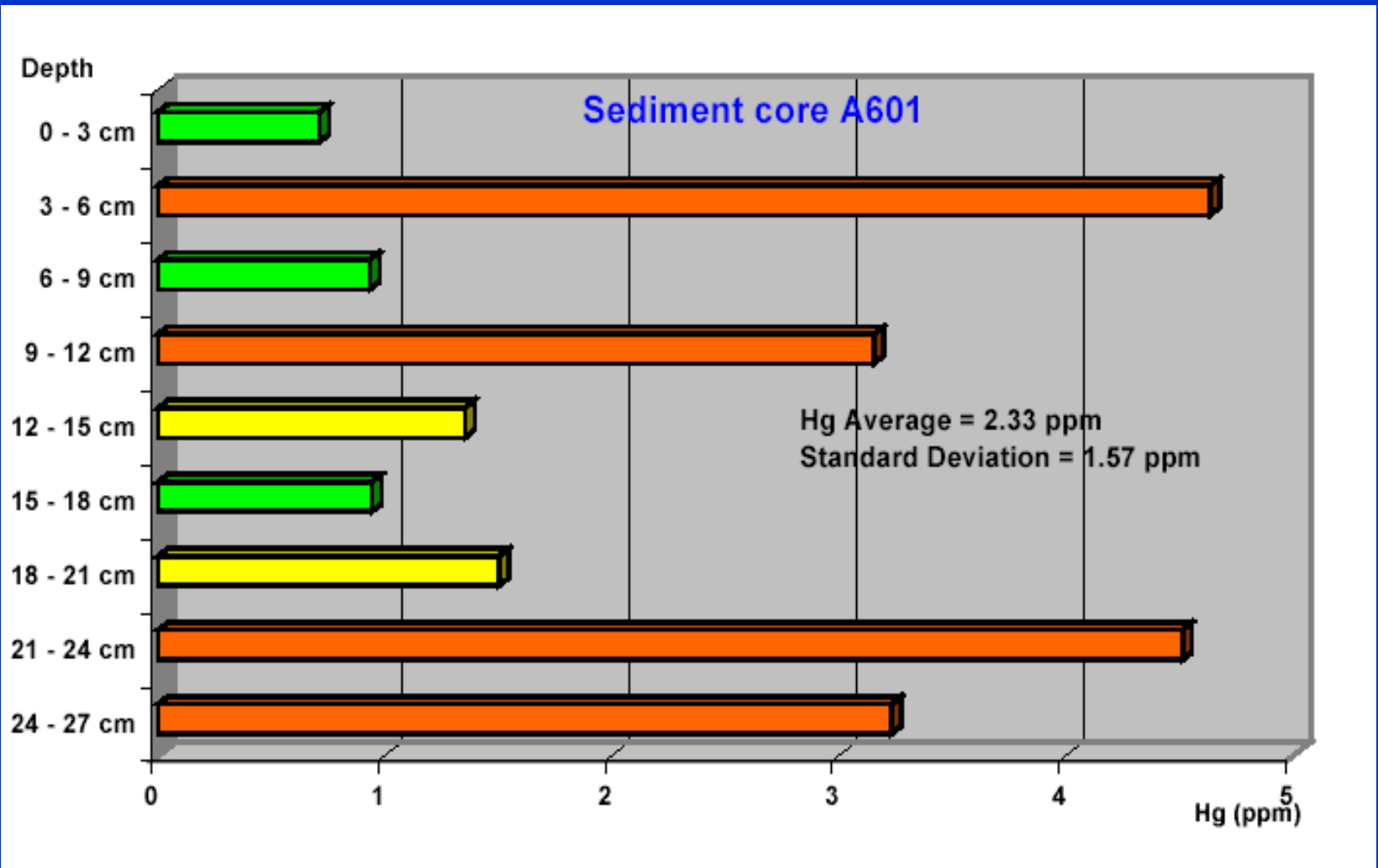
Hg in sediment core sections Katingan River - upstream



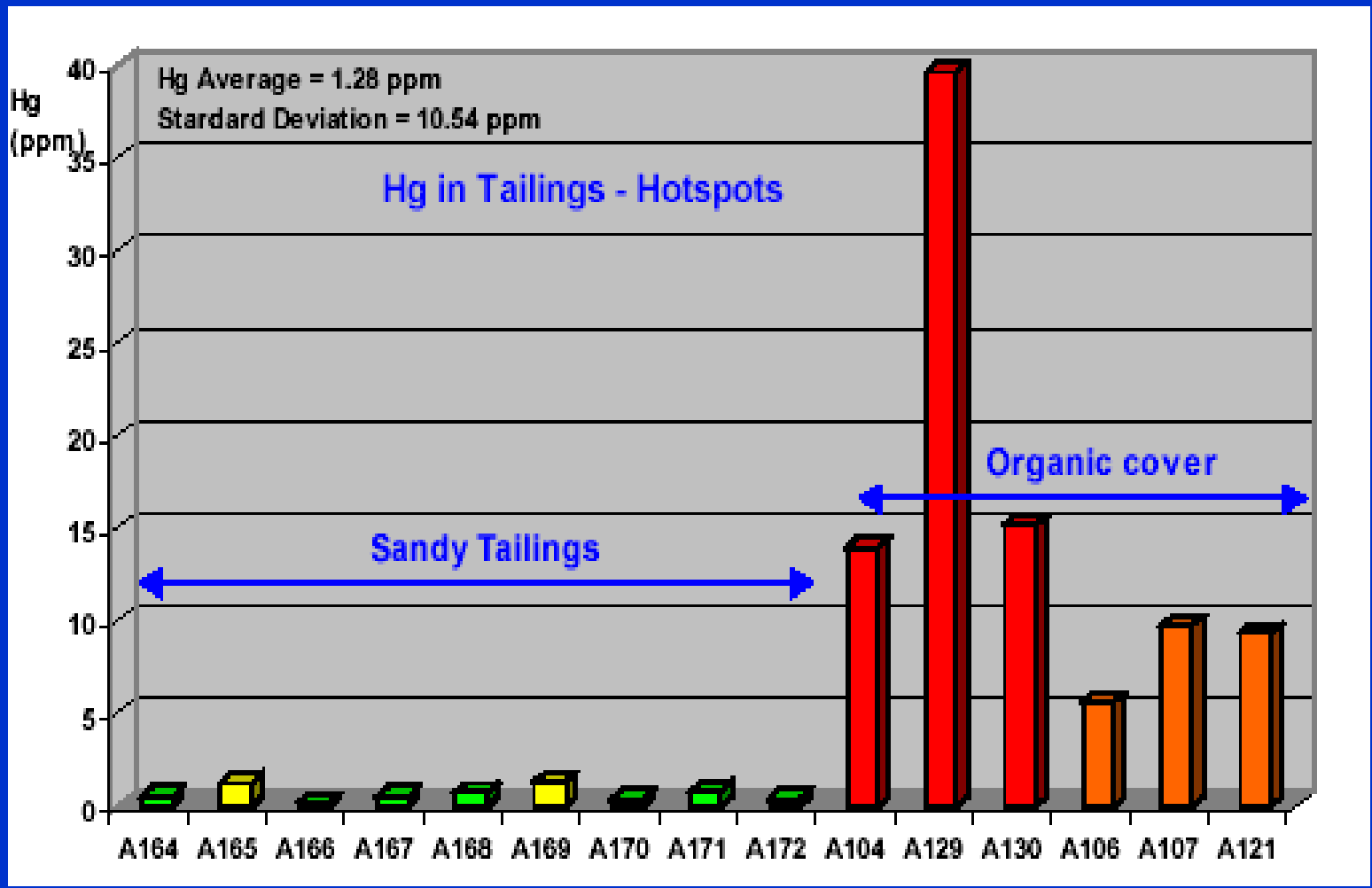
Hg in sediment core sections Katingan River - downstream



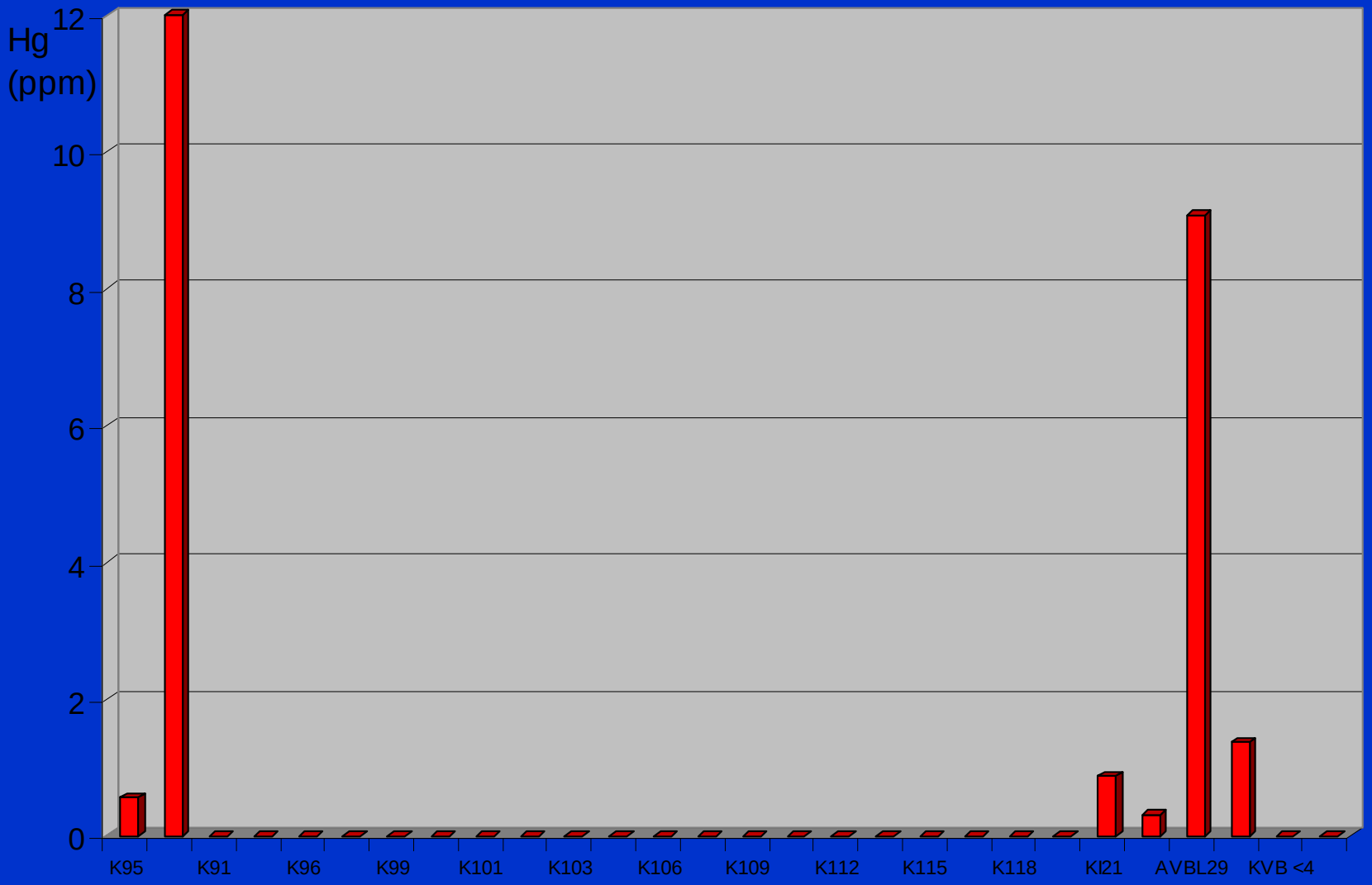
Hg in sediment core sections
Katingan River - downstream



Hg in mining tailings - Galangan



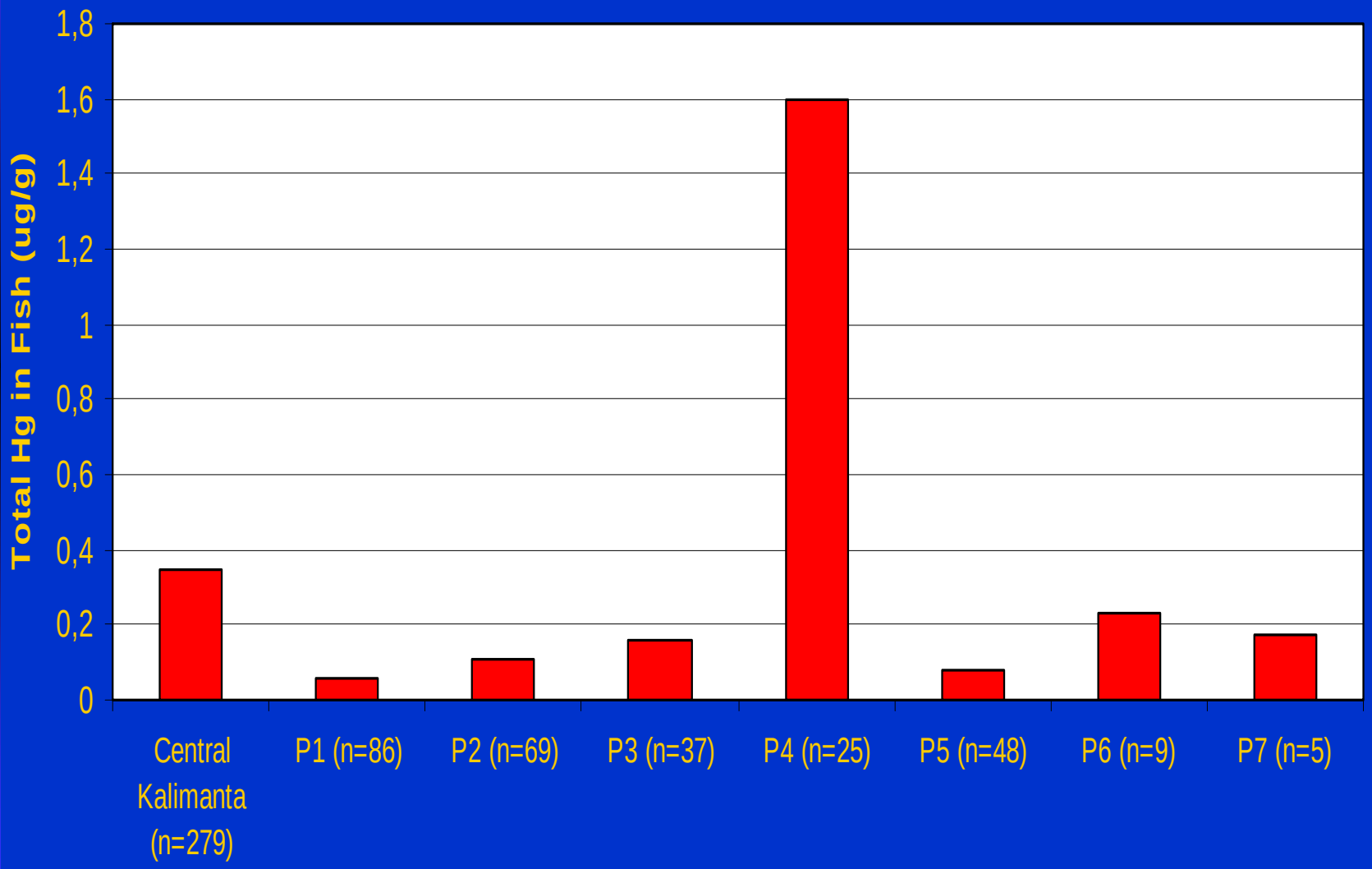
Hg in sediments of the Katingan River - silt-clay fraction – 20 km downstream



Hg in Fish – Central Kalimantan

Sampling location		N	Hg (μg/g)
P1	Katingan river, upstream of mining sites	86	0.06±0.05
P2	Katingan river, downstream	69	0.11±0.08
P3	Reference area 1	37	0.16±0.05
P4	**Pit lakes in mining site areas**	25	**1.60±1.76**
P5	Fish market from Palangkraya	48	0.08±0.09
P6	Kalamanan river, close to Samba region	9	0.23 ±0.04
P7	Reference area 2; Orangotangos reserve	5	0.17±0.08

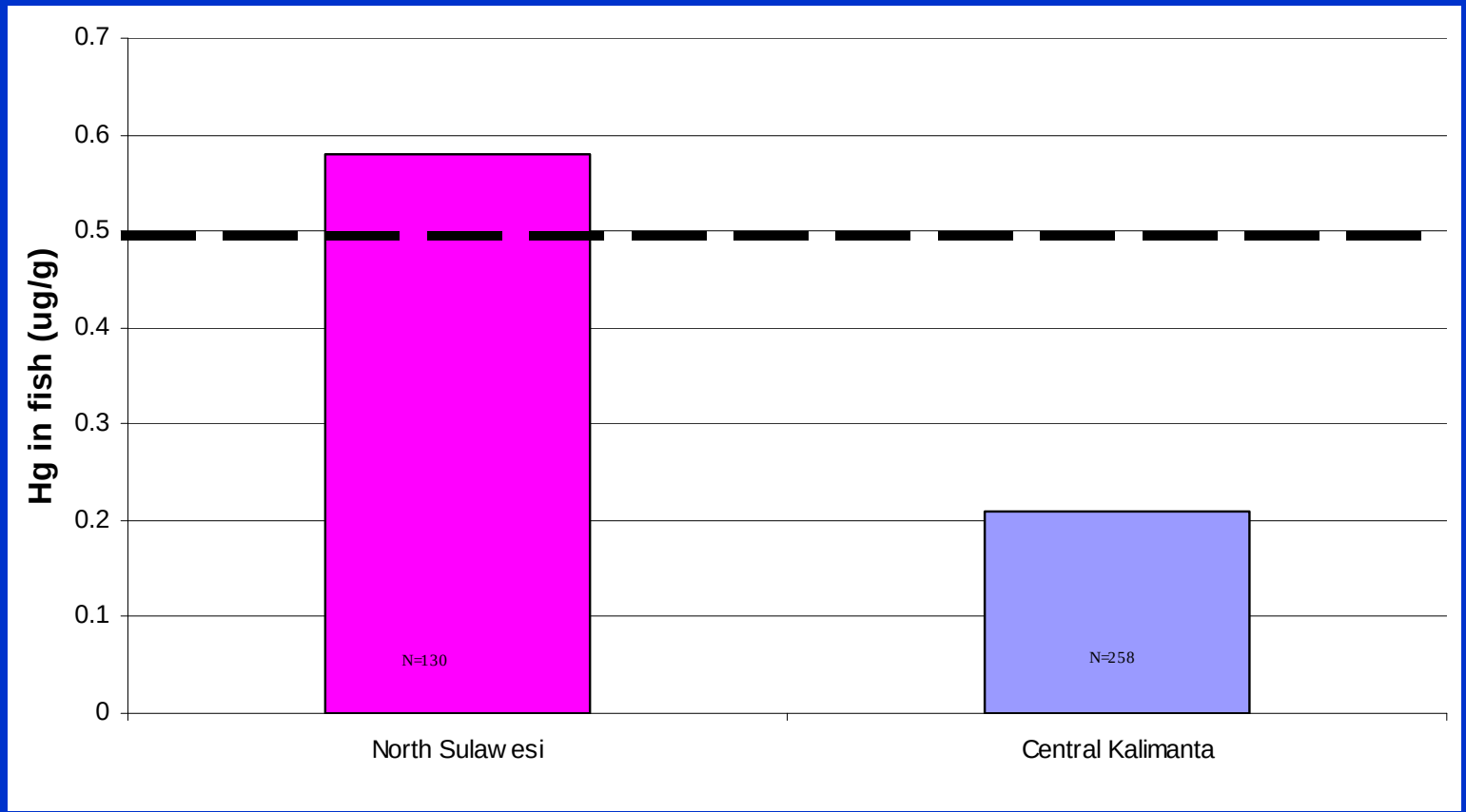
Hg in Fish – Central Kalimantan



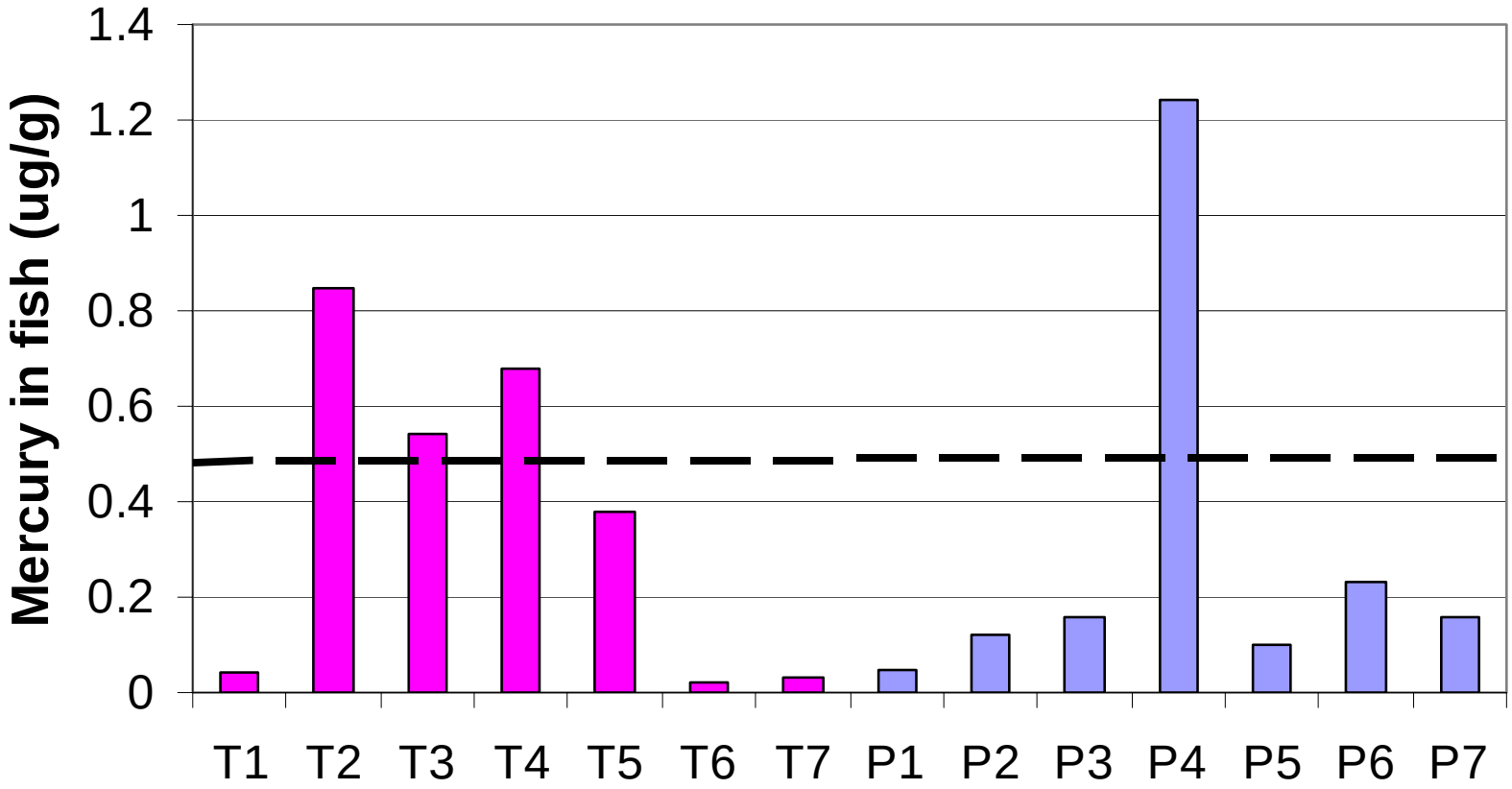
Hg x fish lenght

- Hg levels in fish from North Sulawesi are significantly higher than fish from Central Kalimantan ($p<0.0001$)
- While fish from North Sulawesi are smaller (92.9±29.1mm) than fish from Central Kalimantan (166.0±138.0mm)
- Almost 50% of fish from North Sulawesi showed Hg levels above WHO limit of Hg level to human consumption (0.5 μg/g), while less than 10% of fish from Central Kalimantan did.

Mercury in fish



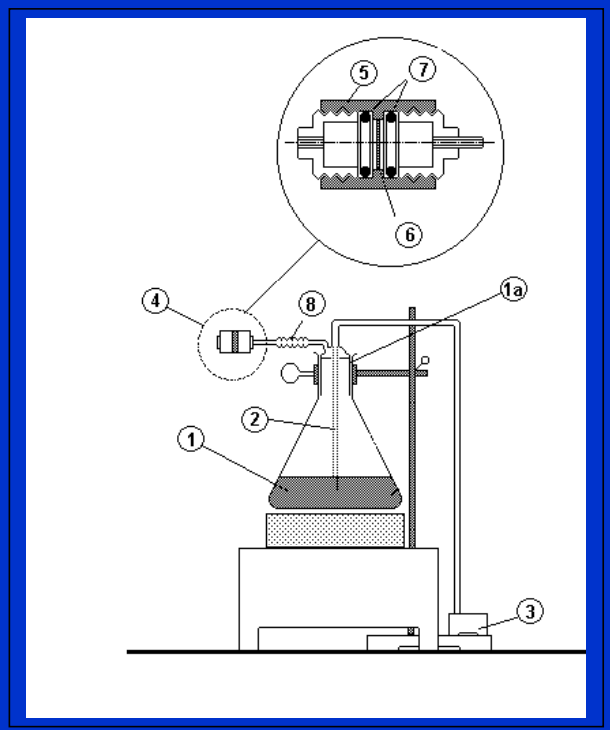
Mercury in fish

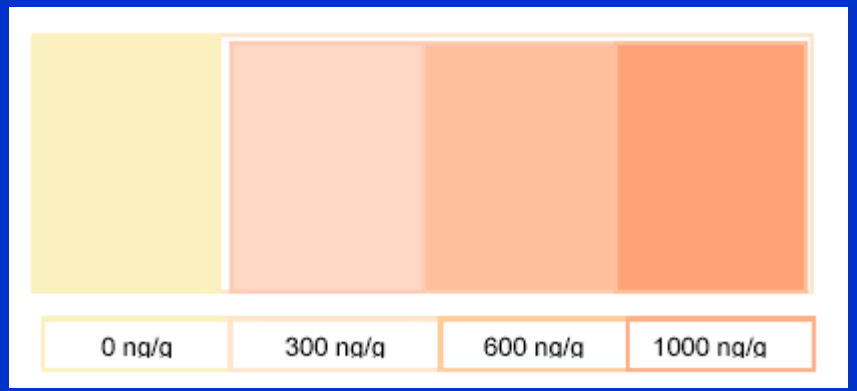


Alternative low cost method for mercury determination in fish: Training of local users in Manado, Indonesia

- Colorimetric method developed by CETEM for the GMP
- The huge extension where mercury polluted areas are found; the lack of laboratory infrastructure and the difficult access; the high cost of conventional analyses has inspired the development of a semi-quantitative, low cost method

Training of local users in Manado, Indonesia
11 local users trained





Conclusions

- Despite of the very high Hg background in the Talawaan watershed, Hg levels in both fish and sediments from the mining sites indicate a very significant anthropo-genic source
- Hg levels in **small fish** in North Sulawesi are similar to those in **large fish** of the Amazon region
- Direct amalgamation of whole ore, without gravity concentration, must be phased out

Conclusions (cont.)

- Regardless environmental and health concerns, the current mineral processing technique used in North Sulawesi does not improve Au recovery (waste of Hg, waste of money)
- There is an indicaton that cyanidation of amalgamation wastes is further releasing Hg under a more bioavailable chemical form (cyanide-mercury complexes)

Conclusions (cont.)

- Higher Hg bioavailability in North Sulawesi than in Central Kalimantan area;
- Hg contamination in North Sulawesi is widespread along the Talawaan river;
- Hg levels in fish from pit lakes in mining areas from Central Kalimantan showed the highest Hg levels.

Conclusions (cont.)

- It is predictable that the huge mercury burden found in both biological and inorganic samples from the Talawaan River is also, to a certain extent, being taken up by the marine biota living in the Manado Bay.

Conclusions (cont.)

- Although there are technological alternatives to Hg (cyanide, electro-leaching with sodium hypocloride), they are hardly implementable in most of SSM communities (illegal, poor)
- Strategies for reduction of Hg releases are more feasible, e.g.: use of retorts; gravity concentration prior to amalgamation; cyanidation without amalgamation; use of fumehoods.

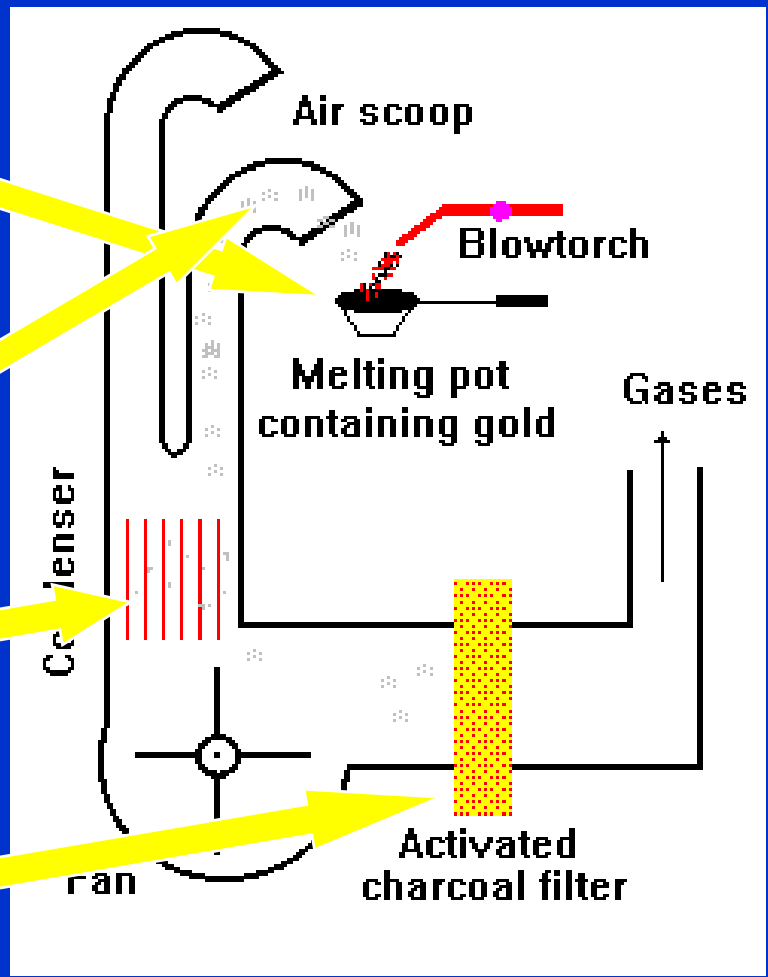
Special Fume Hoods Installed in a Town in Brazil

Gold is melted in front of the miner

Residual Hg vapor is collected...

… and condensed

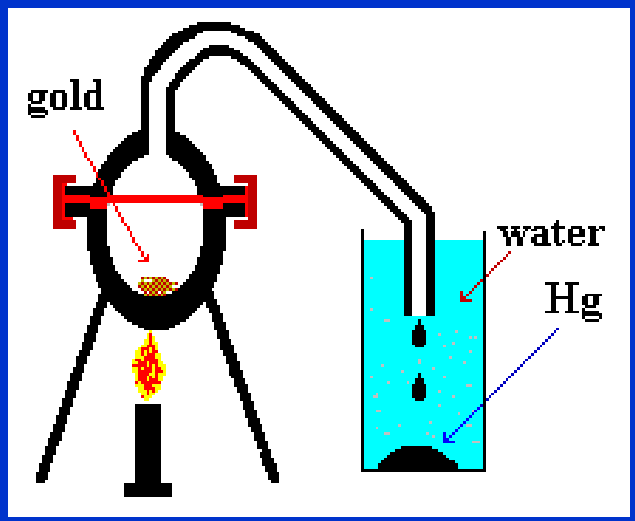
Residual Hg is retained by filter with iodide solution

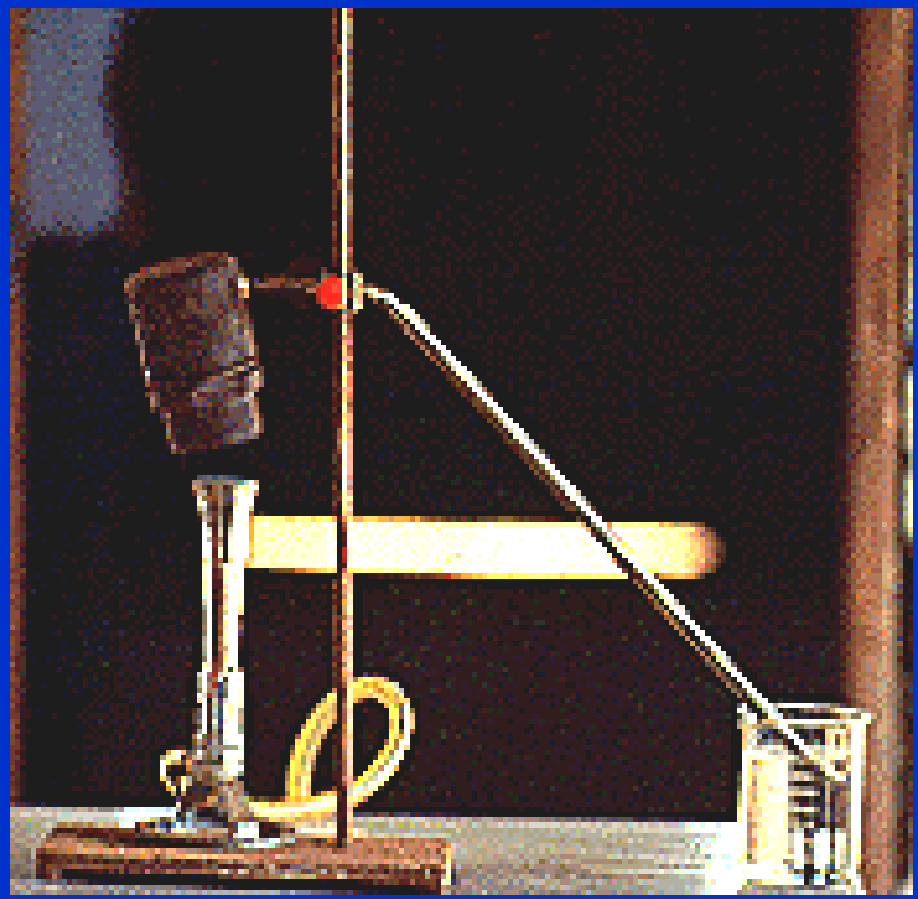


CETEM (1989). Poconé Report

Retorts

Condense Hg vapors and recycle Hg





Solutions for Hg Pollution in ASM

- Accessible Clean Technologies
- Processing Centers (with or without Hg)
- Centralized amalgamation operations; under control
- Policy and Education
- Capacity building (governments and ASM communities)
- Legislation framework appropriate to encourage ASM communities to become legal (ASM cooperatives, ASM companies)
- Legal activity, environmental and social responsability
- Benefits to the miners: credit, long-term planning, citizenship
- Benefits to the society: environmental protection; safe fish consumption

Processing Centers Can Also Be Training Centers

- Improve mining and processing techniques
- Limit Hg use
- Improve occupational hygiene
- Enable to organize (legalize) the activity
- Enable to provide access to financing
- Access to medical and other social services
- Reduce illegal gold purchase

Veiga & Beinhoff (1997)
Healy & Veiga (1997)

Amalgamation Center in Venezuela

Trained operators do the job for miners