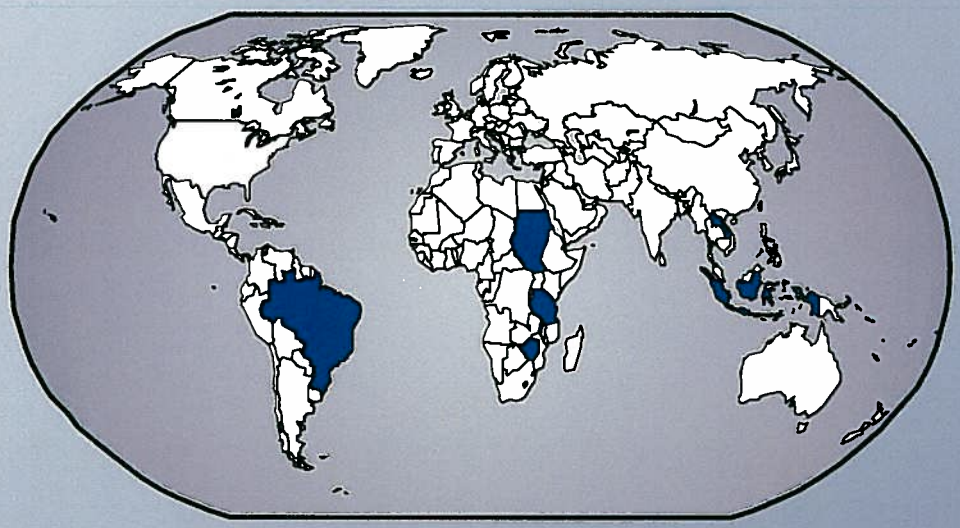
Global Mercury Project



ENVIRONMENTAL AND HEALTH ASSESSMENT REPORT

Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologies

GEF

FOREWORD

With gold rising from US$ 260/oz in March 2001 to US$ 540/oz in March 2006, at least 100 million people worldwide in a minimum of 55 countries have come to depend on artisanal gold mining for their livelihood. An estimated 25-30% of the world gold production comes from some 15 million artisanal miners, including 4 million women and 1 million children. This gold rush is causing highly dangerous mercury pollution throughout the world. The problem derives from the miners' use of mercury to extract fine particles of gold and this method releases about 1000 tonnes of mercury every year, or roughly 1/3 of all the global anthropogenic mercury released annually. Although the gold extraction process known as amalgamation is a simple technology, it is potentially very hazardous and contaminates the air, soil, rivers and lakes with mercury. The health of the miners and other people living nearby is negatively affected through inhalation of mercury vapour, direct contact with mercury, and the consumption of fish and other food contaminated by the mercury.

The Global Mercury Project (GMP) has been sponsored since August 2002 by the Global Environmental Facility (GEF), with the United Nations Development Program (UNDP) as the Implementing Agency and the United Nations Industrial Development Organization (UNIDO) as the Executing Agency. Locations in Brazil, Indonesia, Lao PDR, Sudan, Tanzania and Zimbabwe were selected on key trans-boundary river/lake basins. Roughly 2 million people are directly involved in artisanal gold mining activities in these pilot countries. This report documents the Environmental and Health Assessments (E&HA) commissioned by the GMP with the aim of sharing the results with key global institutions in order to generate awareness about the level of mercury emissions and public exposure in these sites.

An essential conclusion of the report is that the amalgamation of whole ore using copper plates (Zimbabwe, Brazil) or the practice of adding mercury to the grinding process (Indonesia) is leaving large volumes of mercury-contaminated waste material dispersed in the environment. Amalgamation of only gravity concentrates greatly reduces the environmental impact of the mercury. Study areas using whole ore amalgamation demonstrated elevated mercury levels in fish, and high local mercury levels in soils and sediments. The cyanidation of mercury-contaminated tailing (Indonesia, Zimbabwe and Brazil) makes mercury more bioavailable in the effluents and significantly exacerbates the methylation process. Good examples of mining practice were also extracted from the E&HA reports, such as in the GMP site in Tanzania where amalgamation occurs only in designated and contained areas far away from populated centres and water streams. Unfortunately, the artisanal mining sector generally has very little or no legal standards for sustainable operations, and the main mining practice is to dump mercury-contaminated tailing into or beside bodies of water.

It is clear that in all GMP mine sites the main pathway of mercury to humans is through the inhalation of vapour. Once the gold-amalgam is formed, miners decompose it, evaporating mercury from open pans. Frequently this occurs in kitchens in front of children. Not only miners are being contaminated but also their families and neighbours. Even when knowing the health dangers of mercury vapour, miners are generally not aware of the seriousness of the situation and do not adopt any preventive process. A strong educational campaign has been recommended to reduce mercury use, calling in particular on miners to recycle mercury by using retorts. The current high price of mercury in the mine sites provides an additional strong incentive for miners to cooperate. The most contaminated individuals were found in Indonesia, followed by Zimbabwe, Brazil, Tanzania, Sudan, and Lao PDR. Neurological problems were identified and positively correlated with intoxication due to exposure to mercury vapour. It is more difficult to directly compare fish contamination levels, but generally speaking, the most contaminated fish were found in São Chico in Brazil, followed by Zimbabwe, Tanzania, Sulawesi, Creporizinho in Brazil, Kalimantan, Lao PDR, and Sudan.

Artisanal and small-scale mining is primarily a poverty-driven activity and communities often have few other opportunities to generate income. In rural communities, miners make 3 to 10 times more money than farming, but it is often the case that they do not have a strong bond with the land and live separately from other local communities. The transience of miners in the GMP sites is a challenge faced by the project team in their effort to provide widespread education and training. These studies clearly demonstrate the severe environmental and health impacts of poor mining practices on these miners and their communities. However, the outright banning of artisanal and small-scale mining activities would leave communities with even fewer economic options and will often lead to illegal mining. Simple technologies and practices can be implemented which dramatically reduce these impacts and allow more sustainable livelihoods for these communities.

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ENVIRONMENTAL AND HEALTH ASSESSMENT REPORT

Acknowledgements:

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Source documents:

The information presented herein has been taken from the following commissioned environmental and health assessments conducted in each of the Global Mercury Project target regions. Additional GMP documents supplemented the assessments. Visit the GMP website at http://www.globalmercury.org for more information.

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Between 10 and 15 million artisanal & small-scale miners worldwide release as much as 800-1000 tonnes of mercury per annum.

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INTRODUCTION

Artisanal and small-scale gold mining (ASM) is a poverty-driven activity that constitutes an important source of livelihood for many rural communities, but it is also one of the major global sources of mercury contamination. Between 10 and 15 million artisanal gold miners worldwide produce from 500 to 800 tonnes of gold/a and release as much as 800-1000 tonnes/a of mercury. These activities are frequently accompanied by extensive environmental degradation and deplorable socio-economic conditions, both during operations and long after mining activities have ceased. The use of mercury to recover gold, or amalgamation, is a common and simple extraction process, but is potentially very dangerous and contaminates the air, soil, rivers and lakes with mercury. The health of the miners and other people living within the area is negatively affected through inhalation of mercury vapour, direct contact with mercury, and the consumption of fish and other food affected by mercury contamination.

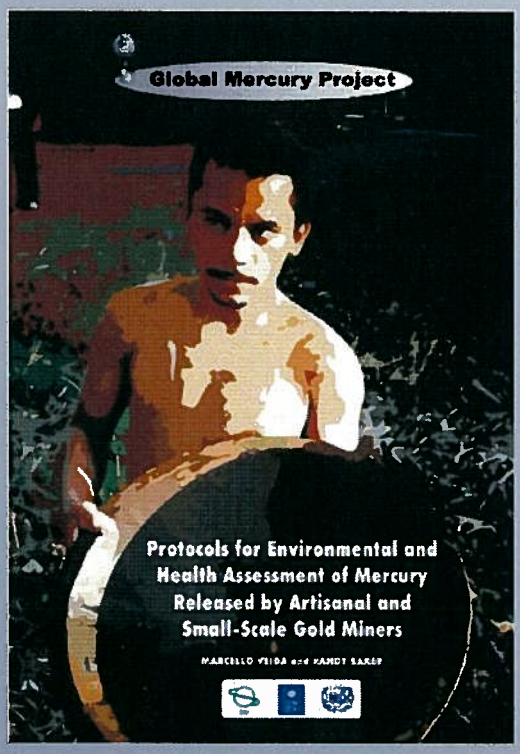
The environmental and health impacts of amalgamation in artisanal gold mining and its effects on international water bodies are similar in most developing countries. Solutions to these problems therefore require concerted and coordinated global responses. The Global Mercury Project was initiated to begin this global response by addressing environmental impacts resulting from mercury released by the artisanal mining sector.

The "Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies," or the Global Mercury Project (GMP), was approved by the Global Environmental Facility (GEF) in March 2002. UNDP acts as the Implementing Agency while UNIDO is responsible for project execution. A suite of ongoing activities, which are financed through the participating countries' own resources and/or bilateral programs, complements the project. Study areas, all located in key trans-boundary river/lake basins, were selected in six developing countries: Brazil, Indonesia, the Lao PDR, Sudan, Tanzania and Zimbabwe. In these areas artisanal gold mining directly involves nearly 2 million people in total, supporting more than 10 million dependents.

The main project objectives are to assist the six pilot countries in the assessment of the extent of pollution from current activities, to introduce cleaner gold mining and extraction technologies which minimize or eliminate mercury releases, and to develop capacity and regulatory mechanisms that will enable the sector to minimize negative environmental impacts. This is accompanied by the development of monitoring programs and, in collaboration with participating governments, the development of policies and legislation that will lead to practical and implementable standards for artisanal gold mining. In order to ensure sustainability of the monitoring programs, the project works to build capacity of local institutions (e.g., local laboratories) through training and material support, enabling them to carry out continuous monitoring beyond the initial project's term. The project aims to increase knowledge and awareness of the environmental impacts associated with amalgamation among miners, government institutions and the public at large. This will be bolstered by the introduction and demonstration of cleaner and more efficient technology that minimizes negative environmental impacts while improving earnings, health and safety.

The first phase of the GMP involves assessment of the environmental and health impacts of ASM in the selected study areas, in order to provide a baseline and to ensure that other GMP activities are properly targeted. EHA (environment and health assessment) teams conducted studies in each pilot country using the "Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners" developed by UNIDO as a guiding reference to facilitate comparison, ensure quality, and provide the basis for a common approach.

The objective of the environmental assessment was to identify hotspots in the project demonstration sites, conduct specified geochemical and toxicological studies and undertake other field investigations in order to assess the extent of environmental pollution in surrounding water bodies. The health assessment was designed to complement the environmental assessment, by providing an indication of the level of mercury poisoning attributable to mercury vapour exposure and/or to ingestion of contaminated food. Based on investigation of the pathways and bioavailability of mercury vapour and methylmercury to the mining communities, the health assessment combines information from biological samples with medical exams to evaluate the level of impact that the pollutant caused or may cause to individuals residing in "mining and environmental hotspots". The integration of the health and environmental assessments is important in order to identify the potential overall effects that any one variable might have on the biophysical and social environment.



The environmental and health assessments summarized in this report are important first steps in characterizing the magnitude of the problems caused by mercury use in artisanal gold mining. However, this program must be followed by the introduction of concrete solutions to reduce mercury emissions, stop human exposure and mitigate critical situations.

BRAZIL

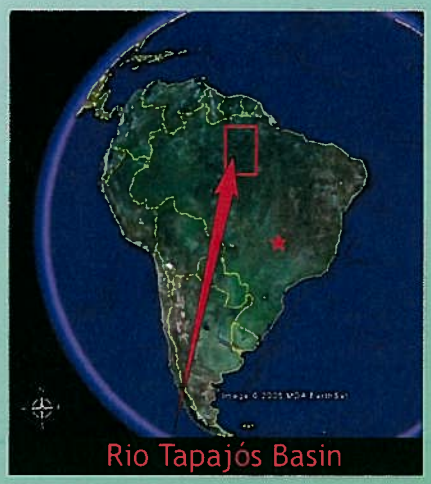
Environmental Assessment Report

Creporizinho and São Chico are located in Brazil's main small-scale gold mining region, the Rio Tapajós Basin, which is home to between 60,000 and 90,000 small-scale gold miners. Virtually the entire population is involved with small-scale gold mining. In the late 1980s and again in the late 1990s, São Chico was a gold rush site with a population of 5,000; an estimated 3 tonnes of gold was extracted and 7.5 tonnes of mercury released in total. The small village now relies on reprocessing tailing for income. Creporizinho is a larger centre, with a church, a school, and some stores. It was also a gold rush town with a peak population of around 10,000. Both locations are isolated and road conditions are poor.

In São Chico during the gold rushes, primary ore was mined, crushed with a hammer mill, and then passed over mercury-coated copper plates. The plates were scraped clean to collect amalgam, which was then openly burned to produce a gold doré. Now tailing originally produced in the 1980s is being reprocessed. Stored tailing material is slurried with hydraulic monitors, then pumped to carpet-lined sluice boxes. The sluice box concentrate is ground with a hammer mill then passed over copper amalgamation plates. As mercury was used in the original operations, reprocessing tailing both reintroduces old mercury and adds new mercury to the environment. In addition, the practice of heap leaching tailing material with cyanide began in 2001, leading to the creation of dangerous mercurycyanide complexes. In Creporizinho, miners focus on processing lateritic soils, primary ore and tailing material. Lateritic soils are mined from open pits. Primary ore is mined from open pits and shafts, transported to processing sites, ground, and then passed over mercury-coated copper plates. Dredges and hydraulic jets are used for reprocessing tailing and alluvial materials. Retorts are often not used. Some operations use centrifugal concentrators, amalgamating the concentrates.

The GMP team collected and analyzed 658 samples, taken from soils, sediments and water. In São Chico, about 50,000 m^2 of the valley basin is covered with contaminated tailing averaging 5 metres in depth. The background level was determined to be 0.15 ppm Hg, by taking samples approximately 30 cm in depth away from mining areas. Surface background levels are in the range of 0.8 ppm Hg, reflecting the heavy use of mercury over the past two decades. Tailing mercury levels are as high as 300 ppm Hg, and average 4 ppm Hg. River sediments near mining areas averaged 7-14 ppm Hg and averaged 2 to 4 ppm further away from amalgamation areas. In Creporizinho, mining activities are located further from town than in São Chico. Amalgamation tailing measured high levels of mercury, reaching up to 48 ppm Hg. However, generally the area was less contaminated than São Chico.

Total mercury concentrations were measured in 234 fish samples, from 16 species, collected from four sites in São Chico and seven in Creporizinho. A positive correlation between log length and log mercury levels was shown for 3 species. Mercury levels in carnivorous fish around São Chico were found to average 4.16 ± 5.42 ppm Hg (wet weight), reaching a maximum of 21.9 ppm Hg. Mercury levels in non-carnivorous fish averaged 1.33 ± 1.38 ppm Hg. These levels are significantly above the WHO safety guidelines of 0.5 ppm Hg. Carnivorous fish in Creporizinho averaged 0.50 ± 0.41 ppm Hg, and non-carnivorous fish averaged 0.32 ± 0.30 ppm Hg. In Creporizinho, 22% of fish sampled showed levels above 0.5 ppm Hg compared to more than 60% in São Chico.



Study Area	Crepurizinho
Population	600
Illiteracy	11%
Income	2,200 $US/a
Hg_{Lost}:Au_{Prod}	1-1.5
Hg Lost	300-500 kg/a

Study Area	São Chico
Population	134
Illiteracy	20%
Income	1500 $US/a
Hg_{Lost}:Au_{Prod}	1.5-3
Hg Lost	30-40 kg/a

Former mining shaft by burnt pasture.

Local miners panning a gold concentrate.

Local Recommendations

The study results confirm extremely high mercury levels in soils and sediments and document a high mobility of mercury in São Chico and Creporizinho. São Chico in particular is burdened with a huge volume of contaminated mine tailing and high levels of mercury in the local fish, which is exacerbated by the introduction of cyanidation. Access should be provided to alternative technologies and best practices. Remaining miners should be encouraged to only amalgamate concentrates and not to leach amalgamation tailing with cyanide. The use of retorts must be encouraged. Residents of São Chico should be dissuaded from consuming mercury-laden carnivorous fish.

BRAZIL

Health Assessment Report

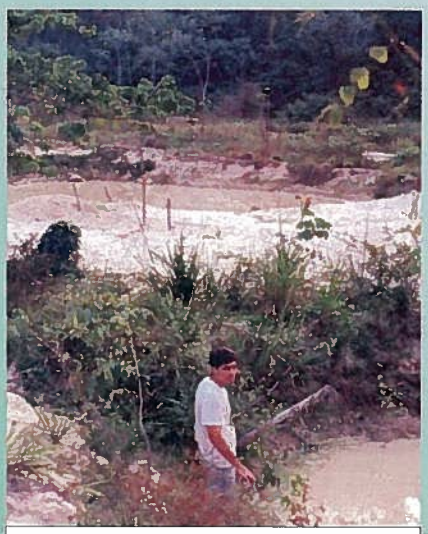
General health conditions in both São Chico and Creporizinho are dire, as demonstrated by an extremely high incidence of malaria, parasithosis, tuberculosis and other diseases. Sanitation is a problem, with most homes using outdoor toilets and either burning refuse or depositing it in unoccupied areas. The only public service in São Chico village is a health post for malaria diagnosis staffed by 1 health assistant. Creporizinho also has a health agent to provide basic health services. Work accidents, including fatalities, are common.

In São Chico, the health status of 246 volunteers, including 109 miners, was assessed using the GMP's environmental and health assessment protocols. The GMP team collected 234 blood samples, 235 urine samples, and 137 hair samples. All participants completed a medical questionnaire. In Creporizinho, the health status of 451 volunteers, including 230 miners, was assessed. The GMP team collected 401 blood samples, 344 urine samples, and 116 hair samples. All participants completed a medical questionnaire. Participants were examined to identify neurological disturbances, as well as other mercury poisoning indicators. Historical / clinical / neurological / toxicological tests were then used to examine general health of the participants and discover symptoms of mercury poisoning. No external uncontaminated control population was available for comparison.

The main pathways to mercury exposure in São Chico and Creporizinho are vapour inhalation during amalgamation and amalgam burning, and ingestion of contaminated fish. Open air amalgam burning, without ventilation or the use of retorts, has been common practice in both areas for decades, so the local populations are chronically exposed to toxic mercury fumes. In São Chico, pasture fires over mercury-contaminated soils constitute another potential source of exposure.

Typical symptoms of mercury intoxication were common and confirm significant exposure to mercury. Symptoms included tremors, poor balance, ataxia, and concentration problems. Mercury poisoning symptoms occurred much more frequently in miners than non-miners. Results were more pronounced among miners from São Chico. Occurrence of symptoms such as metallic taste, excessive salivation, palpitations, and paraesthesia was high across the board, albeit more extreme among miners than among non-miners. Hepatomegaly, splenomegaly, and dyspepsia and arterial hypertension were also close to 5, 4 and 3 times higher (respectively) in prospectors. In general, the mercury burden was observed to be higher for the São Chico participants than in those from Creporizinho.

Aerial view of São Chico



Flooded mining pit outside São Chico.

Gold shop purifying gold doré in Creporizinho.

Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
	Mean values (Maximum values)		
São Chico:			
Non-occupational burdened	16.5 (63)	5.1 (55)	3.2 (15.0)
Prospectors /Amalgam Burners	28 (141)	9.3 (78.51)	3.9
Creporizinho:			
Non occupational burdened	21 (172)	1.9 (12.1)	1.8 (10.5)
Prospectors /Amalgam Burners	25 (129)	6.0 (62)	N/A

Local piranha. Some carnivorous fish sampled measured over 20 ppm Hg wet weight.

Local Recommendations

High mercury levels in the hair and blood of both miners and non-miners indicate that bio-accumulation through consumption of contaminated fish is a significant problem, particularly in São Chico. The communities should be educated as to which fish species are safe to consume. High urine mercury levels indicate frequent exposure to mercury vapour. Miners should be educated about the risks of mercury vapour, in conjunction with a program which introduces simple retorts, best practices, and alternative technology. Women must be educated about the risks associated with exposure to mercury during pregnancy. Due to the poor state of general health in the region, any program addressing the use of mercury should include providing better access to basic health services.

INDONESIA - KALIMANTAN

Environmental Assessment Report

Study Area	Galagan
Population	8,200
Illiteracy	n/a
Income	1056 $US/a
Hg_{Lost}:Au_{Prod}	1.5-2.0
Hg Lost	1-2 t/a

Small-scale mining in the Galangan area of Central Kalimantan is situated near two large rivers, the Katingan and Kahayan. The study area, near the Katingan River, is over 200 km^2 large and extremely environmentally degraded from deforestation, desertification, and mercury contamination as a result of artisanal gold mining. Dredging of the rivers is considerable and has not been assessed, with up to 8,000 operating dredges, causing very high turbidity and an unknown loss of mercury. The artisanal mining work force of about 3,000 people is itinerant, impoverished, and non-local, hailing mainly from Java. The miners have a low level of technical skills and tools, and have little awareness about the harmful effects of mercury.

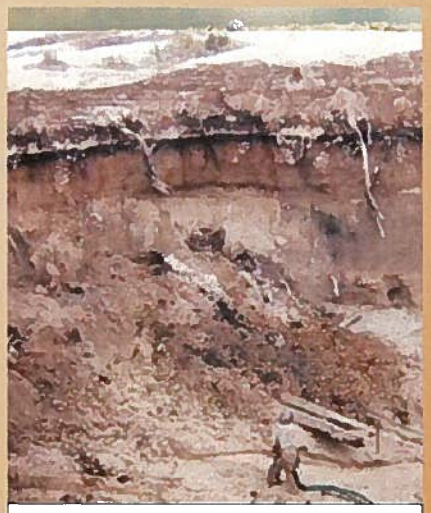
Gold mining in Galangan is generally conducted by small groups of men who operate typical hydraulic monitor mining operations. Subsurface soils from pits around 20 meters deep are dislodged using hydraulic monitors, slurried, and pumped to the surface where they are passed over carpeted sluices. Gold is lost due to high slurry velocity, turbulence, and poor carpet quality. Concentrates from the carpets are amalgamated in flooded open pits beside miners' residences. Up to 1 kg of mercury is inefficiently used to amalgamate concentrate by hand in buckets. Mercury is squeezed through a cloth to acquire an amalgam and retain unused mercury. Overtime, much mercury has been lost to the ponds, which are also used for bathing, washing clothes and raising fish. It is also likely that cooking and drinking water is drawn from these ponds.

Amalgam burning occurs near mine sites and in the local urban environment in the gold shops of Kareng Pangi. Burning generally occurs within a fume hood with no filter, worker protection, or external exit for fumes and takes place in the presence of women and children who are unaware of the health hazards posed by inhaling gaseous mercury. Ancillary problems include death from pit cave-ins, drowning, malaria, malnutrition, and poor air quality due to diesel pumps. Based on mass balances calculated from the analysis of amalgamation waste material and interviews with the miners, the ratio Hg lost:Au produced in Galangan is estimated to be from 1.5 to 2.0, and an estimated 1 to 2 tonnes of mercury are released annually to the area.

The GMP team collected and analyzed 206 soil, sediment, and water samples from the Galangan area. Mercury concentration in surface soils was relatively low because of the coarse grain size of the sand. Background mercury levels averaged 0.38 ppm Hg, whereas the average mercury concentration in soils sampled downstream of mining areas ranged from 2.19 ppm Hg to 2.87 ppm Hg. Mercury was elevated in amalgamation tailing because of extensive mercury use and the presence of organic material in the deeper soils that are mined.

Mean mercury concentration in 264 fish from 25 species was 0.21 ± 0.36 ppm Hg, excluding an outlier with a concentration of 9.83 ppm Hg. These levels are elevated for fish as small (~170 g) as those sampled. Fish grown in amalgamation ponds showed the highest levels of mercury, up to 20 times higher than the levels for the same species taken from the Katigan River (1.29 ± 0.34 ppm Hg vs. 0.06 ± 0.04 ppm Hg for the Banta species). Payanka, a carnivorous species, demonstrated a positive relationship between mercury level and fork length and could be used as a bio-indicator in the area.

Landscape in Galagan after mining.



Mining with a hydraulic monitor.

Pumping alluvial ore to a sluice box.

Local Recommendations

Overall mercury release levels are moderate and whole ore amalgamation is not practiced. However, amalgamation of concentrates occurs in ponds where fish are grown for consumption, making them a source of methylmercury. These open pits are also used for bathing and deposition of domestic wastes and are dangerous pathways of mercury exposure to miners and their families. Amalgamation should be moved away from living spaces and fish farms, and the use of retorts should be encouraged. The urban environment of Kareng Pangi is quite contaminated with mercury because none of the many gold shops where amalgam is burned have any environmental controls and no retorts are used. Local miners need support to introduce cleaner and safer gold mining and extraction technologies.

INDONESIA - KALIMANTAN

Health Assessment Report

General health conditions in Galangan are poor. Hygienic standards are extremely low and infectious diseases such as diarrhea, typhoid and parasitism are common. Road accidents, accidents in pits, malaria, tuberculosis, and sexually transmitted diseases are the dominant causes of morbidity and mortality. Awareness of the harmful effects of mercury is low. There is no clean, safe drinking water and no safe means of disposal for mercury or any other waste. There is one basic health centre in the area.

Health Centre in Kereng Pangi

The health status of 247 volunteers in Galangan and 53 from the control area of Tangkiling was assessed using the GMP's environmental and health assessment protocols. The GMP collected 211 blood, urine and hair samples. Participants were examined to assess their general health condition as well as the possibility of mercury poisoning. Amnestic / clinical / neurological / toxicological tests were used to identify neurological disturbances, behavioural disorders, motor neurological functions, cognitive capabilities, balance, gait, reflexes etc. Blood and hair analysis showed increased levels of mercury in the control group, so in the statistical analysis they were considered another contaminated group. This is likely due to the burning of amalgam in the nearby urban gold shops. The Sulawesi control group was used as a reference instead.

A volunteer completes a heath questionnaire.

Exposure mainly occurs through vapour inhalation and ingestion of contaminated food. Amalgam burned in gold shops that are located in the midst of the village near food stalls, housing areas and a school. Miners wash in the same ponds in which the amalgamation activity occurs. Water for cooking is drawn from other nearby ponds that were likely used for amalgamation in the past. Fish are also grown in the ponds and are a source of methylmercury. This collateral contamination through an important food source is a particularly severe hazard.

Typical symptoms of mercury intoxication were prevalent, especially among amalgam burners, confirming considerable exposure to mercury. Symptoms included signs of a damaged central and peripheral nervous system such as ataxia, dysdiadochokinesia, pathological reflexes, coordination problems and concentration problems.

Burning amalgam without a retort.

Mercury levels in the bio-monitors were significantly higher in all exposed populations than in the Sulawesi control group. Inorganic mercury was the main contributor to the high body burden of the workers. Among amalgam burners and millers, 59% and 43% respectively were diagnosed with chronic mercury intoxication. Of the non-occupationally burdened population, 34% were diagnosed with intoxication. These conclusions should be taken with some caution as other health factors may confound the diagnosis of mercury intoxication.

Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
Control	4.6 (10.1)	0.4 (1.4)	1.5 (3.7)
Non-occupational burdened	8.5 (172)	2.7 (355)	2.6 (7.8)
Millers / Amalgam Burners	10.2 (429)	8.7 (1,697)	3.9 (793)

Median values (Maximum values), <LD = below detection limit

Recovering mercury after amalgamating a concentrate.

Local Recommendations

The Galangan region, although severely environmentally damaged, is separated from the Katingan River by a 1 km wide forest buffer. This buffer must be preserved to prevent erosion and easy movement of mercury contaminated soils to this large river. Mercury is a serious health hazard, and exposed workers demonstrate severe symptoms of mercury intoxication. This is not always evident, as when people become sick, they return home to Java and are replaced by other workers. Exposure of urban residents of Kereng Pangi to mercury is reflected in raised mercury levels in the urine, and symptoms including ataxia, tremors and movement disorders. Children should not be living in the mining area and basic hygienic standards are essential. Zoning of the mining regions into mining, commercial and housing areas is recommended. Awareness-raising campaigns about the dangers of mercury exposure are needed, directed both at miners and women of child-bearing age.

INDONESIA - SULAWESI

Environmental Assessment Report

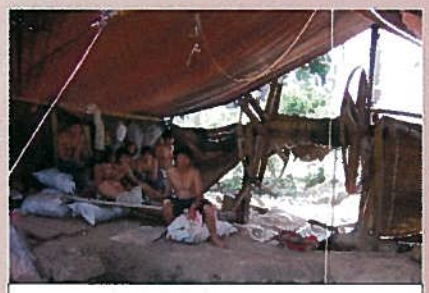
North Sulawesi is situated in the Celebes Sea east of Kalimantan and west of New Guinea. Manado, with approximately 600,000 inhabitants, is the capital of the region. Bunaken National Marine park, an internationally renowned Marine Park popular with divers, is situated just offshore of Manado. There are several small villages surrounding Manado within the Talawaan watershed, about 20 km away from Manado, where gold is mined from primary deposits. This area also has an important commercial fishery.

Miners in the Talawaan/Tatelu region excavate ore from shafts up to 50 m deep that are dug by hand. Child labour is common. Ore is coarsely crushed manually or using stamp mills, before being transferred to trommel mills that grind the ore to a fine powder. Up to 0.5 kg of mercury is added to each trommel containing about 40 kg of raw ore. Each mill unit contains 12 trommels, and consumes an estimated 10 to 15 kg of mercury per month. Since 2001 there has been a gradual transition toward cyanidation. However, the transition is incomplete and mercury is still used at one or more stages of the process in many mining operations. Furthermore, mercury-contaminated cyanidation ponds are often located above streams where they can easily release into the watersheds and into the nearby marine environment, and are a likely source of mercurycyanide complexes. These complexes may be more easily converted to methylmercury than complexes from mercury-only amalgamation processes. The estimated ratio of Hg_{lost}:$Au_{produced}$ in Talawaan is extremely high, on the order of 40 to 60. An estimated 15 tonnes of mercury are released per annum.

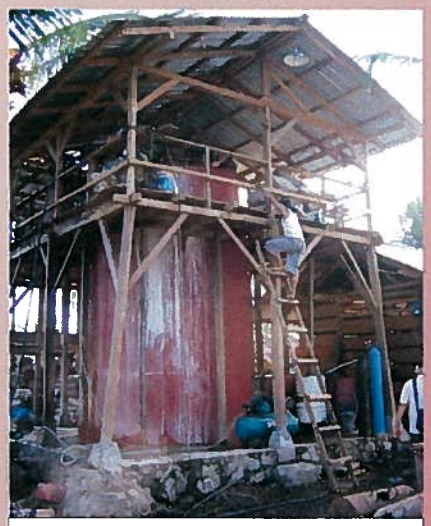
The GMP team collected 142 samples of sediments, soils, plants, and mollusks. Background levels were high, with upstream, uncontaminated sediments averaging 60 ppm Hg, probably due to past volcanic activity in the area. Mercury levels in stream sediments were higher near mines ranging up to 480 ppm Hg with a mean concentration of 154 ppm Hg. Sediment concentrations diminished close to the estuary, with a mean concentration of 6.7 ppm Hg. Mercury levels in mine tailing material ranged up to 1,250 ppm Hg with a mean concentration of 317 ppm Hg. Levels in soils near amalgamation operations ranged up to 690 ppm Hg, with a mean concentration of 270 ppm Hg. Mercury levels in stream biota were also elevated, with aquatic plants growing near cyanidation tailing reaching levels of 370 ppm Hg with a mean of 32 ppm Hg. Concentration levels in mollusks were also very high in the Talawaan River with a mean concentration of 2.6 ppm Hg.

Total mercury concentrations were measured in 156 fish samples, representing 11 species. Mercury in fish from the Talawaan watershed averaged 0.58 ± 0.45 ppm Hg wet weight with a maximum concentration of 2.60 ppm Hg. It is noteworthy that most of the fish collected were quite small and have significantly elevated mercury levels given their small size. Reference area fish averaged only 0.02 ppm, confirming that high mercury levels in fish are due to mining activities. Over 45% of the sampled fish were over 0.5 ppm Hg. Only payangka (Ophiocara sp.), an omnivorous species, demonstrated a positive relationship between mercury level and length. However, no single species was found in all areas, thus it is difficult to assign a species as an appropriate bio-indicator.

Study Area	Talawaan
Population	18,000
Illiteracy	n/a
Income	492 $US/a
Hg_{Lost}:Au_{Prod}	40-60
Hg Lost	15-22 t/a



A small-scale mine's head frame.



Cyanidation of amalgamation tailing.

Whole ore amalgamation with trommels.

Local Recommendations

Mercury release levels from small-scale gold mining in Talawaan are among the highest in the world. Whole ore amalgamation, through adding mercury to ball mills, must stop. Urgent action is required to significantly reduce exposure of processors and amalgam burners to mercury. The use of retorts should be encouraged. The trend toward using only cyanidation is a better alternative to the current general practice, as long as miners do not leach mercury-contaminated tailing material. Child labour should be discouraged, especially around toxic elements or compounds. Access should be provided to alternative technologies and best practices education, in conjunction with basic health education.

INDONESIA - SULAWESI

Health Assessment Report

Health conditions among most workers in Talawaan are poor. The main health problems are tunnel accidents, infectious diseases (especially malaria and TB), sexually transmitted diseases, diarrhea, typhus, skin diseases, parasitism and upper respiratory tract diseases. There is no clean drinking water and no safe means of disposal for mercury or any other waste. There is one health centre in the region, relatively well equipped but lacking the resources to diagnose or treat mercury intoxication. Miners exhibited little awareness of the hazards of mercury or how to prevent exposure.

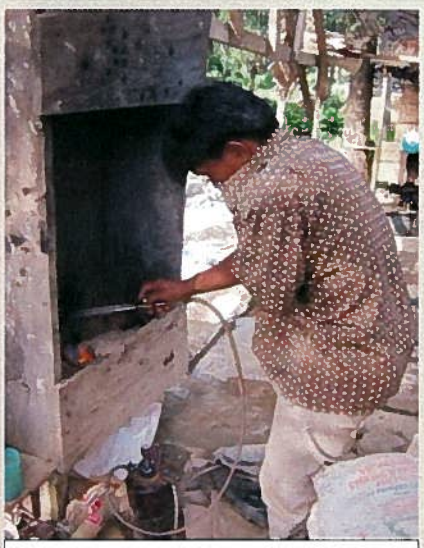
The health status of 222 volunteers from Talawaan and 22 from the control area of Air Mandidi was assessed using the GMP's environmental and health assessment protocols. The GMP collected 116 blood urine, and hair samples. Participants were examined to assess their general health condition as well as the possibility of mercury poisoning. Amnestic / clinical / neurological / toxicological tests were used to identify neurological disturbances, behavioral disorders, motor neurological functions, cognitive capabilities, balance, gait, reflexes etc.

Exposure occurs mainly through vapour inhalation and the ingestion of contaminated fish. Children have access to mercury, often play with it with their bare hands, and are exposed to mercury vapour on a regular basis in and around the trommels. The burning of amalgam is carried out in the immediate vicinity of women, children, mine workers, homes and shops.

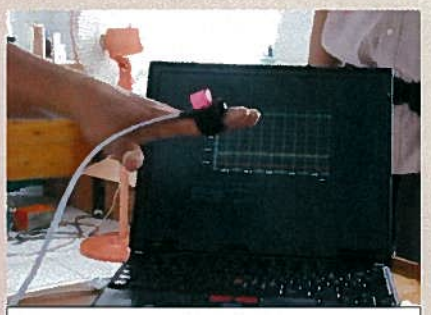
Typical symptoms of mercury intoxication were prevalent, especially among amalgam burners, confirming considerable exposure to mercury. Symptoms included signs of a damaged central and peripheral nervous system such as ataxia, difficulty with coordinated movement of hands, pathological reflexes and concentration problems. No symptoms were observed in the control group.

The highest mercury concentration was found in the bio-monitors of amalgam-burners. The medical score sum plus the bio-monitoring results established that 54% of amalgam-burners were suffering from chronic mercury intoxication. A subset of mineral processors (24%) and non-miners (11%) were also identified as being mercury intoxicated. Among children working with mercury, 18% were deemed intoxicated. In the control group there was no case of mercury intoxication. The diagnosis of intoxication must be made with care as other factors can confound this diagnosis.

Village clinic at Tatelu, where medical test work took place.



Burning amalgam without a retort.



Tremor meter test.

Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
Control	4.6 (10.1)	0.4 (1.35)	1.5 (3.7)
Non-occupational burdened	6.0 (12.6)	2.0 (9.8)	1.7 (10.3)
Millers / Amalgam Burners	12.3 (186)	8.6 (233)	4.4 (239)

Median values (Maximum values), <LD = below detection limit

Pouring mercury into a trommel mill.

Local Recommendations

Mercury losses in Talawaan are the highest among the six countries studied. The high exposure to mercury is reflected in elevated mercury levels in blood, urine and hair, and has led to neuropsychological problems in the community. Children should not be living in mining areas and sanitary conditions urgently need improvement. The practice of amalgamation of whole, unconcentrated ore with mercury must cease. Cyanidation of mercury-contaminated ore is creating dangerous cyanidemercury complexes that are then lost to the wider environment, resulting in high mercury levels in local and marine fish. Zoning of the region into mining, commercial, and housing areas is recommended. Awareness-raising campaigns about the dangers of mercury exposure are needed, directed both at miners and women of childbearing age. Local health facilities need assistance in developing resources to diagnose and treat mercury intoxication.

LAO PDR

Environmental Assessment Report

Chomphet and Pak Ou Districts are located near the World Heritage city of Luang Prabang, about 300 km north of Vientiane, the capital of Lao PDR. The two districts are within the province of Luang Prabang (population 400,000), at the confluence of the Mekong and Ou rivers. About 500 part-time small-scale gold miners live in the eight villages composing the study. Rice farming is the primary occupation in the region and mining only takes place during the dry season between January and June, when access to deposits in the river is possible. Small-scale gold mining began in the 1970s and became common during the 1980s. The area is poor with limited infrastructure.

Mining occurs on the Mekong and Ou rivers during the dry season when river levels have diminished enough to allow the miners, mostly women and older children, to access heavier sediments in the rivers. Both men and women are involved with the excavation of alluvial material, mainly using bowls, buckets and chisels. On the Nam Ou, gold flakes are coarse and can be separated from other heavy sand particles by drying the concentrate and then blowing the non-gold particles away by mouth. Occasionally, accumulated fine sand may be amalgamated with a small amount of mercury to capture any fine gold particles. On the Mekong River, gold particles are quite fine and mercury is used to amalgamate the heavy sands recovered.

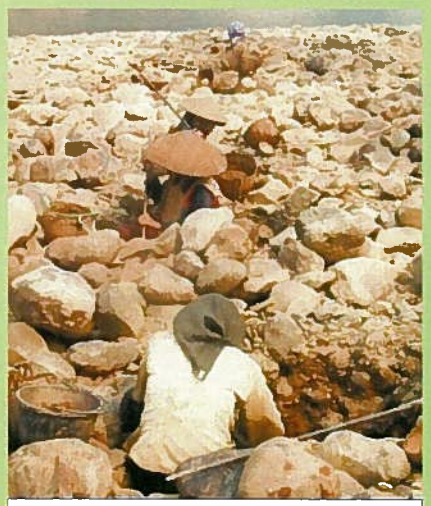
Women and children, using large wooden pans, undertake most of the mining, although on the Nam Ou, men also participate. Generally women roast the amalgam, either along the riverbank over an open fire, or more often, in their kitchens. Overall gold production is relatively low and is estimated at only 3 kg/year in total from this area. The amount of mercury used is also relatively low, at approximately 2-2.5 kg/year, or less than 50 g per household per mining season.

The GMP team collected and analyzed 298 samples, taken from topsoil, sediments and household dust. Air monitoring was also carried out in nine locations. Background mercury levels in soils ranged from 0.1 to 0.2 ppm Hg. In the control village the median mercury concentration was slightly less, at 0.053 ppm Hg. The maximum soil level was 1.763 ppm Hg. Sediment mercury levels were low, with a mean of 0.040 ± 0.027 ppm Hg in the Mekong and 0.075 ± 0.049 ppm Hg in the Ou River. Dust samples taken from within houses were much higher, reaching up to 335 ppm in one kitchen. Kitchen medians ranged from 0.150 to 3.423 ppm Hg in mining villages, versus 0.077 ppm Hg in the control village. Normal mercury levels in the air were less than 0.015 $\mu g/m^3$, but reached up to 100 $\mu g/m^3$ during amalgam roasting in kitchens.

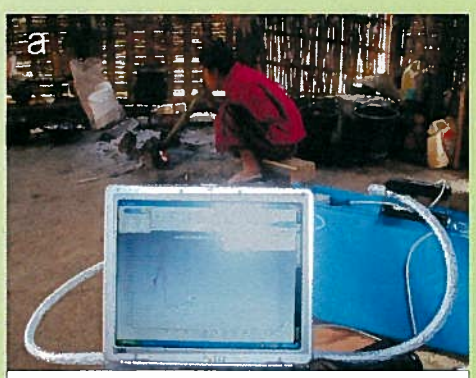
Total mercury concentrations were measured in 65 fish samples, including 55 fish from the Mekong, representing 17 species, and 10 fish from the Ou River, representing 8 species. Mercury levels in carnivorous fish from the Mekong averaged 0.172 ± 0.126 ppm Hg wet weight and 0.052 ± 0.032 ppm Hg in herbivorous fish. Mercury levels in all fish sampled form the Ou River averaged 0.066 ± 0.048 ppm Hg. The highest concentration measured was 0.490 ppm Hg, in a carnivorous fish from the Mekong. These are fairly low concentrations. Bioaccumulation of mercury by fish was not shown to be of concern in the Lao PDR assessment.

Study Area	Chomphet, Pak Ou
Population	3,219
Illiteracy	7-32%
Income	456 $US/a
$Hg_{Lost}:Au_{Prod}$	0.3-0.5
Hg Lost	2-2.5 kg/a

Collecting kitchen dust for analysis.



Excavating alluvial ore from the riverbed



Monitoring air during amalgam burning

Local Recommendations

Overall, mercury levels are moderate to low and whole ore amalgamation is not used. There is no evidence of bioaccumulation of mercury by local fish. Higher levels of mercury in household dust, especially in kitchens, indicate that burning amalgam in homes should be stopped. Elevated levels of mercury in the air during roasting confirm this need. Children and pregnant women should be kept away from amalgam burning and simple retorts should be introduced. Small hand fed sluice box operations will be introduced to increase throughput, gold recovery and income. Mercury contamination is currently low in Chomphet and Pak Ou districts and a basic health and an education program that focuses on general health and safe amalgam burning can ensure that it remains so.

LAO PDR

Health Assessment Report

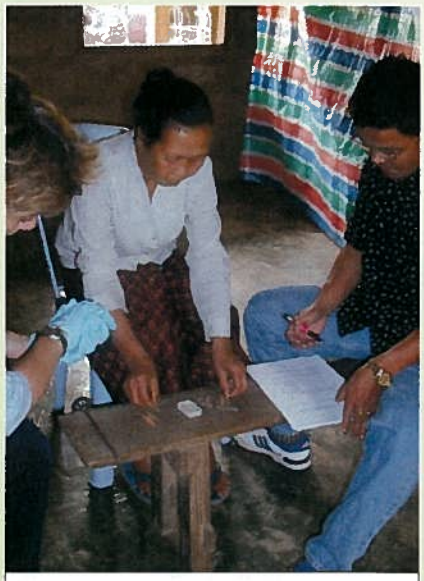
Health conditions in Chomphet and Pak Ou are poor, with access to medical facilities limited. Malaria, acute respiratory illness, diarrhea and abdominal pain are common among the population. Income levels are the lowest of all the sites evaluated in the GMP. Although income is low, diet is generally more varied and rich than many of the other sites. Awareness of the potential impact of exposure to mercury is low.

The health status of 263 volunteers in Pak Ou and Chomptet districts and 56 from a control area of Houay Yen Gnai was assessed using the GMP's environmental and health assessment protocols. The GMP collected 190 blood samples, 186 urine samples, and 315 hair samples. Five breast milk samples were also evaluated. Medical questionnaires were given to 191 participants. Participants were examined to assess their general health condition as well as the possibility of mercury poisoning. Amnestic / clinical / neurological / toxicological tests were used to identify neurological disturbances, behavioural disorders, motor neurological functions, cognitive capabilities, balance, gait, reflexes etc.

Exposure is through vapour inhalation, mercury contaminated dust, and skin contact. Vapour inhalation, primarily through the burning of amalgam by women in their own kitchens, constitutes the main source of exposure. The risk is increased because the exposed population is mostly composed of women and their young children. The high mercury levels in household dust described in the environmental assessment may be a significant secondary source of exposure.

Neurological abnormalities were frequently observed in the cohort, including 56% of men and 41% of women. However, only 16% of the men, versus 71% of the women, actively work with mercury. In the unexposed control group about 38% of the population also showed neurological abnormalities. These abnormalities are not linked to mercury. More frequent neurological abnormalities included movement disorders, abnormal reflexes and frontal signs. Other factors such as war, poverty, poor general health conditions, genetic factors or other environmental factors may be at the root of these abnormalities.

Less than a quarter of the occupationally burdened population showed any elevated levels of mercury in blood, hair or urine and none high enough levels to warrant concern. All of the breast milk samples analyzed had mercury levels below the detection limit. Females were more affected than males, reflecting the reality that most amalgamation burning is carried out by women. The relatively low levels of mercury recorded for urine compared to blood or hair suggests that limited passive exposure to mercury from food is likely. Mercury levels in local fish shown in the environmental assessment were low, but fish represent a large part of the local diet.



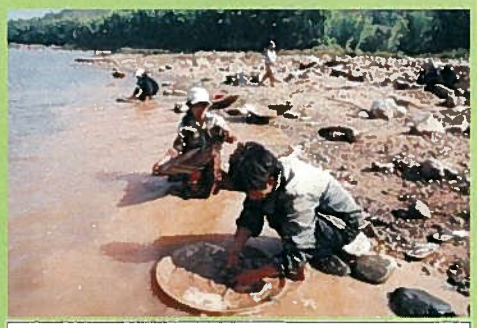
Testing motor neurological functions among villagers

Collecting amalgam from a pan concentrate

Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
Control	1 .0 (3.0)	<LD (5.1)	0.3 (11.0)
Non-occupational burdened	2.2 (8.8)	<LD (3.9)	0.6 (18.0)
Prospectors / Amalgam Burners	2.8 (12.2)	<LD (10.3)	0.9 (16.8)

Median values (Maximum values), <LD = below detection limit



A family panning by the river.

Local Recommendations

Mercury exposure in Chomphet and Pak Ou is moderate to low. An educational/awareness campaign dedicated to encouraging women to start roasting the amalgam outdoors, instead of in their homes, is needed. Such a campaign should encourage the use of retorts to recover mercury, and should perhaps include a shared retort for villagers, as roasting is generally not a daily task. The high rate of neurological abnormalities was not linked to mercury but should be investigated further.

SUDAN

Environmental Assessment Report

Gold was discovered in the central part of Ingessana Hills in 1997. Migrants have flocked to the region, especially those displaced by civil war in the southern parts of the region. The population is now multi-ethnic, including the Dawalla people from the Kurmuk region and the indigenous Ingessana people. The GMP assessment focused on Gugub and Khor Gidad villages, located 80 km southwest of El Damazin, the capital of the Blue Nile state. Although the region's rivers often run dry, the area is in the drainage basin of the Blue Nile, a major tributary of the Nile.

The Ingessana Hills District, with a population of 100,000, is characterized by an extreme shortage of water during the dry season, poor accessibility and lack of infrastructure. The communities are semi-nomadic and impoverished, relying on limited farming, animal husbandry and artisanal mining for their livelihoods. There are approximately 1,100 small-scale gold miners near Gugub and adjacent villages, processing alluvial and primary quartz vein type ores. The miners' illiteracy rate approaches 95%.

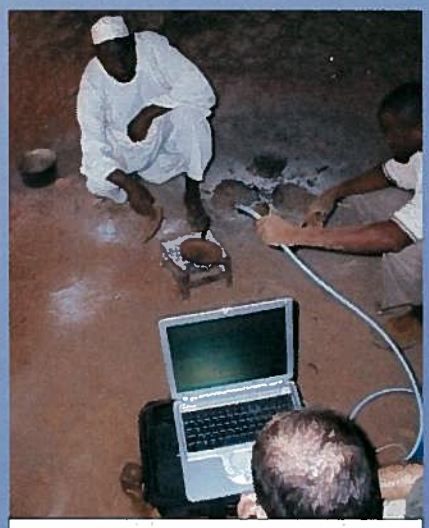
During the dry season, primary gold associated with quartz veins is extracted with simple tools and hand sorted. Then the ore is manually crushed, milled and panned in pools. The pan concentrate is either sold to gold merchants or amalgamated at home. During amalgamation, mercury is hand-mixed into the pan concentrate with water. The resultant amalgam is squeezed through cloth and any excess mercury is reused. The remaining amalgam is roasted openly on pans over wood fires, both inside and outside village huts. Roasting time is short and at low temperatures, leading to residual mercury in the gold doré. Tailing is discarded around village huts. During the rainy season, miners focus on placer gold deposits and do not use mercury.

The GMP team collected and analyzed 170 samples taken from topsoil, tailing waste piles, river sediment, and dust. Air monitoring during amalgam roasting was also undertaken. Background soil mercury levels are low, around 0.1 ppm Hg, as are stream sediment levels. Mercury levels in village soils are up to 10 times higher (0.6 to 1.2 ppm Hg), although still low. Amalgamation areas showed a mean of 46 ppm Hg, with a maximum of 1,000 ppm Hg. Dust sampled in huts had a mean of 47 ppm Hg and a maximum of 840 ppm Hg. Amalgamation tailing levels ranged from 62 to 73 ppm Hg and tailing is stored by gardens or roads. Air monitoring showed mercury levels averaging around 25 $\mu g/m^3$ Hg, or close to the WHO exposure limit for professional workers over an 8-hour period. However, peaks can reach up to 100 $\mu g/m^3$ and roasting can occur inside huts frequented by children.

Total mercury concentrations were measured in 108 fish samples, from 15 different species, collected mainly from the Roseires Reservoir about 50 km from Gugub. A few fish were collected from a small water hole in a nearby dry river. The assessment was undertaken during the dry season as the region is largely inaccessible during the rainy season. No correlation between mercury and fish size was found. Mercury levels were very low, with a mean of 0.05 ± 0.01 ppm Hg (wet weight). Carnivorous fish averaged 0.10 ± 0.02 ppm Hg. No fish showed mercury levels above the WHO safety limit of 0.5 ppm Hg. Bioaccumulation of mercury in fish is not a significant concern in Ingessana Hills.

Study Area	**Gugub, Khor Gidad**
Population	**1,100**
Illiteracy	**90%**
Income	**960 $US/a**
$Hg_{Lost}:Au_{Prod}$	**1.5**
Hg Lost	**45-135 kg/a**

Squeezing off excess mercury.



Air monitoring during amalgam burning.

A woman miner excavating gold ore.

Local Recommendations

Overall, mercury levels are moderate to low and whole ore amalgamation is not practiced. Any change from the current practice of only amalgamating concentrates and placer mining without mercury should be strenuously discouraged. Amalgamation areas should be moved away from living areas, and children and pregnant women should be kept away. Retorts must be introduced and roasting should take place at higher temperatures to ensure lower mercury levels in the doré. Mercury use in the Ingessana Hills is a recent activity and technical assistance in tandem with health and education programs can ensure that mercury contamination remains limited.

SUDAN

Health Assessment Report

Health conditions in the Ingessana Hills are poor. The most common health issues reported in the area are malaria, chest pain, dyspnea, eye problems, fatigue, irritability and depression (especially among women). Daily injuries are common. The nearest clinic is at Bau, approximately 10 km away; serious cases are sent to El Damazin hospital, around 80 km away. The average family eats 2 meals a day, with sorghum and maize porridge or pancakes being the main staple. The nearest fresh food source is 20 km away. Water sources are springs and bore holes located 2 km from project sites and the water is salty and contaminated by bacteria. Awareness of the environmental and health hazards of using mercury in gold processing is very low.

The health status of 111 men, 72 women, 54 children, including 30 people from a control area in Taga, was assessed using the GMP's environmental and health assessment protocols. The GMP team collected 165 blood samples, 180 urine samples and 231 hair samples. Medical questionnaires were given to 183 volunteers. Of these, 95 men and 63 women were artisanal gold miners, with most of the men also declaring farming as a part-time occupation. The gold miners are migrant, and came to the Ingessana Hills seven years ago from a region where gold mining was not practiced. Participants were examined to identify neurological disturbances, as well as other mercury poisoning indicators. The historical / clinical / neurological / toxicological tests were then used to examine general health of the participants and discover symptoms of mercury poisoning.

Miners are directly exposed to mercury through vapour inhalation, particle ingestion, and skin contact. Vapour inhalation, through the burning of amalgam in frying pans in miners' homes or on shop verandahs, constitutes the main source of exposure. The study showed that the population's exposure did not lead to high mercury levels in blood, hair, or urine, primarily due to the small amounts of mercury used in comparison with the other sites.

The clinical examinations consisted of classical tests related to walking, standing, sitting, laying, reflexes, memory, and drawing abilities. The only symptoms of chronic mercury intoxication observed were standing tremors and eyelids, lips, and fingers (ELF) tremors: 40% of participants had slight ELF tremors and 4% had moderate ELF tremors. However, it was not possible to demonstrate that there was any relationship between these signs and mercury use or mercury levels in blood, urine or hair samples. The tremors were more likely due to stress or the context of the examination.

The neuropsychological and bio-monitoring results did not lead to any diagnosis of mercury intoxication. Participants generally did not have a metallic taste in their mouth or have salivation problems. The study concluded that exposure to mercury is low.

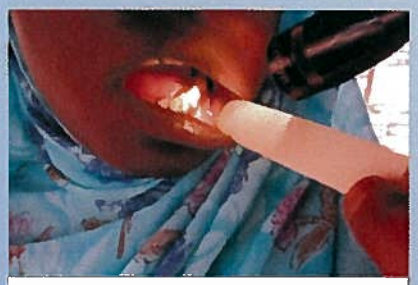
Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
Children			<LD (0.4)
Men	<LD (3.6)	<LD (8.5)	<LD (0.4)
Women	<LD (2.8)	<LD (5.2)	<LD (0.4)

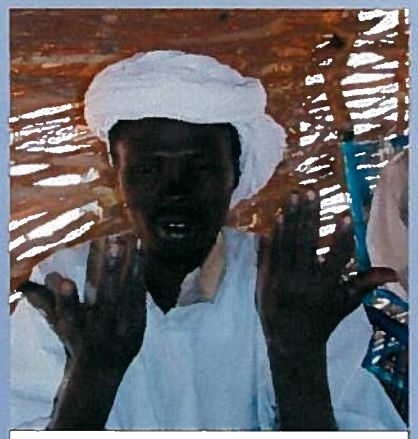
Median values (Maximum values), <LD = below detection limit

Medical Office

Medical exam: Finger to nose test



Examining volunteer's gums.



Medical exam: Dysdiadochokinesis

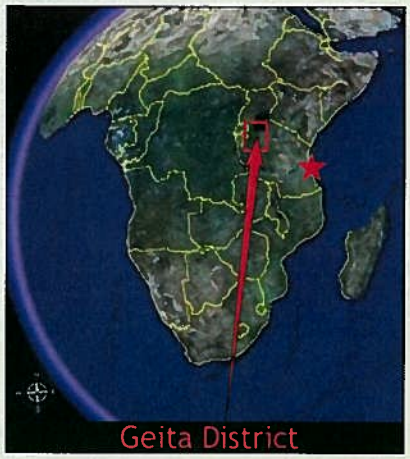
Amalgamating by hand.

Local Recommendations

Mercury exposure in the Ingessana Hills is currently low, but the spread of amalgamation technology could easily lead to a more serious health impact. The population must be informed about the effects of mercury use on human health and the environment, and must be educated on how to prevent these effects from arising over time. Miners must be equipped with simple tools that limit future exposure to mercury in order to preserve their health and that of their environment. The low mercury exposure and relatively recent releases of mercury into the environment make the region a useful baseline for assessing the health and environmental effects of mercury use by artisanal gold miners.

TANZANIA

Environmental Assessment Report



Rwamagasa, with a population of 27,000, is located in the Geita District, south of Lake Victoria. Geita District has a population of around 712,000, including an estimated 150,000 artisanal and small-scale miners, mostly impoverished illegal panners. Geita is located in the Lake Victoria Goldfields region, which produces more than 95% of all Tanzania's gold and has the highest intensity of small-scale mining in the country. Rwamagasa is only 37 km south of Lake Victoria, but the area drains into Lake Tangayika. Intensive small-scale gold mining began there in the 1980s, although mining activities date back over the past hundred years. Most of the population is involved in mining, either as miners, part-time miners, or buyers. Young men tend to work in larger operations, while older people, women and children work in smaller sites.

There are two main small-scale milling areas in Rwamagasa: the licensed small-scale Blue Reef Mine and the independent miners milling and sluicing by the River Isingile. At Blue Reef Mines, 150 people work mining and milling primary ore from underground shafts. The independent millers, employing approximately 300 people at 10 sites, process tailing material or weathered ore from pits or shafts. Ore is transported in bags to the milling centres, manually crushed, and sun dried. The ore is dry milled in small ball mills, without mercury, then slurried and passed over sluices. The sluice concentrates are amalgamated in metal trays, with bare hands, and the amalgamation tailing is stored in concrete or wood-lined tanks and is frequently reprocessed. Amalgam is burned in a small charcoal fire with no retort. Housing, food stalls and schools are all located close to amalgamation sites and contaminated tailing material is stored near wells and agricultural land. The mines release an estimated 27 kg of mercury per annum.

Study Area	Rwamagasa
Population	27,000
Illiteracy	10%
Income	532 $US/a
$Hg_{Lost}:Au_{Prod}$	1.0-1.5
Hg Lost	27 kg/a

The GMP team collected and analyzed 271 samples taken from soils, drainage sediments, tailing material and water. Drainage sediments showed mercury levels ranging from 0.04 to 3.02 ppm Hg, while the level in background sediment was around 0.08 ppm Hg. Tailing material had a mean of 3-5 ppm Hg and ranged from 0.2 to 56.5 ppm Hg. Amalgamation tailing had a mean of 86 ppm Hg and ranged from 28.5 to 193 ppm Hg. About 8 percent of soil sampled exceeded 1 ppm Hg. The team took 21 vegetable samples, but the results did not indicate that vegetables were a significant source of mercury.

A small-scale miner preparing to squeeze excess mercury.

Total mercury concentrations were measured in 285 fish samples from 4 main species, collected from ponds around mining sites, nearby rivers, and further downstream the watershed. Fish sampled from ponds nearest mining activities were the worst affected, with a mean concentration 0.80 ppm Hg wet weight, reaching up to 2.65 ppm Hg. Mercury in fish collected in nearby rivers had lower, although still elevated, mercury levels with a mean of 0.13 ppm Hg. Fish sampled further downstream and in Lake Tanganyika had low mercury concentrations with a mean of 0.08 ppm Hg, suggesting that the mining activities in Rwamagasa do not have a significant impact on the international waters of Lake Tanganyika. Extensive swamps and flooded grasslands located 120 to 350 km downstream of Rwamagasa act as an environmental sink, likely preventing migration of mercury downstream. These places, however, can be transformed into environmental hotspots where mercury transported by sediments from mining areas can be methylated. Fish originating from Lake Victoria and sampled from the Rwamagasa market showed very low levels at 0.01 ppm Hg.

Sluicing contaminated tailing material north of Rwamagasa.

Haplochromis spp, a local fish found in an amalgamation pond.

Local Recommendations

Small-scale mining in Rwamagasa releases significantly less mercury than similarly intensive small-scale mining operations in Brazil, Indonesia, Zimbabwe, or many other locations around the world, as was clearly demonstrated in the soil, sediment, tailing, and fish-sampling program. This is primarily due to current milling practices of amalgamating only sluice concentrates. Wet grinding would be much more energy efficient, but care must be taken not to push to introduce technologies which could lead to whole ore amalgamation. Simple, workable retorts need to be encouraged. Efforts should be made to improve access to alternative technologies and best practices education, in conjunction with basic health services.

TANZANIA

Health Assessment Report

Health conditions in Rwamagasa are very poor, with low basic hygiene standards and high rates of infectious diseases such as diarrhea, typhoid and parasitism. The dominant causes of morbidity and mortality are road accidents, accidents in insecure mining tunnels and amalgamation plants, malaria, TB, and STDs including AIDS. No special health service exists for the mining community; the nearest dispensary is about 10 km away, and all non-minor illnesses must be transferred to Geita hospital. There is no effective disposal system for sanitary or other domestic waste.

The health status of 211 volunteers in Rwamagasa and 41 from a control area in Katoro was assessed using the GMP's environmental and health assessment protocols. The GMP team collected 252 blood samples, 249 urine samples and 212 hair samples. Medical questionnaires were given to 252 participants. Participants were examined to assess their general health condition as well as the possibility of mercury poisoning. Amnestic / clinical / neurological / toxicological tests were used to identify neurological disturbances, behavioural disorders, motor neurological functions, cognitive capabilities, balance, gait, reflexes etc.

Miners and millers are directly exposed to mercury both during amalgamation and burning without retorts. Housing, food areas and schools are all near to amalgamation and burning places. Tailing containing mercury is found within the village, adjacent to cultivated land, and near local water wells. Child labour is very common from age 10 on and children work and play with mercury using their bare hands. Nursed babies of mothers who work as amalgam burners show a high mercury burden, due to placental transfer of mercury during pregnancy and then high mercury concentration in breast milk.

Typical symptoms of mercury intoxication were prevalent in the exposed group. In addition to sleep disturbance, excessive salivation and metallic taste, Rwamagasa workers also demonstrated fine tremor of eyelids, lips and fingers, ataxia, dysdiadochokinesis and altered tendon reflexes. Participants who had worked in the area for five to ten years demonstrated more severe symptoms. The control group in Katoro was healthy and did not show any special problems.

Mercury levels in Rwamagasa villagers' blood, hair, and urine were statistically significant and higher than those in the control group; however, only amalgam burners showed extremely high levels. The GMP team's results indicated that 25 out of 99 amalgam burners were suffering from chronic mercury intoxication, as were 3 out of 15 former amalgam burners. No other inhabitants of Rwamagasa or the control area were diagnosed with mercury intoxication when the symptoms of neuropsychological tests were combined with mercury in biomaterials.

Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
Control Group	1.0 (2.3)	0.2 (0.9)	0.4 (0.7)
Non-occupational burdened	1.5 (5.8)	0.5 (11.6)	0.5 (15.8)
Prospectors / Amalgam Burners	2.6 (33)	3.6 (37)	0.8 (49)

Median values (Maximum values)

Village children in Rwamagasa

Health post, in the control village of Katoro.

Transporting gold ore in Rwamagasa.

Ball mill compound, Blue Reef Mine, Rwamagasa.

Local Recommendations

Proper health services and better education about health issues are urgently required. Child labour involving mercury must be stopped immediately and women of child-bearing age need education about the dangers of mercury exposure to the fetus and nursing baby. Health facilities and health workers need to be equipped and trained to deal with mercury exposure and intoxication. Support for the introduction of cleaner, safer gold extraction technologies is required.

ZIMBABWE

Environmental Assessment Report

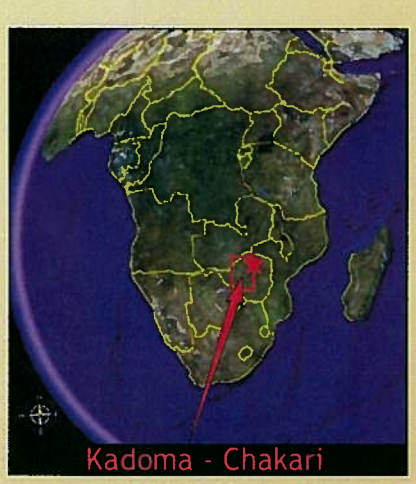
The Kadoma - Chakari Region, one of Zimbabwe's largest gold belts, has the nation's highest density of small-scale gold miners, millers and panners. The area is located about 150 km southwest of Harare along the main Harare-Bulawayo highway in the Zambezi Basin. The Zambezi Basin and its water resources are shared by eight of the fourteen Southern African Development Community (SADC) states. The long-term environmental wellbeing of the Zambezi River, its tributaries, and associated dams and lakes depends on the type and scale of economic activities that take place within the basin.

Kadoma Chakari is characterized by a lack of proper health services, poor access to safe drinking water, and extreme poverty. Approximately one half of the region's total population of 235,000 is involved in mining or milling; many of these are migrant workers. Police, mining and health authorities have little to no control over ASM areas. Poverty is the main reason for the region's disastrous health and environmental problems.

Miners crush gold ore primarily with wet stamp mills, creating slurry, which passes over copper plates covered with mercury. The plates are periodically scoured clean to collect the amalgam, which is then squeezed though a cloth to remove excess mercury. The remaining amalgam is generally roasted openly on wood fires. The mercury-contaminated tailing is usually then treated with cyanide for additional gold recovery, leading to the creation of dangerous mercurycyanide complexes. Some miners use jaw-crushers and ball mills instead of stamp mills and some replace the copper plates with centrifugal bowl concentrates, adding mercury to the bowl. Gold panners working along the rivers also use mercury.

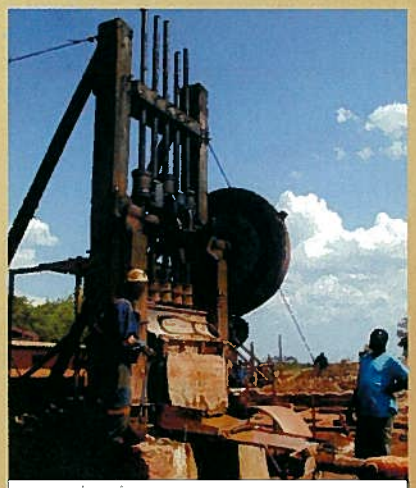
The GMP team collected and analyzed 163 samples taken from soil, stream sediments, water, dust, and tailing material. High mercury levels were consistently measured in soils and sediments near processing areas, particularly near copper plate amalgamation sites. Soil contamination ranged from 7.3 ppm to 43.5 ppm Hg. Dust samples collected near copper-plate centres showed levels ranging from 28.8 - 105 ppm Hg. Mercury levels in soils were lower by bowl-concentrators, although still significant. One village used tailing material for local road construction, resulting in elevated mercury concentrations throughout the village (up to 20 ppm). Background mercury levels ranged from 0.02 to 0.12 ppm Hg. Muzvezve River sediment levels only ranged from 0.01 to 0.26 ppm Hg despite river panning. This sampling program confirms the information gathered through interviews and observation and documents the release of extremely large amounts of mercury.

Total mercury concentrations were measured in 52 fish samples representing six species, collected in the Muzvezve River near milling centres and panning areas. The mean mercury concentration was 0.41 ppm Hg, ranging from 0.03 ppm to 2.61 ppm Hg (wet weight). Carnivorous fish ranged from 1.05 ppm Hg, with a standard deviation of 0.44 ppm Hg, and omnivorous species ranged from 0.12 ± 0.09 ppm Hg, except for one species that ranged from 0.88 ± 0.25 ppm Hg. Fish collected were generally small and no correlation of mercury versus length was found. Some fish had concentrations two to four times the WHO safety limit of 0.5 ppm.



Study Area	Kadoma-Chakari
Population	235,000
Illiteracy	17%
Income	588 $US/a
$Hg_{Lost}:Au_{Prod}$	1-3
Hg Lost	1-18 t/a

Scraping amalgam off a copper plate.



A typical stamp mill and copper plate amalgamation centre.

Brycinus imberi, a local fish with an average total mercury approximately twice the WHO recommended maximum.

Local Recommendations

Small-scale gold mining is of vital importance to the Kadoma-Chakari area and has reached semi-industrial levels. Gold mining activities emit large amounts of mercury into the soil, air, and water, leading to elevated mercury levels in the local environment. Mercury levels measured in some local fish could lead to mercury bioaccumulation in local communities, but mercury vapour is the most likely path to illness. Urgent action is required to significantly reduce exposure of workers, their families and the local environment to mercury. The practice of cyanide leaching the amalgamation tailing must be stopped. Access should be provided to alternative technologies and best practices education, in conjunction with basic health services.

ZIMBABWE

Health Assessment Report

Health conditions in the Kadoma area are extremely precarious, as is reflected by a very low life expectancy at birth of 38.0 years for women and 37.7 years for men. The dominant causes of morbidity and mortality are road accidents, accidents in insecure mining tunnels and amalgamation plants, malaria, TB, and STDs including AIDS. Low hygienic standards and poor nutrition lead to diarrhea, malaria, and parasitism. There is no effective disposal system for mercury, sanitary or other domestic waste. No proper health service exists for the mining community. Mercury is a serious health hazard in the Kadoma area, but the daily fight for survival in the face of poverty requires miners to put their own health and that of their families at risk.

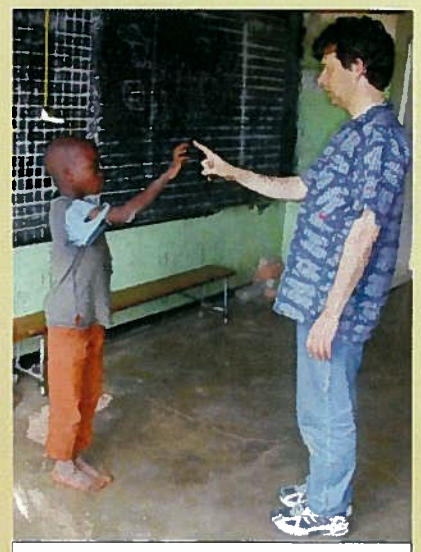
The health status of 218 volunteers in Kadoma and 55 from a control area in Chikwaka was assessed using the GMP's environmental and health assessment protocols. The GMP team collected 269 blood samples, 273 urine samples, and 233 hair samples. Medical questionnaires were given to 217 participants. Historical / clinical / neurological / toxicological tests were then used to examine general health of the participants and discover symptoms of mercury poisoning.

Miners and millers are frequently directly exposed to mercury contamination, primarily through vapour inhalation, particle ingestion, and skin contact at amalgamation and roasting sites. These activities are often performed in villages and along riverbanks. The study showed that the entire population living in the mining areas is severely exposed, with exposure of amalgam burners and children working with mercury being the most extreme. Breast milk in some cases was contaminated with mercury. The control group was within a normal range.

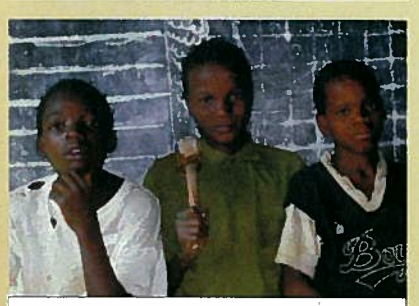
Typical symptoms of mercury intoxication were prevalent in the exposed group and confirm considerable exposure to mercury. Symptoms included signs of a damaged central and peripheral nervous system such as ataxia, dysdiadochokinesia, pathological reflexes, coordination problems and concentration problems. No symptoms were observed in the control group.

Medical score sum plus bio-monitoring results made possible a diagnosis of chronic mercury intoxication in 70% of amalgam burners, 63% otherwise occupational-burdened workers and 23% of former occupational-burdened workers. Five percent of non-occupational burdened population also showed chronic mercury intoxication. Sixty-nine percent of children working with mercury and 33% of children living in the area but not working with mercury were diagnosed with chronic intoxication. No one in the control area was intoxicated.

Mobile field clinic, Amber Rose mill, Kadoma



Neurological exam: Finger-finger-nose test.



Children miners from Kadoma.

Test Program Results

	Blood Hg (ppb)	Urine Hg (ppm creatinine)	Hair Hg (ppm)
Control Group	0.4 (1.9)	< 0.2 (3.6)	< 0.02 (3.3)
Non-occupational burdened	2.3 (10.3)	6.2 (96)	1.6 (15.4)
Prospectors / Amalgam Burners	13.2 (98)	36 (547)	4.5 (112)

Median values (Maximum values)

Mobile Mercury Analysis Laboratory.

Local Recommendations

Poverty is at the root of Kadoma's health and environmental problems. Sanitation needs improvement and amalgamation sites need to be separated from residential areas. A system should be built up to diagnose and treat mercury-related health problems, including funding for facilities, preventative campaigns, and training. A mobile health unit could reach small-scale miners most effectively. Children must cease working with mercury and women of childbearing age need to be educated about the risks of mercury both to the fetus and to nursing babies. Miners and millers need all possible support to introduce cleaner and safer gold mining and extraction technologies to reduce both mercury intoxication and the release of mercury.

CONCLUSION

The GMP environment and health assessment teams studies demonstrate the devastating health and environmental impacts of poor mercury practices on both miners and their surrounding communities. GMP environment and health assessment teams examined a diverse group of communities and mining areas, ranging from areas where small-scale mining had only recently begun (Ingessana Hills, Sudan), to where it was booming (Kadoma, Zimbabwe), to where it was in decline (Creporizinho and São Chico, Brazil). Mining methods varied from traditional (Chomphet and Pak Ou, Lao PDR) to almost industrial (North Sulawesi, Indonesia). The amount of mercury lost ranged from tiny, such as the Lao PDR, where 2-2.5 kg/annum was released, to massive, such as North Sulawesi, where 15-23 tonnes/annum was released. Whole ore amalgamation was practiced in Brazil, Indonesia (North Sulawesi), and Zimbabwe.

Similarly, the health impacts observed varied from minimal in Sudan and the Lao PDR to severe in Brazil, Indonesia and Zimbabwe. Zimbabwe measured the highest urine mercury levels among the miners, with a median of 35.7 ppm Hg, corrected for creatinine. High levels were also indicated in Brazil and both sites in Indonesia, and elevated levels were shown in Tanzania. Similarly, high mercury hair levels were recorded in Brazil, Indonesia and Zimbabwe. Elevated mercury levels in urine are linked with mercury vapour inhalation; these results clearly demonstrate the impact of miners not using retorts. Urine levels are much lower among non-occupationally burdened villagers, although higher than the control groups.

Millers and Amalgam Burners *median (max)*	Blood Hg *(ppb)*	Urine Hg *(ppm creatinine)*	Hair Hg *(ppm)*
Brazil - São Chico*	27.7 (141)	9.3 (78.5)	3.92
Brazil - Creporizinho*	25.2 (128.7)	6.0 (61.6)	N/A
Indonesia - Kalimantan	10.2 (429)	8.7 (1,697)	3.9 (793)
Indonesia - Sulawesi	12.3 (186)	8.6 (233)	4.4 (239)
Lao PDR	2.8 (12.2)	<LD (10.3)	0.9 (16.8)
Sudan**	<LD (3.6)	<LD (8.5)	<LD (0.4)
Tanzania	2.6 (33.3)	3.6 (36.8)	0.8 (48.7)
Zimbabwe	13.2 (97.6)	35.7 (547.4)	4.5 (112.2)

* Mean not median values for Brazil

** Includes all village men examined, including non miners.

Non-occupationally burdened *median (max)*	Blood Hg *(ppb)*	Urine Hg *(ppm creatinine)*	Hair Hg *(ppm)*
Brazil - São Chico*	16.5 (63)	5.1 (55)	3.2 (15.0)
Brazil - Creporizinho*	21.0 (171.7)	1.9 (12.07)	1.8 (10.5)
Indonesia - Kalimantan	8.5 (172)	2.7 (355)	2.6 (7.8)
Indonesia - Sulawesi	6.0 (12.6)	2.0 (9.8)	1.7 (10.3)
Lao PDR	2.2 (8.8)	<LD (3.9)	0.6 (18)
Sudan**	<LD (2.8)	<LD (5.2)	<LD (0.4)
Tanzania	1.5 (5.8)	0.5 (11.6)	0.5 (15.8)
Zimbabwe	2.3 (10.3)	6.2 (96.1)	1.6 (15.4)

* Mean not median values for Brazil

** Includes all village women examined, including miners.

From this broad array of studies three key lessons were made abundantly clear:

First, whole ore amalgamation is unacceptable, especially in conjunction with cyanidation, and leads to widespread elevated mercury levels in the local environment, and severe health problems for both miners and non-miners. Regions which practiced whole ore amalgamation had the highest mercury levels in soils, sediments, and fish. The studies did not provide a clear indication of the impact of methylmercury in fish further downstream, as there are often other confounding sources of mercury. However, the studies did demonstrate that in locations with whole ore amalgamation, elevated levels of mercury are shown in both the local fish and human population, indicating that mercury is getting into the food chain and is methylated. Once methylated, mercury can rapidly move through the food chain, likely leading to impacts downstream as well. In general, if whole ore amalgamation is observed, there is likely a significant local health and environmental impact, and action, not assessment, is required. Cyanidation in conjunction with amalgamation was found to amplify this impact.

Second, amalgamation should only take place in designated, contained areas. Whole ore amalgamation was not practiced in Kalimantan, Indonesia, but mercury levels in blood and fish were similar to areas that did practice it. This was due to the fact that amalgamation of concentrates took place in ponds used to raise fish. Similarly, reprocessing of amalgam tailing both disturbs existing mercury contamination and adds new mercury to the environment.

Third, openly burning amalgam without retorts results in elevated mercury levels in miners and their families, often with severe health impacts. In Zimbabwe, 70% of amalgam burners were diagnosed with chronic mercury intoxication. However, the effect of open burning of amalgam is directly related to the amount of gold produced. In areas such as the Lao PDR and Sudan, which showed limited mercury intoxication in conjunction with open burning of amalgam, relatively moderate levels of mercury intoxication only reflected the smaller scale of gold production.

The area of Rwamagasa in Tanzania had the best practices demonstrated in this study among the more intensive small-scale mining areas studied (Brazil, Indonesia, Tanzania, and Zimbabwe). Whole ore amalgamation was not practiced, and amalgamation involved only concentrates and occurred in only in designated areas, greatly reducing the amount of mercury discharged to the environment. However, retorts were still not used. The Lao PDR demonstrated how small-scale mining can supplement agricultural income without excessive environmental or health impacts, but if the intensiveness of mining activity increased, the negative impacts of mercury use would increase as well.

Overall, these studies show that small-scale mining is a poverty-driven activity that typically takes place amidst dismal health and living conditions. The introduction of simple practices and educational/awareness-raising campaigns can dramatically reduce the health and environmental impact of ASM and better allow income generated from ASM to go toward reducing poverty.

Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologies

In cooperation with the:

University of British Columbia, Vancouver, Canada
Norman B. Keevil Institute of Mining Engineering

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